S. 37

File With ___________

SECTION 131 FORM

Appeal NO:_PL 04.248152

Defer Re O/H ☐

TO:SEO

Having considered the contents of the submission ~~dated~~/ received 29/1/18 from Noonan Linehan Carroll Coffey I recommend that section 131 of the Planning and Development Act, 2000 be/not be invoked at this stage for the following reason(s): to be assessed at inspectorate/Board level.

E.O.: [signature] **Date:** 7/2/18

To EO: ___________

Section 131 not to be invoked at this stage. ☐

Section 131 to be invoked – allow 2/4 weeks for reply. ☐

S.E.O.: ___________ **Date:** ___________

S.A.O: ___________ **Date:** ___________

M ___________

Please prepare BP ___________ **- Section 131 notice enclosing a copy of the attached submission**

to: ___________

Allow 2/3/4weeks – BP ___________

EO: ___________ **Date:** ___________

AA: ___________ **Date:** ___________

S. 37

File With ______________

CORRESPONDENCE FORM

Appeal No: P L 04.248152

M R. O'Hora

Please treat correspondence received on 29/01/18 email as follows:

1. Update database with new agent for Applicant/Appellant ______________

2. Acknowledge with BP 23 3. Keep copy of Board's Letter ☐	1. RETURN TO SENDER with BP ______ 2. Keep Envelope: ☐ 3. Keep Copy of Board's letter ☐

Amendments/Comments Response to appeal from Noonan Linehan Carroll Coffey

4. Attach to file (a) R/S ☐ (b) GIS Processing ☐ (c) Processing ☐ (d) Screening ☐ (e) Inspectorate ☑	RETURN TO EO ☐

	Plans Date Stamped ☐ Date Stamped Filled in ☐
EO: [signature]	AA: [signature]
Date: 7/2/18	Date: 11/2/18

Jennifer Sherry

From:	procbordemail
Sent:	Tuesday 30 January 2018 12:00
To:	Jennifer Sherry
Subject:	FW: Email 1 of 3 - Your ref: PL 04.248152 (244439) PA Reg Ref: 14/557 & Your ref: PL 04.248153 (245824) PA Reg Ref: 14/6760
Attachments:	29.01.2018 - Email Submission Letter to An Bord Pleanála.pdf; 1. Response to HMP FINAL.pdf; 2. Letter from Denis Buckley.pdf; 3. Letter from Patrick Manning 26.01.2018.pdf; 4. Final Barna WAG Reply to An Bord Pleanála 29 Jan 2018.pdf; 5. Map showing house numbers and ownership.pdf
Importance:	High

From: Bord
Sent: Monday 29 January 2018 16:50
To: procbordemail <procbordemail@pleanala.ie>
Subject: FW: Email 1 of 3 - Your ref: PL 04.248152 (244439) PA Reg Ref: 14/557 & Your ref: PL 04.248153 (245824) PA Reg Ref: 14/6760
Importance: High

From: Joe Noonan [mailto:jnoonan@nlcc.ie]
Sent: Monday 29 January 2018 16:48
To: Bord <bord@pleanala.ie>
Cc: Pippa Willows - Legal Secretary, Noonan Linehan Carroll Coffey <pippawillows@nlcc.ie>
Subject: Email 1 of 3 - Your ref: PL 04.248152 (244439) PA Reg Ref: 14/557 & Your ref: PL 04.248153 (245824) PA Reg Ref: 14/6760
Importance: High

Noonan Linehan Carroll Coffey
SOLICITORS
www.nlcc.ie

TO: **An Bord Pleanála**

FROM:

Joe Noonan
NOONAN LINEHAN CARROLL COFFEY
Solicitors
54 North Main Street
Cork.
T12 WY2D

Tel 021 4270518 Fax 021 4274347
www.nlcc.ie

Cyber-crime warning: Please be aware of cyber-crime when dealing with the electronic transfer of funds. Please note that we will only give or accept bank account details in writing on paper. We will **never** ask you to give us your bank account details by email, fax or over the phone. We will **never** give you our bank account details by email, fax or over the phone. If you receive an email claiming to be from us which contradicts this policy, please do not act on it and please let us know immediately

[Evolve:580ca930-56a5-4139-a93b-aba58c9c8899]

Noonan Linehan Carroll Coffey

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The Secretary
An Bord Pleanála
64 Marlborough Street
Dublin 1

~ By Email - bord@pleanala.ie ~

29th January 2018
Our ref: 1501-18/JN/PW

RE: Construction of a substation to replace substation previously granted under PL04.219620 and all ancillary site development works.
Barnadivane, Kneeves, Terelton, Co. Cork
Your ref: PL 04.248152 (244439) PA Reg Ref: 14/557

And

6 no. wind turbines
Lackareagh and Garranereagh
Lissarda and Barnadivane, Terelton, Co. Cork
Your ref: PL 04.248153 (245824) PA Reg Ref: 14/6760

Our clients – Barna Wind Action Group

Dear Sir/Madam,

We refer to two letters received from you dated 9th January 2018, one under each of the above mentioned Board reference numbers. You enclosed material received by the Board in November from the developers and you invited our clients to respond to the matters therein. Our clients wish to respond to the matters raised in both of your letters as follows.

On a preliminary point, this response is supplemental to the materials and arguments already furnished on behalf of our clients to the Board in relation to these two applications since they were first lodged with the Board. Our clients continue to rely on those grounds advanced in the Judicial Review proceedings High Court Record Number 2016/614JR which were not dealt with when the said proceedings were compromised by agreement. We expect the Board to address those grounds.

We must acknowledge two errors in our letter to the Board of 1 August 2017 as mentioned by Hayes McKenzie. The first is an error in citing a Board reference number. The Board has made two Refusal decisions in relation to the Ardglass windfarm development, one in 2014, the second in 2017. We erroneously cited the Board reference number for the second case in our letter. Clearly the first was intended – namely PL04.243630. Our second error was to refer to an increase of 6 – 11 decibels over ambient noise as being an increase of 6 – 11 *times* (6x) ambient levels. That is plainly mistaken and we agree with Hayes McKenzie to that extent.

The basic point remains however – that the Inspector and Board in that first Ardglass case regarded an increase of 6 – 11 decibels over ambient levels as an unacceptable interference with residential amenity. That approach should also be followed in this case.

Hayes McKenzie comment on house number discrepancies in relation to Mr Patrick Manning's properties. This issue is clarified in Mr Manning's letter, which we attach. The Board might please note that the small scale of the maps showing nearby properties makes it very difficult for an individual owner to identify their own property. Mr Manning and we as his solicitors have gone to considerable trouble to identify his three premises on the map furnished (attachment no. 5 to this letter). Note also that while the Applicants' map shows a house identified as house no. 54 we are advised there is no such house in existence.

Our clients have sought expert advice from Mr Dick Bowdler, Acoustic Consultant. His Report is attached. It is accompanied by supporting studies and reference materials.

We request the Inspector and the Board to examine, analyse and evaluate what is said by the experts engaged by our clients and the Applicants. Our clients (and the public) are, we submit, entitled to know the Board's thinking and the weight it attributes to the substantive points made by the respective experts. For that reason, we ask the Board to set out its assessment of the expert views presented to the Board.

Windfarm noise is an issue that we submit the Board has not adequately confronted in its decisions to date. It is the case that several families have decided to abandon their homes as a result of windfarm noise emanating from windfarms operating on foot of planning permissions issued by Planning Authorities including the Board. Families do not abandon their homes except as a last resort. The Board needs, we submit, to ask itself how these planning decisions have had such disastrous consequences. It is not enough for the Board to say this is simply an enforcement matter. Efforts to test operators' claims that they are in compliance by way of enforcement complaints to local authorities have had unsatisfactory results – with certain resource-starved Local Authorities relying on compliance reports from consultants paid by the windfarm operators and other Local Authorities forming the view that the planning permission noise conditions are unenforceable.

None of the windfarm permissions granted by the Board to our knowledge has a condition limiting amplitude modulation (AM) in specific terms, even though AM is now recognised on all sides as a key source of noise complaints from windfarms and it is possible to apply such a condition as Mr Bowdler explains. We submit that the Board should reject any suggestions from the Applicants' consultants that it is sufficient to apply a vague open-ended 'condition' of the kind described at section 3.13 of the Hayes McKenzie response.

Apart from its patent vagueness, multiple contingencies and complete lack of specific metrics, it relies on a methodology published by a trade association, whose website confirms their role as an *'energy* *trade association' – 'We work to represent our members – companies active across Britain and Northern Ireland who care about our energy future and see wind, wave and tidal energy as essential parts of our energy mix, now and into the future.'* Protecting residential amenity of nearby homes by means of a proper robust AM condition is not necessarily going to advance the interests of the trade association's members. The Board is in a position to strike a fair balance and we submit that the Report of Mr Bowdler will assist it in doing so.

We attach the following –please note that due to email capacity limits this letter and the attachments will be transmitted under cover of three emails:

1. Report prepared by Dick Bowdler, Acoustic Consultant. This report is accompanied by 13 no. reference documents as follows:
    a. Notes of Noise Working Group (NWG) Meeting 2 August 2006
    b. Final Minutes of NWG meeting 2 August 2006
    c. Salford University Study into Amplitude Modulation
    d. Denbrook Appeal Decision by Planning Inspectorate
    e. Department of Communities and Government with Decision re Swinford
    f. Department of Communities and Government with Decision re Turncole Farm
    g. Amplitude Modulation Working Group Final Report 09-08-2016
    h. Wind Turbine AM Review Issue 3
    i. Acoustics Bulletin November-December 2017
    j. 2015 Programme for 6th International Conference on Wind Turbine Noise
    k. R243630 Ardglass Inspectors Report
    l. Marshall Day Report on Examination Of The Significance Of Noise In Relation To Onshore Wind Farms
    m. ETSU-R-97
2. Letter from Denis Buckley, local resident and member of Barna Wind Action Group
3. Letter from Patrick Manning, local resident and member of Barna Wind Action Group
4. Letter from Michael O'Donovan and Stephanie Larkin, local residents and members of Barna Wind Action Group
5. Map showing the location of the windfarm development site and the location of houses including those of our clients.

We have a short comment to make on the adverse effect this development would have on nearby property values, supplementing the local expert view of Keane Mahony Smith and the German study which we have already supplied to the Board. In their response on this issue, Fehily Timoney and Co. refer to two studies, neither of which is provided. They give a short statement presumably intended to be a summary of each study. The first study is said to have been *'carried out by RenewableUK'*. We ask the Board not to place any reliance on that as it is plainly not independent nor expert. RenewableUK is a trade association representing its members. It has not claimed any expertise in property valuation. The second is a 2009 US document. This is identified by name and is described in brief terms. As far as we can see however Fehily Timoney do not give any of the study's findings. For that reason the Board cannot rely on it in any way.

We have given the Board both the local expert view, which is uncontroverted, and a detailed international study which is consistent with the local expert view. Finally we submit that it is self-evident that where a disruptive noisy visually intrusive industrial power generation system is inserted into an area that has hitherto been valued by its residents for its rural tranquil nature, those residents will find it harder to find buyers if they decide to move away. Logic and reason as well as experience of the market for properties in the vicinity of similar developments all support the view of Keane Mahony Smith that this leads to a reduced demand for such properties, leading to a reduction in value.

Conclusion.
Several Local Authorities now know that existing planning noise conditions are not fit for purpose. They do not protect residential amenity. The two Ministers with responsibility for the relevant policy areas (Planning and Energy) are on record in the Dail as acknowledging these facts. Despite that knowledge the Board continues to apply similar conditions to those found wanting in the real world, justifying its actions by reference to the fact that the 2006 WEDG have not been formally withdrawn/replaced.

Whatever technical justification may be advanced on that narrow ground for continuing to look no further than the 2006 WEDG, this approach is now unsound and unscientific. It fails to meet the legal obligations on the Board under the EIA Directive in terms of assessment of impacts in the light of current knowledge.

Crucially also it means that the Board is not treating the public concerned (and in this case, our clients) in a manner that is fair and is respectful of their entitlement under the Constitution to reasonable protection for their family and property rights.

We call on the Board to assess all of the multiple impacts of these two developments in light of the specific features of the location, taking into account current knowledge and international best practice. We submit that these applications are not in keeping with the proper planning and sustainable development of this area having regard to their environmental (including socio-economic) effects and should be refused accordingly.

Yours faithfully,

Joe Noonan

Joe Noonan
NOONAN LINEHAN CARROLL COFFEY

Dick Bowdler
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BARNADIVANE WIND FARM APPEAL: PL 04.248152 (244439)

Comments on Hayes McKenzie Response of 16 November 2017

Dick Bowdler

26th January 2018

The Haven, Low Causeway, Culross, Fife. KY12 8HN Scotland

1 INTRODUCTION

1.1 This report is prepared to provide comments on the response by Malcolm Hayes of Hayes Mackenzie Partnership Ltd (HMP) of 16th November 2017 to the submissions by third parties to this appeal. I am instructed by lawyers for Denis Buckley, Stephanie Larkin & Michael O'Donovan.

1.2 The significant issues raised are:

- Amplitude Modulation in the Noonan Linehan Carroll Coffey covering letter which I deal with in my Section 3,
- the Monitor Receptor Locations in the submission by Stephanie Larkin and Michael O'Donovan which I deal with in my Section 4,
- the noise limits suggested for the proposal in the submission by Stephanie Larkin and Michael O'Donovan which I deal with in my Section 5
- Turbine noise levels raised by Patrick Manning and Eleanor O'Leary which I deal with in my Section 6.

1.3 The points raised in the covering letter by Noonan Linehan Carroll Coffey and dealt with by Mr Hayes at §§3.1-3.5 will be answered by others.

1.4 The section numbers (§) referred to in my report are those in the HMP response unless otherwise stated.

2 QUALIFICATIONS AND EXPERIENCE

2.1 I hold the degree of Bachelor of Science in Physics and Mathematics from Queen Mary College of the University of London. I was one of the original members of the Institute of Acoustics (IOA), our professional body, when it was founded in 1974 and I have been a Fellow since 1977. I am also a Chartered Engineer, a Chartered Physicist, a Fellow of the Chartered Institution of Building Services Engineers and a Member of the Chartered Institute of Arbitrators.

2.2 I have been an acoustic consultant for 47 years. I joined Sandy Brown Associates in London in 1970 and became a partner in 1973. In 1975 I became partner in charge of the firm's new Scottish office in 1975 and remained there until I left the company in 1987. I then formed New Acoustics with Colin Frier and retired from that in 2009 to specialise in wind turbine noise and noise induced deafness.

2.3 Over my consultancy career I have carried out or reviewed over 500 environmental noise assessments of various types. About 60% of these were on behalf of developers. I have given evidence at many public inquires on non-wind farm development. I have reviewed over 200 wind farm applications and I have given evidence at 30 wind farm public inquiries and hearings.

2.4 I was a member of the re-convened Noise Working Group set up by the UK Department of Trade and Industry in 2006 that discussed Amplitude Modulation (AM) and which recommended work should be undertaken to progress knowledge of AM.

2.5 In January 2009 I instigated the "Prediction and Assessment of Wind Turbine Noise" (PAWTN) – frequently known as the IOA Bulletin Article. This dealt with some issues of good practice which are either missing from ETSU-R-97 or are ambiguous. It has largely been incorporated into the "IOA Good Practice Guide to the Application of ETSU-R-97 for the Assessment and Rating of Wind Turbine Noise" (IOAGPG).

2.6 In 2011 to 2013 I was one of two acoustically qualified project managers for the large research programme on amplitude modulation commissioned by RenewableUK – the UK wind industry's trade association. I have made invited presentations to British and European wind industry trade associations and to objectors' conferences. I frequently speak at meetings of Environmental Health officers about wind turbine noise.

2.7 I am keen to promote good acoustic consultancy and to ensure that our profession uses best practice. As part of this I encourage debate and am active in organising conferences and meetings. I was a member of the organising committee for the International Conferences on Wind Turbine

Noise held in Rome (2011) and Denver (2013) and since then have been Chair of the organising committee, effectively organising conferences in Glasgow (2015) and Rotterdam (2017) and I am currently actively organising the next conference in Lisbon (2019).

2.8 I am co-editor of a book entitled "Wind Turbine Noise" which was published in 2011.

3 Amplitude Modulation (AM)

3.1 §§3.6 to 3.12 deal with the question of whether amplitude modulation should be considered as part of the board's assessment of the impact of the noise of the development. It arises from the paragraph on "Blade Swish" on page 189 of the EIS. This paragraph put forward two reasons why the authors of the EIS thought that no further account should be taken of AM. The first was that ETSU-R-97 takes account of blade swish and the second that neither the UK nor the Irish guidelines have incorporated AM into the assessment of turbine noise. The first of these points is re-iterated by Mr Hayes in §3.8. I will deal with both these points later (my 3.13 et seq) but first it is important to understand the background behind AM and its significance in the impact of wind farm noise.

3.2 In §3.6 Mr Hayes says that the documents put forward previously (3 papers by MAS Environmental) are inadequate and an analysis of the likelihood of occurrence should have been put forward. In fact, the papers do provide some evidence of the likelihood of AM but a knowledge can also be gained from an understanding of developments in AM over the last ten years or so. I can describe the position in the UK which, together with Korea and Japan, has probably been responsible for much of the advance.

3.3 In 2006 the Department of Trade and Industry set up a noise working party to consider the matter of AM which was considered to be a factor in complaints about wind turbine noise (rather than low frequency noise). Mr Hayes refers to this in §2.7 and he and I were both members of that Group.

3.4 The first draft of the minutes of the first meeting [DB01] (obtained by others by FOI) set out the consensus view at the time. *It was recognised that* *complaints concerning windfarm noise are currently the exception rather than the rule. The cause of these complaints was thought to result mostly from AM even if they are articulated in different ways from Members of the public (blade swish, low frequency noise, whoosh, pulse etc) The trend for larger more sophisticated turbines could lead to an increase in noise from AM and it was therefore timely to review this issue*. This text was removed in the published version. The working group said, in the final minutes [DB02], that *It was also agreed that a greater understanding of the effects and causes relating to AM were required to ensure that this phenomenon can be managed.*

3.5 The Group recommended: *that the NWG should commission a study to gather empirical data from existing sites to better understand the extent and cause of AM. This should be undertaken as soon as possible, but it was recognised that funding had to be secured*. There was a widespread feeling in all parts of the industry that AM would become an increasing problem and needed to be better understood. The research proposed was never carried out but an alternative study usually called The Salford Report [DB03] merely reported on the nature of complaints from wind farms to date. It can be seen from Table 2 on page 14 that about half the wind farms complained of were described in terms suggesting AM, such as whooshing, swishing, thumping and so on.

3.6 We can follow the rise of interest in and concern about AM by looking at contributions to the International Wind Turbine Noise Conferences because it was not merely a British phenomenon. In 2005 there was one paper about AM by van den Berg in The Netherlands who first raised the issue in 2002. The number increased in 2007 and 2009 when there was a paper from Korea and a paper from The Netherlands proposing a mechanism for measuring AM. By the conference in 2015 there was a whole day of papers on AM.

3.7 Going back to 2007, many people on all sides of the industry were concerned that AM would be an increasing problem and that the promised DTI research was clearly not going to emerge. Finally, in 2011 RenewableUK, the trade association of wind farm developers in the UK, commissioned an extensive research project on Amplitude Modulation which was finally published in December 2013. At the same time (though not part of the research) they published a planning condition for AM. That planning condition was not endorsed either by the IOA or by government because it was felt better evidence of the detail was required. The Institute of Acoustics (IOA) took up this task.

3.8 Residents groups began pressing more strongly for amplitude modulation to be considered in wind farm assessments. By the end of 2009, two wind farms had been consented with AM conditions in the UK – Den Brook [DB04] (Conditions 20 and 21) and Swinford [DB05] (Condition 24). Following the rejection by the IOA of the RenewableUK planning condition, some authorities and inspectors applied suspensive conditions on the basis that, by the time the wind farm was under construction a suitable condition would be available. An example of this was at Turncole in Essex in 2014 [DB06] where the inspector at appeal did not incorporate an AM condition. However, when endorsing the inspector's decision to allow the appeal, the Secretary of State added a suspensive AM condition (Condition 25) saying at paragraph 22 that it was reasonable and necessary. So, by 2014, although no formal government endorsement of an AM condition had been made, the Secretary of State believed one was reasonable and necessary.

3.9 The IOA Noise Working Group finally published "A Method for Rating Amplitude Modulation" [DB07] in August 2016. The second paragraph of the executive summary says: "*Given public concern over the issue, there is a recognised need to define a robust procedure for measuring and assessing AM, to provide a consistent means of evaluating complaints and to form the basis of appropriate planning conditions that might be applied to regulate AM from new wind turbine developments. Most planning conditions, currently routinely applied to wind turbine installations, have had the effect of limiting overall noise levels and provide a means of controlling tonal noise characteristics, but have not directly addressed AM*".

3.10 Shortly after that, in October 2016 (though dated August 2016), the "Wind Turbine AM Review" [DB08] which was commissioned by DECC (subsequently DBEIS) was published. Its aim was to: ". . . . *to review the evidence on the effects of AM in relation to wind turbines, the robustness of relevant research into AM, and to recommend how excessive AM might be controlled through the use of a planning condition, taking into account the* *current policy context of wind turbine noise.".* The one single recommendation of the report was " . . . *that excessive AM is controlled through a suitably worded planning condition which will control it during periods of complaint. Those periods should be identified by measurement using the metric proposed by work undertaken by the Institute of Acoustics, and enforcement action judged by Local Authority Environmental Health Officers based on the duration and frequency of occurrence".*

3.11 No model planning condition was recommended by the DBEIS report. However, there are a number of conditions that are already in use and a distillation of some of these was published by several members of the IOA in the Acoustic Bulletin of November/December 2017 [DB09]. The contributors include the two main authors of the DBEIS report, Richard Perkins and Mike Lotinga, Mr Hayes and me and also chair of the IOA AM Working Group, Gavin Irvine. This was published so that there would be a planning condition available to Planning Authorities that would workable and fair. There are still some concerns amongst many people that the penalty graph needs re-visiting but it is better to have something reasonable now than nothing at all.

3.12 The other point to be considered here is whether AM is predictable on a site and, if it is, can it be mitigated. Much research has been carried out in the last 5 years. As well as the whole day session on AM at the International Wind Turbine Noise Conference in 2015 [DB10], there was another whole day of papers dealing with theoretical and experimental research (Aeroacoustic Noise Sources) into how noise is generated by turbine blades including AM. There have been a number of successful schemes to mitigate AM but the methodology is not widely shared as turbine manufacturers keep details to themselves. In most of the complaints about wind turbine noise that I know of, AM is at least a part of the reason for complaint.

3.13 Let me come back now to the suggestions put forward by the applicant that I raised in my 3.1 above. The first was that ETSU-R-97 takes account of blade swish and the second that neither the UK nor the Irish guidelines have incorporated AM into the assessment of turbine noise and therefore it should not be considered.

3.14 Dealing with the first point, the crucial text in ETSU-R-97 is in the last paragraph of page 68 and says *The noise levels recommended in this report take into account the character of noise described* ***in Chapter 3*** *as blade swish* (my bold emphasis). The description in Chapter 3 that is referred to is in the first two paragraphs on p12 of ETSU-R-97. These paragraphs should be read in their entirety, but broadly they are saying that there is 2-3dB modulation depth near any turbine and this reduces as the observer goes away from the turbine. What this means is that, at the distances of neighbouring houses, it is much decreased and certainly well under the 2-3dB suggested. In my experience blade swish becomes undetectable after a few hundred metres. It is therefore wrong to say that any significant AM is included in the ETSU-R-97 limits.

3.15 What the EIS does at p 189 is repeat various descriptions from p68 of ETSU-R-97 which is part of Chapter 6, not Chapter 3. It then concludes by saying "*The noise levels recommended in this report take into account the character of noise described . . . as blade swish"*. This conveniently misses out the words "in Chapter 3". These descriptions in Chapter 6 relate to the blade swish effects that can be measured near reflecting surfaces. Indeed, it says that "*These effects are very specific to the positions at which measurements are undertaken and are more the result of building layouts at the receiver position than a change in the character of the emitted wind turbine noise"*. The problem of measuring close to reflected surfaces is dealt with elsewhere in ETSU-R-97 (at the top of page 103). Mr Hayes in §3.8 repeats similar descriptions from Chapter 6, not Chapter 3, and ends by saying that *This 3 dB Modulation Depth (MD) was* (presumably "has") *been called "normal" AM*. It is unclear who has called it "normal AM" but it was not ETSU-R-97. So, whilst the EIS and Mr Hayes have suggested that significant blade swish is included in the noise limits, ETSU-R-97 itself suggests that no significant blade swish is included.

3.16 As regards the second point, the DoEHLG Guidelines say nothing about the inclusion of AM in the limits and the suggestion in the EIS is that, therefore, AM should not be taken into account. However, since both the DoEHLG Guidelines and ETSU-R-97 were written it has become apparent that there is AM of a type not envisaged in either guidelines. Indeed, in §3.9 Mr Hayes goes on to describe "other AM" and in the next sections to §3.12 he discusses points broadly similar to those I have described above. In §3.13 he suggests a suspensive condition. As I have implied earlier (my 3.11) there is a condition available incorporating AM and I see no reason why it should not now be used.

3.17 However, it is not merely the question of whether a condition can be applied that is relevant here. It is whether this "new" AM should be taken into consideration in the assessment process. The question to be asked is "What is likelihood of occurrence". I have described above how concern about and awareness of AM has grown, particularly over the last 5 or seven years and complaints incorporating AM have been increasing. The papers by Stigwood at al submitted previously provide examples of sites where significant AM is a factor and the anecdotal evidence generally is that AM forms part of, if not is the fundamental basis of most wind farm complaints. The risk of AM should therefore be taken account of in any assessment.

4 Monitor Receptor Locations

4.1 This relates to the suitability of the baseline noise measurement locations. I have not seen the site and so I can only respond to a limited extent.

4.2 My Hayes responds to the monitor locations in §§3.15 to 3.18. However, he does not respond to the specific criticism of H48 and merely speculates, presumably with regard to the criticism of H40, that *measurements at or near the tops of hills are often quieter than valley locations*. He makes no response with regard to this specific location. One might just as well speculate that locations near the top of the hill are often more noisy because they are windier. So the criticism has not been answered. As the assessment is made on the basis of the background noise levels at H40 a robust assessment is clearly essential.

5 Noise Limits

5.1 The key issue as I understand it in the section entitled "Critical Wind Speeds and Turbine Choice" in the submission by Stephanie Larkin and Michael

O'Donovan is the conclusion that the Guidelines do not sufficiently protect neighbours of wind farms. Whether that is true or not, I am particularly concerned that the Guidelines are often mis-used or mis-interpreted by applicants, understandably to their own advantage. I believe this to be the case here.

5.2 According to DoEHLG in quiet rural areas where the underlying background noise level is less than 30dB an absolute lower noise level of turbine noise during the day should be set at somewhere between 35 and 40dB but that otherwise the turbine noise level should be 5dB above background noise. This is interpreted in a somewhat bizarre way by the applicant, that any time the background noise level is below 30dB the turbine noise limit should be 40dB then, as soon as the background noise level exceeds 30dB the turbine noise limit rises abruptly to 45dB. Looking at Tables 9.6 and 9.7 of the EIS (the background noise at all properties is taken as that from H40). At 4m/s the day time background noise is 29.2dB and the noise limit is 40dB – already more than 10dB above background noise. Then at 5m/s the background rises to 31.2dB and the limit to 45dB – almost 14dB above background noise.

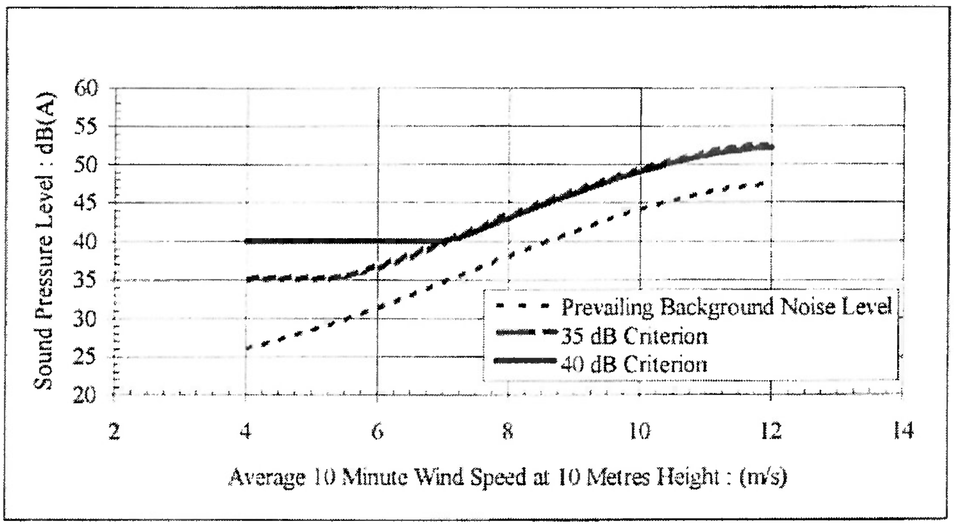
5.3 Whilst I recognise that in a subsequent appeal for the Ardglass site (246824) the inspector took a different view, the inspector for the earlier appeal (PL 04.243630) said in his report [DB11] at the top of p60 that:

> "In terms of the potential for estimated noise levels associated with the proposed development having the potential to represent nuisance for residents in the area, I refer to the guidelines which suggest a *maximum increase of 5dB(A) above background noise at nearby noise sensitive locations is considered appropriate to provide protection to wind energy development neighbours*. At an increase of 5dB(A), the increase in noise levels is perceptible. In terms of the information provided as part of the appeal documents, and just by way of example of my concerns, taking one house, H47, which lies in proximity to the measuring equipment used at location identified NSLA, and at a wind speed of 7m/s, the baseline noise in this area has been recorded at 28.8dB LA90,

10min during the day and 25.2dB LA90, 10min at night. The predicted noise associated with the development is indicated at 40.7dB LA90, 10min which represents a potential increase in noise at this location of between +11.9 – 15.5 dB LA90, 10min. To apply the higher noise levels in this environment, while ensuring that the wind farm might comply in the main with the requirements, would have a significant and negative impact on the existing residential amenities of the area".

5.4 The position here is very similar. The 35 to 40dB limit for low noise environments originates from the UK guidance and, as the figure below from ETSU-R-97 shows, the lower limit of 35dB or 40dB should be followed by a limit of 5dB above background noise. There is no jump to 45dB as can be seen from Fig 3 taken from page ix of ETSU-R-97.

Fig 3



Example of day-time noise criterion

5.5 The DoEHLG Guidelines refer to using the fixed 35-40dB in low noise environments. They do not say the fixed limit should be used when the noise is less than 30dB. A low noise environment is one where underlying noise level is less than 30dB – that is the level excluding weather related noise.

So, in terms of the Guidelines, if a location has underlying background noise less than 30dB on a still day then it should never be given the 45dB limit

5.6 I further suggest, in line with the same maximum increase of 5dB set out in the Guidelines (p30) that the lower limit should be 35dB not 40dB in this case. No justification has been given for using 40dB rather than 35dB or any other figure. This would still result in noise limits in excess of 5dB above background noise and so 35dB should be the highest acceptable limit.

5.7 Although the Guidelines have not been updated Marshall Day Acoustics (MDA) was commissioned by the DoEHLG in 2013 to review the current Guidelines though their report was never implemented. The MDA report [DB12] recommended a flat noise limit at all wind speeds of 40dBA. This is not the forum to debate the pros and cons of the MDA report but it shows that those European countries that use absolute limits are generally lower than 40dB. In Denmark, areas that are used for or designated as residential have a limit of 37dB(LA90) at 8m/s. In Germany the night limit is residential areas is 33dB(LA90). Many other countries that have hybrid limits have lower limits of less than 40dB(LA90) for rural areas and it is rural areas where the greatest problems arise. For example, South Australia, Victoria, Ontario, Quebec and Alberta – in fact all the examples listed in the Marshall Day report including Ireland's 2006 Guidelines.

6 Turbine Noise Levels

6.1 I have no comments on the responses in §§3.21 to 3.29 but the authors of the original comments may want to reply.

7 Conclusions

7.1 The predicted turbine noise level without any AM penalty is very close in many cases to the applicants proposed limits in the EIS. There is clearly a significant risk that the nearest houses will suffer from AM and in this case, any penalty will cause a breach of the limits.

7.2 If, as I suggest, realistic limits are applied to comply with the Guidelines then there will be a breach of those limits by a considerable margin. Any AM penalty will increase that breach further to the extent that it may be impossible to mitigate turbine noise sufficiently.

Denis Buckley
Moneygoff East
Coppeen
Enniskeane
Co Cork

Response to An Bord Pleanála

To whom it may concern,

The submission I am making is in relation to my horses. When they are not racing they are stabled in my farmyard or graze in the fields at the above address. My farm boundary is less than 300 meters from turbine 6 of the proposed wind farm in Barnadivane.

An Bord Pleanála have received objections from horse breeder Aidan O'Brien in relation to proposed wind farm developments near his farm where he has highlighted that horses are very sensitive to noise from wind turbines.

On the 1st and 2nd of January this year the wind was blowing from the north east. My stables are **more than 2 kilometers** from the existing Garranreigh wind farm and on these dates the noise from the Garranreigh wind turbines was extremely loud. The horses became very distressed and on advice from veterinary surgeon Tom O'Leary in Macroom the horses were moved to stables in Glanmire, Co Cork.

This is a serious health and safety issue for me and my horses. I could be seriously injured by them under these conditions and/ or they could seriously injure themselves.

If the proposed development goes ahead I will have 10 wind turbines (6 Barnadivane & 4 Garranreigh) around my farm, to the west, the northwest, the north and the northeast. Farming and horses are my whole life but this prospect will force me to sell my property as I will not be able to continue under such conditions.

Yours sincerely,
Denis Buckley

Denis Buckley

Mr. Patrick Manning
Barnadivane,
Terelton,
Macroom,
Co. Cork
26.01.2018

To whom it concerns

In relation to the ***Barnadivane Wind Farm, Co. Cork, (An Bord Pleanála Planning Ref. PL04.248153, Cork County Council Planning Ref. 14/6760) – Response to third party submissions*** made to An Bord Pleanála by Barna Wind Energy (BWE) Ltd on November 2017, I want to highlight the fact that BWE Ltd has conveniently neglected to consider my investment property, identified as H38, for a noise pollution assessment. In section 3 of the report by BWE, they have considered my investment property to be a derelict dwelling and thus did not consider it for excess decibel (db) levels.

Additionally, this property is only circa 400 metres from turbine **T4**. This clearly falls short of the minimum distance required under Irish law. As turbines are required to be built a distance of at least 4 times the height of the turbine from a residential area, safe and considerate planning would ensure that the minimum distance of **524m** (4 x 131m height) is adhered to for both of my properties, H38 and H55 respectively.

Furthermore, it can be clearly seen from the decibel contour map detailing the predicted decibels for the effected properties, that the property where I reside (identified as H55) in addition to H38 will be subjected to noise levels in excess of the allowable 43db limit. I will also point out that these predicted db contours are just that – predictions! This is due to the fact that noise levels are determined due to a variety of factors which are not related to distance but which can affect the transmission of sound, including topography, ground cover, wind speed and wind direction.

I will also point out that Barnadivane is located in a quiet rural setting. The Environmental Protection Agency's recommendation for quiet areas is **30db** and **27db** for day and night time periods respectively. Several studies, including James (2012), Hanning (2010) and Thorn (2011) have suggested that a setback distance of up to 2400m is required for noise levels to sufficiently dissipate.

No approved planning application should encroach upon another person's property in terms of db level or the turbines physical location.

James, R. (2012) *Wind Turbine Infra and Low-Frequency Sound: Warning Signs That Were Not Heard.* Bulletin of Science, Technology & Society 32(2) 108-127

Hanning, C. (2010) *Wind Turbine Noise, Sleep and Health*.

Thorne, B. (2011) *The Problem with "Noise Numbers" for wind farm noise assessment*. Bulletin of Science Technology & Society 31(4) 262-290

Yours Faithfully Patrick Manning 26/1/18.

Patrick Manning

Patrick Manning

Reply to An Bord Pleanála ref 248152 & 248153 by Barna Wind Action Group 26 January 2018.

We make our comments below to assist and enable 'the interests justice' in this case.

Visual Impact:

Fehily Timoneys interpretation of the interaction of a wind farm and the local community is completely at odds with the vast majority of the said local community. The evidence for this is the phenomenal opposition and number of submissions (259) against this proposed development lodged by the aforementioned local community.

In their response to our previous submission Fehily Timoney, yet again, threaten our local community with the building of the previously permitted wind farm (granted permission now lapsed) even though this is an impossibility. Are the Board ever going to chastise Fehily Timoney for continuing to present misinformation and provocation?

Regarding the designation of the area as '*accepted in principle*' for wind energy development Fehily Timoney have made a huge leap between what the guidelines say and their own interpretation of this, which is that the building of wind farms should be encouraged in these areas. This is a very biased interpretation that obviously favours their argument and wishes. Many of their arguments follow this direction.

There has been a certain amount of confusion on the part of Fehily Timoney about house numbers H37, H38, H39 and H55. If they cared to review the files they will find there are objections lodged by the owners of these properties.

Eirgrid:

We still have not received a satisfactory explanation for the need for this newly proposed substation. The applicant had planning permission for a smaller substation in a much more discrete location and there is no valid reason that we know of why that substation could not have been built except that the developer wished to up the capacity of the substation to facilitate other developments. This contradicts what he explicitly said in the SID application to the Board previously and in the planning application to the local planning authority for the newly proposed substation, i.e. that the proposed substation would only facilitate the Barnadivane windfarm.

Therefore it appears to us that this newly proposed substation is simply more convenient for the applicant. He has decided he wants a bigger substation to facilitate further developments (which have only been revealed bit by bit to us all) and in deciding this has had to make an agreement with Eirgrid. It is this agreement which brings the 2011 Eirgrid standards for substations into the picture. If he stuck with the permitted substation this argument would not exist. He has been very economical with the truth in this matter if not downright duplicitous.

We have put in FOI and AIE requests to Eirgrid on this matter. We were told Eirgrid had 1000s of documents relating to this substation but they have only released a very small number to us and these were already in the public domain. We are proceeding to appeal this matter to the Data Protection Commissioner as we believe there is vital information contained within these documents with regard to the true nature of this proposed substation at Barnadivane. We therefore ask the Board to allow us time to gather this information and present it to the Board.

Recreational Activity:

It is unfortunate that Fehily Timoney like to speak in absolutes as they have done in this instance when they speak of 'no' recreational activities at the site. As far as we know they are not omnipotent and should some weekend pay a visit to the site and enjoy a walk with other users of the area. They will find a number of signposted walks all around the proposed wind farm site.

Just to set the record straight with Fehily Timoney Bride Valley Walking Group made a submission on this matter to the local planning authority. 259 locals have also made submissions and the content of many of these relate to recreational activity in the vicinity of the proposed wind farm. Field surveys are the lowest and most basic form of survey that can be carried out and it is not surprising that valid extant walks have not been found during their limited searches.

Property Valuations:

Please note that regardless of what Fehily Timoney say in this matter their quoted evidence is not related to Ireland and therefore remains irrelevant to the argument. The fact stands 259 local people living around the site do not want this development.

Planting Plan:

We take exception to the Fehily Timoney rational that the planting plan is there mainly to provide a wildlife conduit. A review of the relevant files will reveal to Fehily Timoney that among others, Cork planning authority were mostly interested in the planting plan with regard to its screening potential for the substation. Which in itself speaks to level of visual intrusion this substation would have on the landscape. The response given by Fehily Timoney in this instance does nothing to address the extremely inadequate planting plan as we have previously outlined.

Aarhus Convention and Public Participation:

Fehily Timoney state '*the planning application has gone through significant consultation both voluntary and statutory .....*' we disagree and this neatly avoids the point we made about serious preplanning stage consultation as per Aarhus. As the requirements if the Aarhus convention regarding public consultation have been ignored by the applicant in this case and also ignored by Cork Planning Authority and the Board itself (and indeed the Irish State) taking into consideration the level of local opposition (some of us attended the public meeting and gave our feedback which was not reflected in the subsequent planning application) it is critical that the Board give due consideration and weight to all our concerns in the interests of justice.

Wintering and Breeding Birds:

The response from Fehily Timoney is as expected, a complete rebuttal of the facts we have presented. They are hiding behind their woefully inadequate bird surveys and will not come out until the Board or the Court, be it Irish or European, forces them to.

Breeding snipe will be returning to the site very shortly and we think it would be advisable for the Board to have new field work carried out so as to avoid future embarassments in Europe for Ireland. In any event, we will be carrying out our own surveys again, which will have audio and photographic evidence which we will use in further litigations if necessary.

On another related point, a member of our group spoke with a bird observer at the proposed development site who said he had been employed to carry out a Barn Owl survey for the proposed wind farm application. This man was known to the member of our group as both were members of Birdwatch Ireland Cork Branch and they chatted for a while. As they did, the bird observer remarked upon the presence of a large amount of Spotted Flycatchers at the site. This record does not appear in the EIS. Can Fehily Timoney explain this omission?

List Of Breeding Bird at or Near the Proposed Site Not Recorded in the EIS:

Snipe – on site
Mallard – less than 250 meters from location of Turbine 6
Reed Bunting - less than 250 meters from location of Turbine 6
St0nechat – on site

Kestrel – adjacent
Sparrowhawk – adjacent, sometimes onsite
Long eared Owl – forages, breeds nearby
Grasshopper Warbler – onsite
Spotted Flycatcher – onsite
Buzzard – new breeder – adjacent and foraging onsite
This list is to demonstrate to the Board the unreliability of the bird surveys in the EIS.

Bat Surveys:
Fehily Timoney are again trying to hide behind a secret agreement between them and BCI. This agreement has no legal basis. We state again that many of the members of our group have bat roosts on their land or premises, none of us have been approached by Fehily Timoney and our bats have not been appropriately surveyed.

Is Fehily Timoney trying to tell us that BCI know about all the bat roosts in our homes and that they have surveyed them? If they have, it is news to us and we DEMAND TO SEE THOSE RECORDS.

In conclusion, Fehily Timoney have chosen to simply refute the content of some of our observations. However they have not addressed the majority of our concerns. Therefore should we to conclude from this that what they have not commented on they agree with? Simply repeating the same arguments and not addressing our real concerns is not engaging with the issues we have identified and certainly is not serving the interests of justice.

In the last few days the Irish state has been fined by the EU for its failure to carry out a proper EIA on the site of the Derrybrien Windfarm, Co Galway, having been ordered to do so in 2008. The Irish environment is being seriously compromised by inadequate environmental impact assessment by the relevant authorities and the tax payer is footing the bill. It is an incompatible argument to push through renewable energy projects quoting government targets and policies that claim to protect our environment while at the same time failing to carry out the proper and robust environmental impact assessments. Such behaviour by the State and its agencies cannot continue without further censure from Europe. We therefore request the Board in the interests of justice to ensure that due diligence is applied in this case.

Yours sincerely,
Michael O'Donovan and Stephanie Larkin on behalf of Barna Wind Action Group

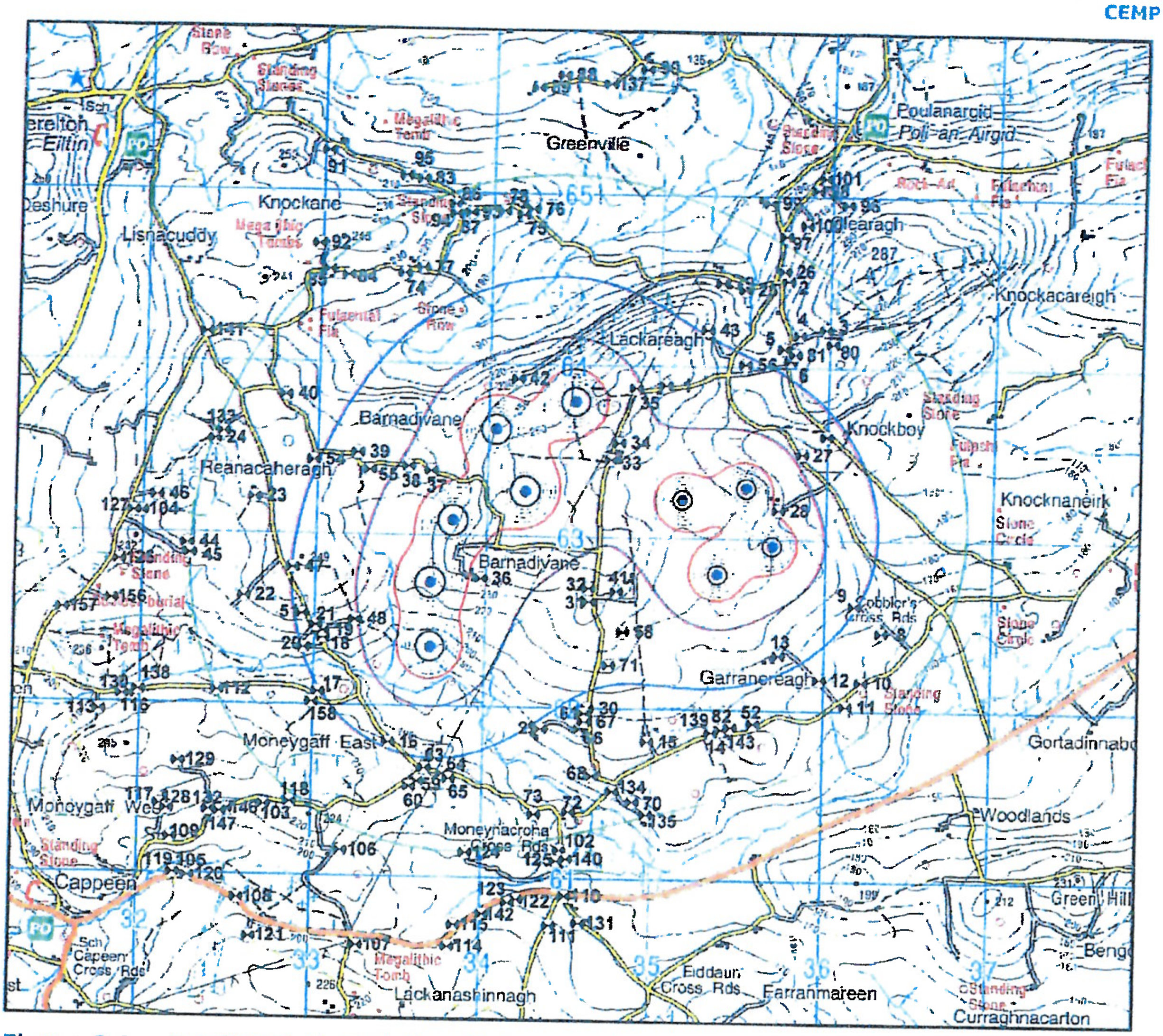


Figure 2.3: Predicted Cumulative Noise Levels at 10 m/s Standardised 10 m Height Wind Speed

House number ownership

16 – Stephanie Larkin & Michael O'Donovan (Home)
18 – David & Martina Forde (Home)
29 – Dan Galvin (Home)
38 – Patrick Manning (Investment Property)
39 – Patrick Manning (Unoccupied)
41 – Jerome Coholan (Home)
54 – John Galvin (field and expired planning permission but no house)
55 – Patrick Manning (Home)
59 – Connollys (Home)
60 - John Paul & Denise O'Callaghan (Home)
63 – Denis Buckley (Home)
64/65 – Pat & Noelle Sheehan (Home) & Nora Sheehan (Home)

Jennifer Sherry

From:	procbordemail
Sent:	Tuesday 30 January 2018 12:00
To:	Jennifer Sherry
Subject:	FW: Email 2 of 3 - Your ref: PL 04.248152 (244439) PA Reg Ref: 14/557 & Your ref: PL 04.248153 (245824) PA Reg Ref: 14/6760
Attachments:	a) DB01-Notes of NWG Meeting 2 August.pdf; b) DB02-FINAL minutes of NWG meeting 2 August 2006.pdf; c) DB03-Salford University Study into AM.pdf; d) DB04-Denbrook+APPEAL+DECISION-1.pdf; e) DB05-Swinford - SS.pdf; f) DB06-Turncole Farm Southminster 2174982.pdf; g) DB07-AMWG Final Report-09-08-2016_0[1].pdf; h) DB08-Wind_Turbine_AM_Review_Issue_3__FINAL_[1].pdf
Importance:	High

From: Bord
Sent: Monday 29 January 2018 16:50
To: procbordemail <procbordemail@pleanala.ie>
Subject: FW: Email 2 of 3 - Your ref: PL 04.248152 (244439) PA Reg Ref: 14/557 & Your ref: PL 04.248153 (245824) PA Reg Ref: 14/6760
Importance: High

From: Joe Noonan [mailto:jnoonan@nlcc.ie]
Sent: Monday 29 January 2018 16:49
To: Bord <bord@pleanala.ie>
Cc: Pippa Willows - Legal Secretary, Noonan Linehan Carroll Coffey <pippawillows@nlcc.ie>
Subject: Email 2 of 3 - Your ref: PL 04.248152 (244439) PA Reg Ref: 14/557 & Your ref: PL 04.248153 (245824) PA Reg Ref: 14/6760
Importance: High

Noonan Linehan Carroll Coffey
SOLICITORS
www.nlcc.ie

TO: **An Bord Pleanála**

FROM:

Joe Noonan
NOONAN LINEHAN CARROLL COFFEY
Solicitors
54 North Main Street
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T12 WY2D

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www.nlcc.ie

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Confidentiality: This email and any attachments are confidential to the person named above. If we have sent this email to your email address by mistake, please reply and let us know. Then please delete the email and any attached files from your system. You should note also that the material contained in this email and any attached files may be legally privileged. The unauthorised use of any of this material may be unlawful.

[Evolve:c3cb5688-6a90-4d1b-8edb-5487abc9cc6d]

Noise Working Group (NWG)

DTI, 1 Victoria Street
2 August 2006

Present:

Alan Smith (DTI)
Jonathan Perks (FES)
Mark Dorrington (FES)
Helen Matthews (DEFRA)
Richard Perkins (DEFRA)
Andy McKenzie (Hayes McKenzie Partnership Ltd)
Bob Davies (RD Associates)
Dick Bowdler (New Acoustics)
Geoff Leventhall
Marcus Trinnick (Bond Pearce)
Mark Jiggins (Hoare Lea Acoustics)
Andrew Bullmore (Hoare Lea Acoustics)
Mike Anderson (RES)

Notes of the Meeting

Introduction by Chair
Alan Smith welcomed those present. He introduced the background to the meeting and highlighted DTI's objectives for the Group which is to provide clear expert advice and guidance on the Aerodynamic Modulation (AM) issue raised in the Hayes McKenzie report on Low Frequency Noise.

Terms of Reference
The following Terms of Reference and Objectives were agreed:

Noise Working Group – Terms of Reference and Objectives

The DTI have requested that a peer review of the Hayes McKenzie report will be undertaken by the Noise Working Group (NWG), most of whom were involved in the Working Group on Noise From Wind Turbines and the authors of "The Assessment and Rating of Noise from Wind Farms" (ETSU-R-97).

The NWG will address issues specifically relating to the Hayes McKenzie report:

- Consider and agree the main conclusions of the report
- Consider the report's findings relating to aerodynamic modulation
- If appropriate, provide a means to assess and apply a correction where aerodynamic modulation is a clearly audible feature
- Make clear recommendations, which will assist planning authorities. These recommendations will provide clarity and minimise any confusion when assessing applications
- Recommend actions (if any) to be taken in relation to updating ETSU-R-97

It is intended to complete this review and publish its recommendations in Autumn 2006.

Review of the Hayes McKenzie Report
The main conclusions of the report were agreed. It was noted that "Aerodynamic Modulation" should really be called Amplitude Modulation and is sometimes referred to as Blade Swish. These and future notes will refer to this as 'AM', and this for the purposes of the Noise Working Group is defined as aerodynamic modulation, amplitude modulation and blade swish. The causes of this effect are unknown, but there are theories that have been developed by Van de Berg and Oerlemans. It is possible that the effect is caused by a combination of these causes.

It was recognised that complaints concerning windfarm noise are currently the exception rather than the rule. The cause of these complaints was thought to result mostly from AM even if they are articulated in different ways from Members of the public (blade swish, low frequency noise, whoosh, pulse etc) The trend for larger more sophisticated turbines could lead to an increase in noise from AM and it was therefore timely to review this issue.

There was a discussion concerning whether the levels of AM measured by McKenzie were significantly higher than the levels specified in ETSU–R-97 as stated in the Hayes McKenzie report (page 58). It was agreed that we needed clarification from the author on this point.

Action on FES to seek clarification from Malcolm McKenzie on this issue.

There was also a discussion on the night time criteria level specified in ETSU-R-97. This level was based on the empirical evidence available at the time and was consistent with published WHO (World Health Organisation) guidance. There was a lengthy debate about whether it would be appropriate to reduce the existing night time levels as set out in ETSU-R-97, but it was agreed that there is currently insufficient evidence to change this level. Given the lack of existing evidence, relatively few complainants relating to noise issues from sites already developed, consistency with WHO guidance, the NWG considered that ETSU-R-97 struck the right balance between energy policy and planning advice and this document was robust in terms of existing noise level limits, and that this should be communicated to all users of ETSU-R-97.

Identify and Agree Solutions
It was agreed that an understanding of the causes of AM should be developed. A pragmatic and staged approach would be appropriate, the first stage being to gather empirical data from existing developments. It was agreed that the NWG should commission a study to gather empirical data from existing sites to better understand the extent of the AM issues. This should be undertaken as soon as possible, but the group were of the view that due to the nature of the noise and the weather, this would have to be carried out in the summer months and it may be too late to mobilise this year. The study will include:

1a	Literature study to review the current knowledge of AM
1b	Identify potential sites which could be used to carry out objective noise measurements Maximum of 10 sites (including 5 where there had been complaints). This would include: • Asking LPAs for information on which sites they had received complaints concerning noise • Identifying control sites (where there had been no complaints) • Developing a methodology for carrying out noise measurements
1c	Contact • turbine manufacturers to find out what their understanding of AM is and what work they are doing to address this issue • windfarm developers to see whether they have any historical data which would help determine the circumstance when AM occurs
	Report findings back to DTI / DEFRA / NWG
2	Carry out objective noise tests as defined in 1b It was agreed that it would be sufficient to carry these measurements outside of buildings; this would considerably reduce the difficulties of obtaining permissions and access
3	Analyse results This will include the quantification of AM as well as the frequency and length of time AM is found to occur at each site
4	Make recommendations if required
	Report findings back to DTI / DEFRA / NWG

A very rough estimation was that this would take 12 months to complete and the cost would be of the order of £100k.

DTI and DEFRA agreed to consider how this could be supported taking into consideration their funding situations and other commitments.

Recommendations / Review of Actions

It was agreed that ETSU-R-97 has been a useful document to assist the planning process and that there is currently insufficient evidence available to recommend any change to this document. However, since it was agreed that AM may become more of an issue in the future, the work recommended above would provide a foundation for clearly identifying and understanding the extent of the AM noise issue and therefore whether any amendment to ETSU-R-97 would be appropriate at some future date.

In the meantime it was agreed that the advice should be given to all stakeholders involved in windfarm development including LPAs:

- Aerodynamic Modulation is a real effect in a few cases, but the cause is currently not understood and therefore when and where it occurs cannot be predicted.

- For future windfarm developments, developers may wish to allow some margin to allow for the noise created by this effect. This means that developers should not exploit the existing 43DB limit by going right up against it and should therefore allow margin to tune the blades, or in such areas where AM may be an issue develop say a 3 not 4 turbine site and keep well below 43 DB.
- Existing developments (which have or are seeking consent) must be unaffected by this advice: they can't be penalised retrospectively.
- Research will be commissioned to understand the issues surrounding Amplitude Modulation

AM refers to aerodynamic modulation, amplitude modulation and blade swish.

This advice was framed such that it was fair to operators of existing and planned developments and would allow developers of future developments to prepare appropriate risk strategies.

These recommendations and actions were agreed by those present; following agreement by the members of the working group, who were unable to attend, DTI (with the help of FES) will prepare a statement, based on the recommendations described above, to send to appropriate organisations and individuals.

Any Other Business
There was no other business.

Date of Next Meeting
To be agreed.

Jonathan Perks and Mark Dorrington
3 August 2005

Notes of Meeting

Noise Working Group (NWG)

DTI, 1 Victoria Street
2 August 2006

Present: Alan Smith (DTI)
Jonathan Perks (FES)
Mark Dorrington (FES)
Helen Matthews (DEFRA)
Richard Perkins (DEFRA)
Andy McKenzie (Hayes McKenzie Partnership Ltd)
Bob Davis (RD Associates)
Dick Bowdler (New Acoustics)
Geoff Leventhall (Consultant)
Marcus Trinick (Bond Pearce)
Mark Jiggins (Hoare Lea Acoustics)
Andrew Bullmore (Hoare Lea Acoustics)
Mike Anderson (RES)

Apologies: Alan Purdue (Castle Morpeth LA)
Bernard Berry (Consultant)
David Spode (Shrewsbury LA)
Huw Thomas (Anglesey LA)
Jeremy Bass (RES)
John Warren (nPower)
Malcolm Hayes (Hayes McKenzie Partnership Ltd)
Mark Legerton (nPower)
Mike Raw (Scottish Borders LA)

<u>Introduction by Chair</u>
Alan Smith welcomed those present. Alan briefed the Noise Working Group (NWG) on the background for calling the meeting and highlighted DTI's objectives for the NWG which is to provide clear expert advice and guidance on the issue surrounding Amplitude Modulation of Aerodynamic Noise (AM) raised in the Hayes McKenzie report on Low Frequency Noise (The Measurement of Low Frequency Noise at Three UK Wind Farms, W/45/00656/00/00, URN No. 06/1412).

<u>Terms of Reference</u>
The NWG will address issues specifically relating to the Hayes McKenzie report:

- Consider and agree, if thought appropriate, the main conclusions of the report
- Consider the report's findings relating to AM
- If appropriate, provide a means to assess and apply a correction where AM is predicted to be a clearly audible feature
- Make clear recommendations to advise Government

Review of the Hayes McKenzie Report
In line with the 'Terms of Reference' the main conclusions of the report were discussed. The group agree with the conclusions of the report concerning infrasound and Low Frequency Noise. It was also agreed that a greater understanding of the effects and causes relating to AM were required to ensure that this phenomenon can be managed.

It was agreed that the NWG should commission a study to gather empirical data from existing sites to better understand the extent and cause of AM. This should be undertaken as soon as possible, but it was recognised that funding had to be secured. The study could incorporate the following tasks:

1a	Literature study to review the current knowledge of AM
1b	Identify up to 10 potential sites which could be used to carry out objective noise measurements (including 5 where there had been complaints). This would include: • Asking LPAs for information on which sites they had received complaints concerning noise And if needed: • Identifying control sites (where there had been no complaints) • Assess the potential for developing a methodology for carrying out noise measurements
1c	Contact • turbine manufacturers to find out what their understanding of AM is and what work they are doing to address this issue • windfarm developers to see whether they have any historical data which would help determine the circumstance when AM occurs Report findings back to DTI / DEFRA / NWG

If the NWG agreed having reviewed the empirical data that further work is required the following should be carried out:

2	Carry out objective noise tests as defined in 1b It was agreed that it would be sufficient to perform these measurements outside of buildings; this would considerably reduce the difficulties of obtaining permissions and access
3	Analyse results This will include the quantification of AM as well as the frequency and length of time AM is found to occur at each site
4	Make recommendations if required Report findings back to DTI / DEFRA / NWG

A very rough estimation was that the second stage of the report would take up to 12 months to complete - mainly due to weather conditions. DTI and DEFRA agreed to investigate how this study could be supported and report back at the next meeting. In the meantime FES to investigate potential costs.

Recommendations / Review of Actions
The work recommended above will provide a foundation for clearly identifying and understanding the extent of AM noise.

Any Other Business
There was no other business.

Date of Next Meeting
To be agreed.

19 October 2006

Appeal Decision

Inquiry opened on 23 July 2009

Site visits made on 3 August and 27 October 2009

by Andrew Pykett **BSc(Hons) PhD MRTPI**

an Inspector appointed by the Secretary of State for Communities and Local Government

The Planning Inspectorate
4/11 Eagle Wing
Temple Quay House
2 The Square
Temple Quay
Bristol BS1 6PN

☎ 0117 372 6372
email:enquiries@pins.gsi.gov.uk

Decision date:
11 December 2009

Appeal Ref: APP/Q1153/A/06/2017162
Land to the south east of North Tawton and the south west of Bow

- The appeal is made under section 78 of the Town and Country Planning Act 1990 against a refusal to grant planning permission.
- The appeal is made by RES Developments Ltd against the decision of West Devon Borough Council.
- The application Ref: 8250/2005/OKE, dated 10 November 2005, was refused by notice dated 31 January 2006.
- The development proposed is nine 3-bladed horizontal axis wind turbines, electricity transformers, access tracks, crane hardstandings, control building, sub-station, met mast, temporary construction compound and met masts.
- The inquiry sat for 13 days on 23, 24, 27-31 July, 3 August, 20-23 and 26 October 2009.
- This decision supersedes that issued on 22 March 2007. That decision on the appeal was quashed by order of the Court of Appeal.

Preliminaries

1. At the Inquiry an application for costs was made by RES Developments Ltd against the West Devon Borough Council. This is the subject of a separate Decision.

2. The original public inquiry into the above appeal was held in November 2006. The appeal was successful but the decision was challenged in the High Court. Although the challenge was unsuccessful, the appeal decision was subsequently quashed by the Court of Appeal in July 2008. The decision was therefore returned for re-determination taking account of all matters raised. I held a pre-inquiry meeting in Spreyton to consider the arrangements for the inquiry on 1 June 2009. Two third parties were granted Rule 6 status for the purposes of the inquiry. These are: the Den Brook Judicial Review Group Ltd (DRJRG), and the Campaign to Protect Rural England (CPRE).

3. An Environmental Statement (ES) was prepared in 2005 under the provisions of the Town and Country Planning (Environmental Impact Assessment) (England and Wales) Regulations 1999 to accompany the application. Volume II of the ES is accompanied by Volume I, which comprises a non-technical summary, and Volume III is a series of plans, drawings, maps, photographs and photomontages. Supplementary Environmental Information (SEI) was prepared and issued in 2006 in three equivalent volumes on behalf of the appellant and before the first inquiry. It pays attention to the landscape and visual assessment of the scheme, together with assessments of its archaeological impact, and its effect on scheduled ancient monuments and the

historic landscape. Before the second inquiry further Supplementary Environmental Information was prepared. It comprises a revised noise assessment and a capability statement. I have taken account of all the submitted material. Evidence submitted on behalf of the appellant indicates that, although not recorded on the application form, the turbines would be removed after 25 years. I have taken this into account also.

4. I carried out a formal visit to the site and its surroundings with the parties on 3 August. I visited the 6 locations at which background noise recordings were made on 27 October. I made unaccompanied visits to various locations including Cosdon Hill, Ramsey Hill, and Belstone Tor; relevant locations on the Tarka Trail, and the Two Moors Way; and the bridleways between Staddon Farm and Higher Nichols Nymett, and that to the north-east of Burrow.

Decision

5. I allow the appeal, and grant planning permission for nine 3-bladed horizontal axis wind turbines, electricity transformers, access tracks, crane hardstandings, control building, sub-station, met mast, temporary construction compound and met masts on land to the south east of North Tawton and the south west of Bow in accordance with the terms of the application, Ref: 8250/2005/OKE, dated 10 November 2005, and the plans submitted with it, subject to the conditions included in the schedule at the end of this decision.

Main issues

6. In additional to the matters to which I have referred above, I have also taken account of material submitted at the application stage; at the time of the first inquiry; the first appeal decision and the subsequent court proceedings; and, of course, the evidence and submissions made at the second inquiry. Taking account of all these matters and of my own assessments resulting from my visits to the site and its surroundings, I have concluded there are two main issues in this case.

7. These are:

(i) the effect of the proposed development on:

- the character and appearance of the surrounding area, including the historic environment;
- local ecology, especially bats;
- the living conditions of local residents, especially in relation to possible noise disturbance; and

(ii) whether any harm resulting from the first main issue could be sufficiently regulated by conditions, or would be outweighed by the benefits of renewable energy generation, to justify the development.

8. There is inevitably a good deal of overlap between the matters considered at and identified as main issues in the first inquiry. However, that decision was referred to and quashed by the courts largely on the basis of the manner in which possible noise disturbance had been considered. Although the consequences of the scheme in relation to noise were raised at the first inquiry,

it is evident that it was not the subject of specialist evidence by the principal parties to the inquiry. As I have recorded above, that inquiry also pre-dated the SEI prepared in 2009. The council's position in relation to this matter remained the same for both inquiries – it raises no objection to the scheme on noise grounds, but notwithstanding this I have identified it as a component of the first main issue as far as this re-determination is concerned.

Reasons

9. The nine turbines would be sited on land within the valley of the upper reaches of the Den Brook – a tributary of the River Yeo which itself flows to the north into the River Taw. The appeal site covers an area of approximately 2km^2 (200ha), although the land actually occupied by turbine bases and ancillary development would amount to just over 3½ha. The ES records that the actual make of turbine has not yet been selected, but at its maximum extent it would not exceed a height of 120m above ground level. The blades would be about 45m in length, and the tower would be approximately 75m in height. The turbines would be generally arranged on a south-west/north-east axis over a distance of about 1500m. The scheme includes the erection of two temporary 80m high monitoring masts, together with a network of 4.5m wide access tracks and a centrally located temporary construction compound. The control building and sub-station would also be centrally located. The necessary grid connection does not form part of the appeal proposal, but I understand the current proposal would follow a route to the west and north-west to North Tawton.

10. The ES is based on turbines with a nominal capacity of 1.65 – 2.3 MW, and, subject to the weather and ground conditions, the development operations would take up to about 12 months. The scheme envisages the delivery of most plant and materials from the A30 at Whiddon Down, along the A382 and the A3124 towards North Tawton, and thence to a new site entrance off the A3072. Some minor road improvement and traffic management works would be necessary at Whiddon Down, at the railway bridge on the A3124, and at the A3124/A3072 junction.

Character and appearance

11. The appeal site lies in the gently rolling agricultural landscape which characterises that part of mid Devon between Dartmoor to the south and Exmoor to the north. The site and its surroundings fall within two of the character areas included in the Countryside Agency's character map of England – area 148: Devon Redlands, and area 149: The Culm. The former area extends from the east and includes most of the appeal site itself. Amongst other key characteristics, reference is made to the hilly landscape of villages, hamlets, farmsteads, hedgebanks and winding lanes. The village of Bow lies within this area. However, this character area forms a relatively narrow extension into The Culm. This includes extensive areas to the north, south and west, and it comprises the vast majority of the land between Dartmoor and Exmoor.

12. Reference is made, amongst other key characteristics, to rolling open pasture separated by many small valleys; to the wide views across a remote landscape, and the scattered hamlets and farms connected by winding sunken lanes.

Similar areas are identified in Map 5 of the *Devon Structure Plan 2001 to 2016* (2004). Policy CO1 of the structure plan refers to the more finely defined Landscape Character Zones. On the basis of this assessment both the appeal site and most of the surrounding land to the north and west fall within area 8 – the Mid Devon Farming Belt. Much of the surrounding land to the south falls within area 16 – the Tedburn St Mary Area. Policy CO1 (Landscape Character and Local Distinctiveness) requires that the distinctive qualities and features of Devon's Landscape Character Zones should be sustained and enhanced.

13. A still more detailed study was carried out on behalf of the West Devon Borough Council to identify the Landscape Character Types (LCTs) within the council's area. The assessment was issued in June 2008. On the basis of this analysis the appeal site falls within LCT 1F – farmed lowland moorland. The description refers to the open, gently rolling or flat landscape where the pastoral farmland and rough ground has an elemental, empty character, dominated by wet unenclosed moorland. Most specifically in relation to the appeal proposal, the management guidelines advise that the introduction of wind farms would have the potential to impact on and dilute the local landscape character. The surrounding area to the north, west and south falls within LCT 1D – inland undulating uplands. This type consists of open rolling and sloping uplands mainly in pastoral cultivation with little arable land. It has an open downland character locally. It is subject to the same guidance in relation to wind farms as area LCT 1F.

14. The appeal site lies close to the boundary between West Devon Borough Council to the west, and Mid Devon District Council to the east. The land to the east of the appeal site, including the settlements of Bow and Zeal Monachorum, falls within the mid Devon farming belt (gently rolling farmland) landscape type. Key characteristics include the rolling, rounded medium-scale hilltops with convex valley sides falling gently towards major river valley floors. The area has a strong agrarian flavour, and the historic village centres are considered to be features of higher quality than much of the landscape.

15. Policy NE10 (Protection of the countryside and open spaces) of the *West Devon Borough Local Plan Review* (2005) records that development within the countryside outside settlement limits or not otherwise in accordance with the policies of the plan will not be permitted unless it provides an overriding economic or community benefit which avoids unacceptable harm to the distinctive landscape character of the area. Natural features which contribute to the character are protected, including views. However, in relation to wind energy proposals this policy is essentially subject to Policy PS10 (Energy production in West Devon). For this supports wind energy proposals provided they have no significant adverse impact on: the qualities and special features of the natural landscape or townscape; nature conservation; or the conditions of those living and working nearby. In this respect the local plan accords with the contents of structure plan Policy CO12 (Renewable Energy Development). While it too seeks to promote renewable energy development in the context of the sub-regional target of 151MW by 2010, such development is rendered subject to its impact on the qualities and special features of the landscape and on the conditions of those living or working nearby.

16. The northern edge of the Dartmoor National Park lies about 5½kms to the south of the appeal site. Between the two – and at its closest about 2kms to

the south and south-west of the site – the land is designated as an Area of Great Landscape Value. Structure plan Policy CO4 records that such areas are particularly sensitive to new development, and local plan Policy NE9 is similarly protective. However, in the determination of renewable energy schemes both paragraph 24 of Planning Policy Statement (PPS) 7: *Sustainable Development in Rural Areas* and paragraph 15 of PPS22: *Renewable Energy* promote the use of criteria-based policies in preference to such local designations.

17. The highest parts of the Dartmoor National Park lie along its northern edge, and there is a distinct boundary between the surrounding agricultural landscape and the moorland itself. Other than in the vicinity of Whiddon Down, the designated area is essentially defined by the A30 dual-carriageway, but the proximity of the high and open moorland to the surrounding agricultural landscape facilitates an appreciation of the qualities and characteristics of both areas in both directions.

18. Amongst other matters, structure plan Policy CO2 (National Parks) records that the application of particular care is necessary to ensure that no development outside the Park is permitted which would damage its natural beauty, character or special qualities. Similarly, local plan Policy NE7 (Dartmoor National Park) seeks to avoid development which would have an unacceptable adverse effect on the setting of the Park's landscape, or on viewpoints within the Park. The significance of national designations is also recognised and acknowledged in PPS22. Although paragraph 14 records that buffer zones should not be created around designated areas, it also specifies that the potential impact of renewable energy projects close to their boundaries will be a material consideration to be taken into account in the determination of planning applications. At the inquiry my attention was drawn to the contents of the *Dartmoor National Park Management Plan 2007.* It includes a comprehensive list of Dartmoor's special qualities. Amongst these, reference is made to the extensive views across Devon which the moor is able to provide.

19. Policy EN 1 of the *Regional Planning Guidance for the South West* (RPG10) (2001) also provides for both the strong protection of the region's nationally important landscape areas and the conservation and enhancement of local character. The *Regional Spatial Strategy for the South West* (RSS) is in the course of preparation. The draft revised version incorporating the Secretary of State's proposed changes was issued in July 2008, and I am therefore able to lend it significant weight in this appeal. Policies ENV1 and ENV2 also seek to protect and enhance the region's natural and historic environment, and Policy ENV3 records that particular care will need to be taken to ensure that no development is permitted outside the National Parks which would damage their natural beauty, character and special qualities.

20. During my visits to the appeal site and the surrounding area I was able to consider all the views expressed on behalf of the both the principal parties and those who have made representations. I visited the four closest settlements – North Tawton, Bow, Spreyton and Zeal Monachorum – together with most of the viewpoints discussed, including those on Dartmoor. I have considered the impact of the scheme in terms of its effect on both landscape character and visual amenity.

Landscape Character

21. At the ES stage it was concluded that the wind farm would result in a re-definition of the local landscape character zones. The new zone would cover the wind farm site itself and its immediate environs, covering an area of about 8km². Within the new zone the turbines would be dominant. Beyond this zone it was assessed that there would be a buffer zone up to approximately 2kms in width where the turbines would be co-dominant with the character of the existing zones.

22. At the inquiry the council's landscape witness indicated his agreement with the principle that the proposed development would be sufficient to result in the changes to zones described in the ES. However, in his view a significantly larger area would be affected. He considered the turbines would be prominent in an area defined by North Tawton, Bow and Spreyton - an area of approximately 30km². In contrast, the appellant's landscape witness noted that the site is a localised area of larger scale more open landscape, including open views where the scale of the landscape can be readily appreciated. He makes a distinction between the area of the site itself and the smaller scale, undulating and more vegetated landscapes beyond, in which the turbines would have more limited visibility with increasing distance. In his view the development would be dominant in an area defined by the A3072 to the north, Broadnymett to the east, Ham Farm and Itton to the south, and Cocktree Moor and Halse Farm to the west. In the surrounding area, defined by North Tawton, Zeal Monachorum, Bow and Spreyton the turbines would be significant but not dominant. He considered the change would be insufficient to result in the creation of a localised wind farm landscape.

23. I have referred above to the narrowness of the Devon Redlands character area and to The Culm to the north, south and west. In my opinion the distinction is readily visible in the landscape, and its lack of width renders it more sensitive to change. I believe the development proposed would be sufficient to result in a localised zone in which the turbines would effectively dominate and define the landscape within and around them. However, I also agree with the appellant's view that within The Culm and beyond, the landscape character, combined with distance, would help to attenuate this dominance quite rapidly. In landscape character terms I do not believe the development would give rise to a co-dominant surrounding zone.

Visual Effects

24. As I have recorded above, the appeal site lies in the upper reaches of the valley of the Den Brook. More accurately, seven of the proposed turbines would lie on land which drains into the Den Brook. The two most southerly turbines would be sited on land which drains into the unnamed stream which crosses Itton Moor. It too flows into the River Yeo, just to the south-west of the Den Brook/Yeo confluence. Neither of the valleys is deeply incised, and from some vantage points the topography of the site takes the form of a relatively extensive shallow basin which is overlooked from higher ground in all the surrounding directions. It is evident from the site itself however that the land is not flat. The two streams are separated by a low ridge and the land rises gently from the north-east to the south-west. The turbines would occupy sites between about 122m AOD (T5) and 160m AOD (T1). With increasing

distance, in my view the topography of the site itself becomes less significant – a perception which to my mind would be reinforced by the number, distribution and height of the turbines.

25. The ES includes a total of 13 photographs of the site and its surroundings, with a photomontage for each viewpoint indicating the appearance of the proposed turbines. Photographs were also taken from an additional 11 locations and wireframes prepared. These were supplemented with the submission of the initial SEI by revisions to the photomontages for viewpoints 1, 3, 4 and 9, and by the addition of 4 further viewpoints – A, B, C and D. At the inquiry I also had the benefit of photographs from 25 viewpoints supplied by the landscape witness for the DBJRG. I have considered the photographic material and the wireframes within the terms in which they were supplied – as an aid to my experience of visiting the site and many of the viewpoints.

26. The site is crossed by a railway line which I gather is subject to modest seasonal use by passenger trains, but I saw on my visit that visibility from the line would be severely curtailed by trees. The closest publicly accessible vantage points to the turbines would be to the south where a minor road from the A3124 at Itton Cross passes through the hamlet of Itton, before crossing Itton Moor and turning south towards Spreyton. The closest turbine (T3) would be about 150m from the lane. I agree with my predecessor however that the more attractive prospects of the appeal site and its background are to be obtained from the north. From this general direction, and especially from the north-east, the bulk of Dartmoor is invariably present. Quite apart from the difference in height, the distinction between the agricultural landscape of the foreground and middle-distance, and the moorland leading to the horizon, enables the viewer to appreciate and value the interdependence of its components.

27. ES Viewpoint 1 from close to Nichols Nymett Moor Cross is an example of the views available from the minor road which connects North Tawton with Zeal Monachorum and Bow. The appellant draws attention to the low proportion (14%) of the 30km radius zone of theoretical visibility study area from which the turbines would be theoretically visible. Although this proportion would be further reduced by characteristic high hedgebanks and hedges, I noted on my visits that prospects were available in the direction of the appeal site and beyond through field gates, lanes and tracks. Such apparently fortuitous glimpses are always gratifying in the countryside. From this and similar vantage points the viewer would be at about 150-200m AOD at a distance of just over 2kms to the nearest turbine. The complete height of most of the turbines would be visible, but the panorama is extensive and the essential components of the scene are on a large scale. I recognise the turbines would exceed the scale of trees and farmsteads by many times, but on the contrary, their size would complement the scale of the scene as a whole. In this sense I do not depart from my predecessor's view that the turbines would be framed by the landscape. It follows that in my opinion the proximity of the site to Dartmoor would not detract from the appreciation, experience or prospect of the national park. Although the turbines themselves would be very large, I consider that in number and extent the project would not be excessive in relation to its landscape setting.

28. From the viewpoint of ramblers or riders one of the most significant routes from which the turbines would be visible is the bridleway between Higher Nichols Nymett and Staddon Gate – passing through Westacott Barton and Staddon Farm. Although most of the route lies to the north of thick or high hedges, the turbines would be readily visible through field gates. To the east of Staddon Farm the right of way lies on the south side of the field boundary. In any event, riders would be able to see over most of the hedges. At its western end the bridleway would be about level with the hub height of the lowest of the turbines, but the route gently declines to about 160m AOD. The impact of the turbines would thus be rendered greater by their height in relation to the potential vantage points from the north. From the viewpoints of the observer however, the turbines would be offset from the highest parts of Dartmoor. The northern slopes and tops of Cosdon Hill, Belstone Tor and Yes Tor would all appear to the south-west of the observer. Notwithstanding the proximity of the observer to the turbines, in my view they would not seriously diminish the impact or presence of this part of the moor. At a maximum blade tip height of 280m AOD (T1) this would still be well below the three high points of 550m (Cosdon Hill), 479m (Belstone Tor) and 619m AOD (Yes Tor). The prospect to the south-west from the bridleway to the north-east of Burrow is at about the same height, but in this case the turbines would be directly in line with Dartmoor. I conclude that from this particular location the scheme would have a harmful effect on visual amenity.

29. SEI Viewpoint A is to the north-east of Sanford Barton and is representative of views from the A3072. It is from a lower elevation than Viewpoint 1 and the distance to T5 is only 1.2kms. The northern tors and hills of Dartmoor form the south-eastern horizon, but one effect of the lower level would be to increase the perceived height of the planned turbines. From this location the balance between the turbines and their landscape setting would not be as evident, and the height of the turbines would be emphasised by their breaching of the skyline. From this location also I consider the turbines would have a harmful effect.

30. ES Viewpoint 2 provides an indication of the impact of the proposed development on North Tawton. In this regard I agree with the council's landscape witness who considered at the inquiry there is a distinction to be made between the visual impact of wind energy schemes on individual dwellings on one hand and whole settlements on the other. Although the *Guidelines on the Environmental Impacts of Windfarms and Small Scale Hydroelectric Schemes*[1] suggests a buffer zone is desirable in relation to both forms of human occupation of the land, a rural village or small town has a social and community function which cannot similarly apply to an individual dwelling. To my mind the impact of a wind energy scheme on the landscape setting of such a settlement must be a matter of greater significance than the effect of the same scheme on isolated dwellings. In the case of North Tawton however the theoretical zone of visual influence included in the ES indicates that most of the town would be out of sight of the proposed turbines. Visibility of the development would be confined essential to an area at the southern entrance to the settlement. The upper parts of the turbines would be visible

[1] CD49, paragraph 2.4.4

over the horizon to the south-east, but in my view they would be sufficiently distant not to have an adverse effect on visual amenity.

31. A gateway at Itton Cross (ES Viewpoint 3) is a good vantage point for the assessment of the visual effect of the proposed turbines from the west. At this location the viewer would be above the level of the turbine bases, and the topographical context – the shallow basin – of the development would be evident. The fields in the foreground are quite large, and the ridge to the east of North Tawton provides a degree of enclosure. In contrast to the prospects from the north however, there is no complementary upland area and the turbine blades would be seen against the background of the sky. Although in clear weather Exmoor is visible to the north-east, in my view it is too distant to make the same contribution as Dartmoor does in views from the north.

32. The proposed wind farm would be theoretically visible from Spreyton looking north-west. However, the principal street through the village follows an east-west route blocking visibility to the north. ES Viewpoint 8 is from a footpath at the northern end of the village. I saw on my visit that there are variations in the prospect along the footpath, but in my view the resultant differences in the visibility of the wind farm would have only a minor effect. From this viewpoint the landscape has a different character with smaller fields, more hedgerow trees and steeper slopes. The trees would partially obscure some of the turbines, the closest of which would be some 2.9kms away. I do not dispute that the turbines would change the prospect from this part of Spreyton, but in my view the overall effect would be limited.

33. Bow would be a little closer to the nearest turbine than Spreyton, but more significantly, the valley of the River Yeo effectively connects the village with the appeal site. The village is sited on rising land on the east side of the valley and the turbines will therefore be clearly visible – especially from houses with south-west facing windows in, for example, Hobbs Way, Nymet Avenue, Collatons Walk and Gregory Close. ES Viewpoint 7 indicates the visual impact of the turbines from the village hall and playing fields. The photograph shows some of the houses on streets in the south-western quadrant of the village. From the viewpoint selected three of the turbines would be almost in line – an arrangement which in my view is bound to increase the impact of the rotation of the blades by continually creating and recreating a series of angles. On the other hand, the proximity of the turbines to each other would result in the wind farm occupying a lower proportion of the total scene than equivalent views from the more southern or northern viewpoints. As the viewpoint illustrates, the scene includes the northern hills of Dartmoor – principally Cosdon Hill. A wind farm would be an uncompromisingly new and man-made addition to the landscape, but in the light of its design, form and purpose I would not regard it as a challenger to Dartmoor. Nor do I consider the view of Dartmoor would be blighted. In my view a wind turbine has a readily comprehensible design simplicity, and although the proposed turbines would undoubtedly be large, I do not consider the number and distribution of turbines would be inconsistent with its landscape setting as seen from the village.

34. The churchyard at Zeal Monachorum would be nearly 4.3kms from the nearest turbine. The surrounding village occupies a low hill-top and the Zone of Visual Influence plans included in the ES indicate that the turbines would be visible at both blade tip and hub heights. Many potential views from village streets

would be interrupted by buildings however. I do not believe the appeal proposal would have as substantial a visual impact on the village as the parish council fears. Nevertheless, I do not dispute the parish council's observation that, from the churchyard, the most easterly turbine (T5) would be directly in line with the summit of Cosdon Hill. Indeed, this is confirmed by the appellant's wireframe view. However, the photomontage which is derived from the wireframe also indicates both that the blades would remain below the horizon, and the majority of the turbines would be hidden by foreground or middle-distance trees. In my opinion the effect of the visible turbines from the churchyard would be limited. I consider the impact on the setting of St Peter's Church as a listed building later in this decision.

35. The height, proximity and status of the Dartmoor National Park justify an assessment of the visual effects of the proposal from greater distances to the south and south-west. The ES Viewpoints include: 4 Whiddon Down; 5 Ramsley Hill; 9 Yes Tor; and 10 Cosdon Hill. All the locations are at significantly higher altitudes and distances than the other viewpoints. Whiddon Down is at 261m AOD and 7.0kms to the nearest turbine; Ramsley Hill is at 260m AOD and 7.4kms; Yes Tor is the highest and most distant at 614m AOD and 14.1kms; and Cosdon Hill is at 550m AOD and 9.5kms.

36. I have taken account of the designation of Dartmoor as a national park. In the context of a wind energy scheme this necessity is perhaps most notably acknowledged in paragraph 14 of PPS22. This records that the potential impact on designated areas of renewable energy projects close to their boundaries will be a material consideration to be taken into account in determining planning applications. In addition, paragraph 21 of PPS7 notes that the national parks have been confirmed by the Government as having the highest status of protection in relation to landscape and scenic beauty. However, in my view it does not follow that significant change is therefore to be avoided, and in any event, over-reliance on the designated status of Dartmoor would be inconsistent with the requirement of paragraph 19 of PPS22 that the landscape and visual effects of renewable energy schemes will vary on a case by case basis.

37. I have already referred to the special qualities of Dartmoor and in particular to the extensive views across Devon which it affords. In the context of the northern edge of the moor, I have taken account of the intervisibility between Dartmoor and Exmoor. The latter is also a national park. At their closest the northern edge of Dartmoor is about 38kms from the southern edge of Exmoor, and on clear days the two moors are readily visible from each other. From Exmoor however the turbines would be about 32kms away at their closest. They would be indistinct, and motion of the blades would be lost. I recognise that the intervisibility of the moors helps to define their setting, the appreciation of both, and the intervening area of Devon; but the impact on the prospect from Exmoor would be very limited. In my view the distance is too great to fall within the terms of paragraph 14 of PPS22.

38. On the contrary, and although I understand from evidence submitted on behalf of CPRE the appeal site does not fall within the area of a parish adjoining the moor, the proximity of the appeal site to Dartmoor renders the potential impact of the turbines on this national park an important material consideration. I have already recorded my views in relation to the effect of the scheme where

Dartmoor forms part of the background. From the opposite direction I believe there is a distinction to be made between viewpoints where no part of the moor is visible and those where the prospect includes part of the designated area. Although ES Viewpoint 4 at Whiddon Down would provide an elevated view of the turbines, no part of the designated area would be included, and it is difficult to contend that from this location there would be any effect on the moor. I acknowledge however that such circumstances would apply in only a limited number of cases.

39. To my mind, the other ES Viewpoints which include part of the designated area in the foreground are of much greater significance. There is no dispute as to the visibility of the proposed turbines from both the tops of hills and tors and from the slopes below them. Another of the special qualities referred to in the national park's management plan is the absolute peace which can still be experienced, contributing to the strong sense of wildness on the open moorland. This aspect of the experience of the moor is emphasised in visual terms by its openness and the almost complete lack of trees. Some of these qualities are evident in ES Viewpoints 9 (Yes Tor) and 10 (Cosdon Hill) and from Belstone Tor. The openness of the moor also results in far fewer interruptions to visibility than those which occur in the agricultural and settled landscape closer to the appeal site.

40. I have considered whether the openness and wildness of the moor, as aspects of its natural scenic beauty, would be compromised or diminished by the visibility of the turbines. One of the principal benefits of the extensive views across Devon from the edges of the open moorland area is to be found in the contrast it affords and appreciation of the differences it makes possible. The lower ground is settled by small towns, villages, roads, railways and farms. It is an agricultural and occupied landscape where human activity is continually present. Notwithstanding is size and impact, in my opinion a self-evidently man-made structure such as a wind farm is more appropriately and compatibly sited in such an area. From the highest vantage points the tops of the turbines would be well below the level of the observer, and although the same would not apply to ES Viewpoint 5 (Ramsley Hill), this lies within a different landscape character zone under the Devon County Council appraisal. It falls within the enclosed moor (Zone 30), which virtually surrounds the high moor (Zone 31).

41. I have taken account of the status afforded to Ramsley Hill through its identification by the Ordnance Survey as a recognised viewpoint. It is also located on the Dartmoor Way long distance recreational route. I understand the chimney to the north-west of the viewpoint is a remnant of former mining activity, and this too sets it apart from the prospects provided by the high moor. Although the turbines would appear above the horizon from this vantage point, I believe their number and distribution would ensure that the development as a whole would be but one component of the scene. I do not think the turbines would detract from the prospect as a whole.

42. I have considered the impact of the appeal proposal from vantage points on two other long distance footpaths – the Tarka Trail and the Two Moors Way. The Tarka Trail passes the site to the west along the valley of the River Taw. At its closest it is just over 2kms away and it follows a north/south direction. Along this length it is either close to the river or on minor roads between hedgebanks. The ZVI plans indicate that the turbines would be only partially

visible from this part of the footpath, and I do not consider they would have a serious adverse effect. The footpath also crosses an area of open moor below Belstone Tor from which the turbines would be visible at a distance of approximately 10kms to the north-east. At this distance and altitude the turbines would constitute but one component of an extensive prospect. In my view the wind farm would be sufficiently distant from and below the general level of Dartmoor to neither diminish nor harm the essential qualities of either the moor or the trail. The Two Moors Way also follows a north/south route and at its closest passes just under 5kms to the east of the appeal site. Although I believe the turbines would be visible through a gateway at Whelmstone Cross they would constitute no more than a glimpse – much of the path in the vicinity is between thick hedges which circumscribe the outlook to the west.

Historic Environment

43. Both the council and the DBJRG are concerned about the effect of the scheme on aspects of the historic environment. At the inquiry I received evidence from the Devon County Archaeologist on behalf of the council. There are a number of archaeological sites in the vicinity of the appeal site, including most notably, scheduled ancient monuments to the west and north-east.

44. That to the west includes a complex of large Roman military enclosures together with series of smaller enclosures and ring-ditches in fields around The Barton on the east bank of the River Taw. One of the camps survives as low earthworks just to the south of the railway which crosses the appeal site. It would be about 2kms from the nearest turbine (T10). The course of the Roman road leading to the site also crosses the appeal site, and, as I saw on my visit, it is also visible in part. The Tarka Trail long distance footpath passes to the west, but the camp earthworks themselves are obscured by hedgerow trees. In any event, the council considers that the impact on the setting of the camp is not unacceptable[2]. I agree.

45. In contrast, the council is concerned about the effect of the proposed development on the setting of the scheduled monuments near Bow. Amongst others, these include the site of a henge close to the south-west corner of the field to the south-west of Hampson Cross. I gather it is now considered the group of prehistoric monuments centred on the henge site were developed over a long period, perhaps from before 3000BC. The henge itself was probably constructed just before the end of the third millennium BC, and it would have been surrounded by a concentration of barrows and ring ditches. There is reason to believe the location had a ceremonial, rather than a strictly utilitarian, function.

46. My attention was drawn at the inquiry to the manner in which archaeologists now rationalise the relationship between such sites and their landscape setting. I understand this has grown in recent years, so that it can be said of many such monuments that they have a landscape role. More locally, there is no reason to distinguish between the archaeological importance of prehistoric monuments on Dartmoor – which happen to have been constructed from granite, from those in lowland Devon – which would have been construed of

[2] It is noted in passing that the latest proposed grid connection route passes through the Scheduled Monument. Scheduled Monument Consent is necessary for a number of works affecting such ancient monuments.

earth or timber. Most specifically, it is considered the principal means of access to the henge would have followed an east-west axis, but that the earth mound on its south side could have constituted a representation of Cosdon Hill visible on the horizon. Thus the setting of the henge would have a direct relationship with the horizon of the principal landform to the south-west.

47. The appeal site lies almost directly between the henge site and Cosdon Hill, as illustrated in SEI Viewpoint C. There would be no impact on the monument from the works themselves, but its setting would be affected, and I agree with the council that the intrusion of development into the setting of a monument – albeit one which is not upstanding – can impair our appreciation of its function, location and context. As is recorded in paragraph 6 of PPG16: *Archaeology and Planning,* archaeological remains are part of our sense of national identity and they are valuable both for their own sake and for their role in education, leisure and tourism.

48. However, paragraph 27 of PPG16 refers amongst other matters to a presumption against proposals which would have a significant impact on the setting of visible remains. It thus effectively makes a distinction between the settings of upstanding monuments and those which are now only or largely below ground level. There must remain a substantial element of debate and speculation about the design and form of the henge, and about the extent to which it would have sought to derive its inspiration from the surrounding landscape. In any event, the proposed development would not obscure Colson Hill – its presence would remain clear and obvious, and I cannot see that the proposed development would hinder the archaeological interpretation of the monument site. I conclude that notwithstanding its archaeological importance, the effect of the turbines on the setting of the monument is of limited significance. In my view the appeal scheme would breach neither the terms nor the purpose of structure plan Policy CO8 (Archaeology) or local plan Policy BE7 (Archaeology and Sites of Local Importance).

49. St Martin's Chapel at Broadnymett is both a scheduled ancient monument and a Grade II* listed building. It forms part of a small complex of buildings at Broadnymett, and would be just under 800m from the nearest turbine (T5). The chapel dates from the late thirteenth century and it is no longer in use, other than as an agricultural store. It originally served the ancient parish of Broad Nymett – an area of only about 17ha (42 acres) – before it was absorbed into the parish of North Tawton. SEI Viewpoint B shows both the chapel and its proximity to the proposed wind farm.

50. I saw on my visit to the chapel that its setting is already severely affected by agricultural buildings and activities, although the effect of these is ameliorated by an extensive growth of trees and bushes close to the chapel itself. In contrast to the henge, the chapel is both a visible and tangible expression of historic interest. The photomontage reveals that it would be possible for the chapel and the turbines to be simultaneously visible, but in my view the chapel can now have only a very limited setting. It is a small building in a very secluded location, and to my mind its impact is confined to a very limited surrounding area. I do not consider the setting or the experience of visiting the chapel would be diminished by the existence of the proposed turbines. In this respect I depart from the view expressed by my predecessor as the chapel becomes visible only from close locations.

51. My attention has been drawn to a number of other listed buildings in the vicinity. Broadnymett Farmhouse and Crooke Burnell Farmhouse are both Grade II buildings within about 800m of the nearest proposed turbines. Although in my view the setting of a farmhouse usually includes a larger area than a dwelling which has no such functional relationship with the surrounding land, in neither case do I consider this extends as far as the proposed turbines. The topography surrounding the farmhouses would remain undisturbed, and I do not believe the turbines would compromise or diminish their appearance or quality as listed buildings.

52. There are four listed houses (two with barns) on the sloping land to the north of and overlooking the appeal site. They are: Staddon Farmhouse; Westacott Barton and barn; Nichols Nymett House; and Upcott Farmhouse and barn. The buildings are between 1800m and 2160m from the nearest turbines, and Westacott Barton and Upcott Farmhouse are both Grade II* buildings.

53. Each of the dwellings occupies a similar setting in the sense that they lie in the open countryside below the crest of the hill slope. In my view, and in each case, their settings are limited to the surrounding fields and enclosures, and although the turbines would be visible when Westacott Barton is approached from the north, I do not believe its setting would be impaired. Indeed, although the barn is sited close to the bridleway, the house occupies a much more secluded location which curtails an appreciation of its interest. I consider furthermore that the turbines would be too distant to have a harmful effect on the setting of the buildings. Similar points arise in relation to Staddon Farmhouse. Although this is more visible from the bridleway, the proximity of the house to the right of way would prevent the turbines from interfering with an appreciation of the building. I saw on my visit to Nichols Nymet House that although the prospect to the south across the valley to Dartmoor must be a benefit for those living in or visiting the house, its status as a listed building and its setting are understood and appreciated from much closer and in the opposite direction. I conclude that the settings of the listed buildings identified would not be seriously adversely affected, and that the scheme would not conflict with structure plan Policy CO7 (Historic Settlements and Buildings) or local plan Policy BE3 (Listed Buildings).

54. I have also considered the impact of the scheme on St Peter's Church at Zeal Monachorum. It too is a Grade II* listed building, and a particular concern of the Zeal Monachorum Parish Council. In its later submission the council reproduces a photograph taken from the north-east corner of the churchyard but including the east end of the church itself. The scene includes trees within the church yard and adjoining properties as well as the more distant landscape leading to Cosdon Hill. It is an attractive, concentrated and varied prospect to which the component parts all make their own valued contribution. I visited the location during my site visit. Although the trees would obscure some of the turbines, others would be visible in the middle distance with Cosdon Hill forming the background.

55. In my view the setting of a parish church can extend to far larger distances than those which apply to dwellings. Paragraph 2.17 of PPG15: *Planning and the Historic Environment* describes how the identification of the setting of a listed building can vary with the circumstances. I see no reason why in some cases this should not include the background landscape, especially when the

two elements of the scene (the building and the landscape) contribute so much to each other. However, the nearest turbine would be 4.3kms, and the top of Cosdon Hill is 15kms away. There is disagreement as to whether the blades would or would not just break the skyline, but in my view it is unlikely that, in most conditions, they would be as distinct as suggested by the parish council. Furthermore, the turbines would be below the ridge level of the church roof, and well below the top of the tower. In addition, the corner of the church yard from which the photograph is taken cannot be a frequently used route. I thus conclude that, notwithstanding their visibility, the turbines would not detract excessively from the setting of the building.

56. I have also given consideration to the effect of the proposed development on the setting of the relevant local conservation areas and on views out of them. It is suggested on behalf of the DBJRG that, particularly in relation to the Bow, North Tawton and Zeal Monachorum Conservation Areas, the turbines would intrude into the views of the valleys and the approaches towards the settlements. However, although at some locations it would be possible to simultaneously observe both the turbines and buildings falling within the conservation areas, the distances would be such that I do not believe they would seriously harm their character or appearance. Nor do I consider harm would result to views out of the areas sufficient to compromise the preservation of their character or appearance.

Conclusion on character and appearance

57. Except perhaps in a limited number of industrialised or urbanised locations, it will invariably be the case that modern commercial wind turbines will be out of scale with both the natural vegetation and other man-made structures in the vicinity. Similarly, it might have been expected within the context of the Devon landscape that the proposed wind farm would be too large for its landscape setting. The wind farm would be most closely observed from the minor road which passes through Itton, but this is only a lightly trafficked route. In contrast, the next closest route is the A3072, and this is relatively heavily trafficked. In my view the greatest visual harm resulting from the scheme would be experienced both on this route, and, to a lesser extent, from the bridleway to the north-east of Burrow. In this sense the scheme would therefore conflict with the landscape protection policies, or parts of policies, of the development plan to which I have referred – principally structure plan Policy CO1, local plan Policy NE10, Policy EN 1 of RPG 10, and Policy ENV1 of the emerging RSS.

58. There would certainly be an impact on the prospects towards, through and beyond the turbines at many other locations, but the development would be seen from greater distances and in the context of larger panoramas. From the north, and perhaps ironically, the presence and scale of Dartmoor would allow the comparatively smaller mass of the wind farm to provide a landscape context for the development. Similarly, from Dartmoor the distance from the site and the difference in height would ensure that the visual effect of the scheme would be manageable[3]. From these locations I believe the development would not be incompatible with the landscape protection policies

[3] In this respect I believe the case is distinguishable from that at Yelland (CD27v) where, although the turbines would have been smaller and fewer, the site was on higher land significantly closer to the national park boundary.

of the development plan cited above. In relation to Dartmoor I see no overriding conflict with structure plan Policy CO2, local plan Policy NE7 or Policy ENV 3 of the RSS. Nor, in relation to the historical environment, do I see any overriding conflict with structure plan Policies CO7 or CO8, local plan Policies BE3 or BE7, or Policy ENV2 of the emerging RSS.

Local Ecology

59. An ecological assessment of the site taking particular account of protected species was carried out on behalf of the developer at the ES stage of the project in 2004. Amongst other matters the assessment noted a moderate to locally high level of bat activity, mainly associated with the hedgerows, woodland edges and wetlands. A total of seven species of bat was identified; the distribution suggesting that individuals were entering the site from roosts around the periphery. However, most of the bats were observed flying at between 2 and 10m above ground level and in this case the blades would not be closer than 30m above ground level. It was recognised that the noctule bat would be more vulnerable as it often flies between 10 and 20m above ground level.

60. The ES refers to the then level of knowledge concerning the interaction between bats and wind farms as inadequate to formulate a definitive impact assessment of the operational phase of the scheme. Since that time (and since the 2006 Inquiry) more guidance has been issued. Most notably, Natural England has published Technical Information Note TIN051: *Bats and Onshore Wind Turbines: Interim Guidance.* This in turn derives from Eurobats Publication Series No 3: *Guidelines for consideration of bats in wind farm projects* (2008). To minimise the risk to bat populations the Technical Information Note advises a 50m buffer around any feature (trees, hedges) into which no part of the turbine should intrude. On the basis of the proposed turbines in this case the DBJRG calculates that the base of each machine should be approximately 62.25m from trees and hedges. The DBJRG is also critical of the equipment used; of the length and time of day of the surveys; and the omission of surveys in April and October. Attention is drawn to the manner in which bats may be attracted to the moving parts of turbines, possibly in pursuit of insects which in turn are drawn by heat.

61. In response it was observed on behalf of the appellant that there are some notable differences between the bat populations of the United Kingdom and those in the rest of Europe. There is no large scale migration of bats in the UK for example, and the danger of building a wind farm on a migration route does not therefore arise. The survey conducted at the ES stage was undertaken on three evenings spread throughout the active season using the guidelines available at the time. In any event, the survey effort is a matter for the professional consultant, and the surveys conducted were adequate and sufficient. Further surveys would be unlikely to result in different or conflicting results. Most recently, barotrauma has been identified as a possible cause of death when bats come into close contact with wind turbines. This involves tissue damage where there is a rapid or excessive pressure change associated with the rotation of the blades.

62. The majority of bats at the site are common pipistrelles. Although it is considered these bats are at a medium level risk of collision, their population is

not thought to be threatened. The parties agreed that the most vulnerable species found at the site is the noctule bat. It both flies at a higher level and does not adhere to linear features such as hedges. However, only low numbers were recorded, and it is not considered by the appellant that the proposed wind farm would significantly impact on the conservation status of the local populations.

63. The appellant acknowledges that, although no turbine would be located closer than 50m to woodland habitat, some would be located closer to hedgerows. I understand that this would only happen at locations near to relatively defunct hedgerows and/or areas of relatively low bat activity. It is considered this would minimize the overall impact on the conservation status of the local bat populations. Hedgerow enhancement would not take place at such locations, and the maternity roost (previously proposed for the centre of the site) has been dropped[4].

64. I have considered the possible effect of the scheme on bats and on the local bat population in the light of the advice included in PPS9: *Biodiversity and Geological Conservation.* It records that the aim of planning decisions should be to prevent harm to biodiversity interests. If significant harm cannot be prevented, adequately mitigated, or compensated for, then planning permission should be refused. As far as protected species are concerned, planning permission should be refused where harm to the species or their habitats would result, unless the need for, and benefits of, the development clearly outweigh that harm.

65. Figure 6.6 of the ES reproduces the data from the bat surveys onto an OS base with the areas of high and moderate activity identified. The plan clearly illustrates the importance of both hedgerows and watercourses for foraging purposes. The principal routes are: the course of the Den Brook itself across Broadnymett Moor; the access track south of Sandford Barton towards the railway; the course of the Roman road; and the route of the minor road north-east of Itton leading to Itton Moor. Along these routes there appears to be only one turbine site (T1)[5] which would be close to the existing hedgerow. The submitted layout plan indicates the centre of the turbine site would be about 60m from the hedgerow to the north.

66. I recognise that understanding the relationship between bats and wind turbines is a developing area, and the potential for surveys to become out-of-date exists. An additional survey using the latest equipment would doubtless have improved the extent and detail of our knowledge of the site. However, in my view the work carried out in 2004 constituted a thorough survey of the land, and I agree with the appellant that new surveys would be unlikely to reveal significantly changed circumstances. I do not dispute the danger that turbines present to bats, including the noctule bat. The scheme thus entails the threat of some harm to individuals, but not to roosts, and there is no suggestion that the turbines would constitute a threat to local bat populations.

67. The possibility of birds colliding with the turbines was also raised by the DBJRG. The ES noted the abundance of starlings at the appeal site, with a

[4] See Figure 6.21 Rev 0.1 attached to Dr Holloway's Proof.

[5] The site of T3 appears to have been incorrectly plotted on this plan. The site layout plan (Figure 3.1) shows the site some distance further north.

flock of approximately 21,000 recorded in December 2004. I understand there is a roost of many hundreds of thousands at Okehampton Camp about 9kms south-west of the appeal site, and the area is used for foraging. The DBJRG is particularly concerned that the assessment for the potential for collision may have been made on the basis of incorrect turbine heights. However, paragraph 6.2.5 of the ES correctly records the form of the proposed development and the maximum height of the turbines. In any event, I agree with the appellant that taking account of the abundance of the species, fatalities would be likely to be insignificant and not a threat to the breeding population.

Conclusion on Ecology

68. I therefore conclude in relation to this matter that the potential effect of the proposed development on local ecology has been the subject of detailed investigation and assessment, including special consideration for protected species. In my view the project is in conformity with the relevant parts of Policy EN 1 (Landscape and Biodiversity) of RPG 10; with structure plan Policy CO10 (Protection of Nature Conservation Sites and Species); and with local plan Policy NE6 (Protected Species).

Possible Noise Disturbance

69. Although structure plan Policy CO12 (Renewable Energy Development) is favourable to the provision of renewable energy developments, it is subject to the consideration of their impact on the conditions of those living or working nearby. Policy CO16 (Noise Pollution) provides greater definition. It records that development should not be located where it would result in a significant increase in the level of noise affecting existing land uses in the vicinity. The local plan specifies similar safeguards. The support for renewable energy in local plan Policy PS10 is subject to there being no significant adverse impact on the conditions of those living and working nearby, and Policy BE18 (Potentially Polluting Activity) states that noise generating development will not be permitted if it would be liable to increase unreasonably the noise experienced by the users of noise-sensitive development nearby.

70. Paragraph 22 of PPS22 also recognises that the renewable technologies may generate increases in noise levels. In addition to its suggestion that development plans might include minimum separation distances, it recommends the use of a report by the Energy Technology Support Unit (ETSU) of the former Department of Trade and Industry – *The Assessment and Rating of Noise from Wind Farms* (ETSU-R-97) – published in 1996. In this case the development plan does not set out any minimum separation distances, and the status of ETSU-R-97 is thereby enhanced. The Companion Guide to PPS22: *Planning for Renewable Energy* provides further advice. Amongst other matters, it records that well-specified and well-designed wind farms should be located so that increases in ambient noise levels around noise-sensitive developments are kept to acceptable levels with relation to existing background noise[6]. It too refers to ETSU-R-97 as relevant guidance on good practice which should be used when assessing and rating noise from wind energy developments.

[6] Page 167, paragraph 41

ETSU-R-97

71. The purpose of ETSU-R-97 is recorded as being the description of a framework for the measurement of wind farm noise with indicative noise levels thought to offer a reasonable degree of protection to wind farm neighbours, without placing unreasonable restrictions on wind farm development or adding unduly to the costs and administrative burdens on wind farm developers or local authorities. It thus attempts to strike a balance between the environmental benefits of wind energy development on one hand (which are often expressed on a global scale), and the potential for environmental damage by noise pollution (which are assessed at a local scale). The guidance constitutes an exhaustive – even elaborate – examination of the issues relating to the assessment of wind turbine noise and its regulation, but it was recognised by the authors that it and its recommendations should be reviewed 2 years after publication[7]. However, there has been no review, and evidence submitted by the appellant indicates that there are no current plans to revise ETSU-R-97[8].

72. It is recognised by the parties nevertheless that the commercial wind turbines currently favoured (and proposed in the current case) are materially larger than those considered by the authors of the report. At the inquiry it was clear there was agreement that ETSU-R-97 fails to pay adequate attention to the impact of wind shear resulting from atmospheric changes, and the manner in which wind turbine noise is propagated is not considered. Amongst many other matters, the report promotes a correlation between background noise levels at receptor locations with simultaneous measurements of the mean wind speed at 10m above ground level measured at the proposed site. Some of the acousticians who practice in this field fear that the failure to pay sufficient regard to variations in wind shear could result in significant errors when comparisons are made between background noise levels and wind turbine noise immission[9] levels. A methodology has been identified which seeks to overcome this problem[10].

73. The report (ETSU-R-97) refers to a number of source documents including PPG24: *Planning and Noise,* and BS 4142: 1990: *Method for rating industrial noise affecting mixed residential and industrial areas.* The latter records that, in relation to background levels, a difference of +10 dB or more indicates that complaints are likely, while a difference of +5 dB is of marginal significance[11]. ETSU-R-97 favours the setting of noise limits relative to the background in a manner similar to that adopted in BS 4142, but it adopts a number of limits derived from different times of the day and different locations.

74. For small schemes or in remote locations away from noise-sensitive receptors the report recommends a simplified limit of 35 dB(A) $L_{A90,10min}$ for 10m high wind speeds up to 10m/s. This obviates the need for a background noise survey. In locations where a background survey is necessary – as in the current case – a night-time (23:00 – 07:00) limit of 43 dB or 5 dB above background, whichever is the greater, is specified outside the relevant building (usually a dwelling). This is derived from the 35 dB(A) sleep disturbance

[7] CD61, pages 2 and 111
[8] Document 32
[9] As in 'to send in' or 'inject'; the correlative of emission
[10] CD100, *Prediction and assessment of wind turbine noise,* Acoustics Bulletin March/April 2009
[11] CD62, paragraph 9

criteria cited in PPG24, with an allowance of 10 dB(A) made for attenuation through an open window, and 2 dB subtracted to account for the use of L_{A90}s rather than L_{Aeq}s.

75. During the day-time the equivalent limit is 35-40 dB(A) or 5 dB(A) above background, whichever is the greater. The actual value for the day-time lower limit depends on an assessment of 3 factors – the number of dwellings in the neighbourhood of the wind farm; the effect of the limits on the number of kWh generated; and the duration and level of exposure. The day-time limits are also perhaps rather curiously based on the sleep disturbance criterion from which the night-time limit is derived. Strangely, the day-time lower limit thus appears to be lower than the night-time lower limit; but the night-time limit is derived from an internal standard. Finally, the report recommends a higher limit fixed limit of 45 dB(A) at dwellings occupied by those who are financially involved with the scheme. In such circumstances consideration should also be given to increasing the permissible margin above background, although the margin is not specified.

76. As is evident from the above paragraph, most of the various noise limits are precisely and numerically expressed. Theoretically, they are capable of being translated into minimum distances between the turbines and receptor locations. Given the precision in ETSU-R-97 it is not surprising that much of the debate at the inquiry was concerned with the accuracy of the background noise data at receptor sites; the correlation between this and the noise generated at critical wind speeds; the propagation of turbine noise; the variations between different turbine models; the effects of differences in wind shear and wind direction; and the inherent uncertainties in all such measures and assessments.

77. In order to consider these matters in the context identified in the report, I have considered the purposes of the different limits. Various reasons are identified. The 35 dB(A) simplified limit is described as being sufficient for the 'protection of amenity'. The increased fixed limit with financial involvement is described as being derived from 'the level of disturbance and annoyance caused by a noise source'. The origin of the day-time and night-time lower limits are however more precise. Both refer to sleep disturbance criteria, and the latter cites the 35 dB(A) limit included in paragraph 5 of Annex 2 of PPG24. This in turn is derived from the World Health Organisation (WHO) guideline designed to 'preserve the restorative process of sleep'[12]. To my mind the different criteria imply different thresholds. The need to avoid sleep disturbance is a significantly more demanding and compelling criterion than the mere evasion of disturbance or the protection of amenity, and the use of a limit derived from the WHO inevitably suggests that a breach might legitimately be regarded as a threat to health. My attention has been drawn to more recent WHO publications. The *Guidelines for Community Noise* was published in 1999[13]. It recommends a limit of 30 dB(A) $L_{eq, 8h}$ for continuous noise in bedrooms – which equates to about 28 dB(A) L_{A90}.

[12] Environmental Health Criteria 12 – Noise. World Health Organisation, 1980.
[13] CD64

78. Uncertainty over the variously expressed purposes of the limits is aggravated by the WHO's most recent advice – *Night Noise Guidelines for Europe*[14]. This recognises the variations which exist in relation to the health effects observed in the population to different levels of night noise, and refers to the needs of vulnerable groups such as children, the chronically ill and the elderly. It concludes that the population should not be exposed to night noise levels of greater than 40 dB $L_{night,\ outside}$ during the part of the night when most people are in bed. This, of course, is less than the 43 dB(A) night-time lower limit referred to in ETSU-R-97, and it serves to emphasise the critical importance of the limits. As the appellant observes, this limit would equate to 38 dB(A) L_{A90} and I acknowledge that it is based on a whole year of nights. Although I accept the wind would not be blowing in the same direction for a whole year, it is evident nevertheless that the wind can blow in the same direction for long periods.

79. I mention in passing that the noise levels to which I have referred in PPG24 are identified in relation to the boundary between noise exposure categories (NEC) A and B. The NECs are designed to assess proposals for residential development close to noise sources. Paragraph 8 of PPG24 records that the NEC procedure cannot be used in the reverse context for proposals which would introduce new noise sources into areas of existing residential development. According to Annex 1 this is because in general, developers are under no statutory obligation to offer noise protection measures to existing dwellings which will be affected by a proposed new noise source.

80. I have referred to these matters to both provide a context for the ensuing considerations, and to record my sympathy with the view that a review of ETSU-R-97 is overdue. Nevertheless, I recognise and acknowledge its significance in the context of the current case.

81. Other than participating in the discussion of draft conditions the council did not offer any evidence in relation to possible noise disturbance at the inquiry. Evidence was submitted primarily by the appellant and DBJRG. The parties did seek to produce a Statement of Common Ground in respect of noise matters[15], but I fear much of this document records the extent of their disagreement. In this decision I have sought to consider and take account of what I regard as being the most critical differences.

Background surveys

82. The Companion Guide to PPS22 records[16] that noise levels from turbines are generally low and, under most operating conditions, it is likely that turbine noise would be completely masked by wind-generated background noise. A link is thereby established between the noise generated by the turbines at varying wind speeds and the noise experienced by nearby receptors who, it is assumed, will be experiencing corresponding meteorological circumstances – at least as far as wind is concerned. The existing (pre-development) noise environment at potential receptor sites therefore needs to be established. Chapter 7 of ETSU-R-97 provides detailed guidance about the practices to be adopted. The ES and SEI record the 6 locations where background surveys

[14] Document 44
[15] Document 40
[16] Page 167

were conducted. These were at: Broadnymett, Coxmoor and Ham Farm – to the north-east, east, and south-east of the appeal site respectively; and at Itton Manor, Halse Farm and Crooke Burnell – to the south-west, west and north-west.

83. Five of the 6 survey locations are the closest dwellings to the appeal site in the relevant directions recorded. To the south-west Lower Itton is marginally closer than Itton Manor, but I make no issue of that. In my view the dwellings are sufficiently close for the survey results to be representative. The survey locations are selected on the basis that if the predicted turbine noise falls below the limits included in ETSU-R-97, all other dwellings in the relevant direction in the area will also be below the limits. The DBJRG is critical not so much of the locations but of the precise sites, and of the manner in which the surveys were conducted. I visited all 6 sites on a moderately windy day.

84. ETSU-R-97 indicates that background noise measurements should be made in the garden or other area used for rest and relaxation, but, in order to avoid reflected noise, the site should not be closer than 3.5m from the façade of a building. I saw on my visit to Crooke Burnell that the site favoured by DBJRG would have been closer to the house, but at both sites the dominant noise was of the wind blowing through trees and pampas grass.

85. At Halse Farm the site lay within the front garden of the house. DBJRG is concerned that leaves left on the ground may have artificially increased the recorded background noise level. On the day of my visit there was significant noise from the wind blowing through the trees surrounding the garden, but the leaves at ground level were not moving. They were effectively held in place by the grass and I could detect no noise derived from that potential source. In contrast, fallen leaves at the side of the house on a tarmac surface were both moving and generating noise. However, to my mind this did not constitute a potential external amenity space, and I agree with the appellant that the site was appropriately selected.

86. At Itton Manor the recordings were taken in the garden of the house where an external table and chairs indicated an area used for rest and relaxation. I have no reason to doubt the appellant's assurance that the pond pump located in the garden was not working at the time of the survey, and I saw that the adjacent road was very lightly trafficked. Most of the noise was being generated by the wind blowing through trees and hedges, and I noted that the garden of Lower Itton was similarly sized and had a similar relationship with the adjoining house.

87. I agree with the appellant that there is no readily apparent external amenity area at Ham Farm. Potential sites close to the farmhouse were either too close to buildings or self-evidently not amenity spaces – including the site suggested by DBJRG. The site used in the survey is indeed close to a small generator building, but its noise was removed from the record. Again, the dominant noise during my visit was that generated by the wind blowing through trees and hedges close to the buildings.

88. There are a number of potential external amenity locations at Broadnymett. I considered the alternative site suggested by DBJRG. It was indeed closer to the house, but I could detect no apparent difference between that and the site

of the recordings. I acknowledge that a site closer to the building may experience lower wind speeds, but it may also be subject to greater reflections. The dominant noise source during my visit was again that generated by the wind in the many surrounding trees.

89. I am more sympathetic to the views expressed by DBJRG in relation to the selection of a site at Coxmoor. Although I do not describe the site as being in the middle of a field, it was certainly some distance from the house and its adjoining neighbouring property, and it did not have the appearance or character of a domestic curtilage. There are more appropriate areas for external rest and relaxation in the extensive but domesticated garden to the south and south-west of the house. Although these locations were more sheltered than the site actually chosen, I am far from convinced that background noise levels would be lower as suggested by DBJRG. The sites closer to the houses were surrounded by trees, and, on the contrary, I would anticipate that wind generated noise would be rather greater. During my visit however I noted that at all the locations the dominant noise was the wind in the trees.

Rain distortion

90. Under the heading of the 'analysis and derivation of background noise levels', ETSU-R-97 discusses[17] the effects on the noise environment of receptor dwellings of both weather conditions not associated with wind speed and other sources of noise. It is considered in particular that rain results in a distortion of the background environment, and it is suggested that recordings made during periods of rain should be removed from the data. The DBJRG contends that this can only be reliably achieved when a rain gauge is located at the same site as the microphone. I acknowledge that this would increase the reliability of the circumstances when there is a need to remove rain-induced noise recordings. I also agree with DBJRG that some rain events can be very localised. However, in my experience such events are more likely to be associated with significant increases in wind speed. The appellant has used rainfall records from the met station at North Wyke to remove data which may be affected by rainfall, and it is less likely that rain falling over more extensive areas would be associated with localised high winds. I conclude that an appropriate correlation exercise has been executed in accordance with the purpose of the guidance included in ETSU-R-97.

91. At the inquiry DBJRG also referred to other typical background noises mentioned in ETSU-R-97. In my view it is not entirely clear whether it was the intention of the authors that such noises – work in fields, milking equipment and milk chillers, traffic and aircraft noise – should or should not be included. The position is clearer for the night-time; the noise of traffic and owls should be included as part of the noise environment of the dwelling concerned. In general I favour the appellant's view that, even in countryside locations like the appeal site, the artificial circumscription of background surveys would result in a misleading record of the rural environment.

[17] Page 86

Equipment

92. I have considered the criticisms made by DBJRG in relation to the design of the microphone and its wind shied; together with the exclusion of under-range and over-range data. While I recognise that the design and capacity of the recording equipment could obviously have an effect on the background levels recorded, and that this results in part from the approach adopted by ETSU-R-97, in my view it is neither desirable nor necessary to pursue the scientific levels of accuracy which the criticism implies. I have no reason to doubt the appellant's observation that equipment capable of measuring below the levels within the capacity of the more robust external equipment is essentially confined to laboratory conditions. It was suggested in the inquiry on behalf of DBJRG that acoustics is not an exact science, and I do not believe it is desirable to exaggerate the degree of precision necessary.

Wind shear

93. Having heard and considered the evidence submitted by the parties I am generally confident about the adequacy of the background noise survey in relation to the approach included in ETSU-R-97. Notwithstanding their differences, the parties did agree that ETSU-R-97 does not adequately confront the issue of wind shear. This is considered to be at least in part a result of the significantly increased height of modern commercial turbines compared with those which were used at the time of publication. Wind shear is defined in ETSU-R-97[18] as a description of the increase in wind speed with height above ground level, and it is self-evident that there will be a potentially greater difference between ground level and a hub height of 30m and ground level and a hub height of 75m.

94. ETSU-R-97 indicates that wind shear can be calculated from a formula where the only variables are height, wind speed and ground roughness. As the appellant records, it is now acknowledged that the formula fails to take account of the effect of atmospheric stability. During the day-time the heating of the surface by the sun causes the air to be buoyant. This modifies the frictional force on the airflow. At night, as the surface cools the air become negatively buoyant, and the frictional force is modified in the opposite way. During the day the atmosphere is generally unstable, but at night it becomes stable. When buoyancy is not acting in either direction, the atmosphere is neutral. The shear is larger in stable conditions and smaller in unstable conditions.

95. When atmospheric conditions become extremely stable – for example, on a clear night with low wind speeds – the maximum wind speed can occur at a certain height with lower speeds at both greater and lesser altitudes. This is known as a nocturnal jet. The frequency of nocturnal jets below 100m above ground level in the UK is not known, but I understand they are not considered to be a regular feature of the boundary layers where clouds are present. Evidence submitted on behalf of the appellant indicates that there is a complex relationship between atmospheric stability, roughness and wind direction. In this case for example, it is thought that isolated patches of woodland to the north-west and south-east of the appeal site could constitute sufficient roughness to lead to increased shear in the downstream wind profile.

[18] Page 120

96. ETSU-R-97 discusses[19] the effects of variations in topography on wind speed and noise experienced at receptor locations. It appears the increasing height of modern turbines renders the effect of variations in atmospheric stability on wind shear of equal importance. Wind direction can also have an important effect in relation to both the wind profile and the more readily apparent effect on downwind propagation. To my mind all these factors serve to illustrate the complexity of the subject – especially taking account of the continual and substantial variations in wind speed and direction which are such a notable feature of the weather in the UK. The characteristics of two such capricious phenomena as wind and noise, and the effect of the former on the latter, must make predictions at receptor locations inherently uncertain. Indeed, paragraph 5.4 of the Statement of Common Ground (Noise)[20] records that the parties agree there is no single mathematical expression which will hold true at all times to describe the vertical wind profile. I think the circumstances serve to emphasise the necessity, at the least, for the imposition of robust and adequate noise conditions. By referring to conditions I do not mean to undermine the attempt to forecast turbine noise as it would be experienced at receptor locations, but I do believe it must be an exercise fraught with difficulty and uncertainty.

97. Partly in response to the realisation that stability induced wind shear was not taken into account by ETSU-R-97, the appellant's acoustic advisors have altered the manner in which they seek to predict the noise generated and propagated by turbines. They have departed from the guidance included in ETSU-R-97. My attention was drawn by DBJRG at the inquiry to many locations within ETSU-R-97 which refer to the correlation of measured background noise levels with wind speeds up to 12m/s measured on the site of the proposed development at a height of 10m above ground level. As I understand it the justification for the correlation to the 10m high site wind speed was adopted because this was the height of readily available portable anemometer masts[21], and because this is the reference height used by turbine manufacturers.

98. Although I agree with DBJRG that 10m above ground level is the height frequently cited in ETSU-R-97, I see no overriding reason why the necessary correlation should not be made with the wind speed at the actual proposed hub height of the turbines. I recognise that omitting the correlation with the 10m reference height amounts to a departure from the methodology adopted by ETSU-R-97, but in many other respects DBJRG is critical of the document. In any event, although ETSU-R-97 enjoys the status afforded it by PPS22 and subsequent Government endorsements, I see no reason why alternative improved or otherwise adequate methodologies should not be utilised. There is no useful purpose to be served by slavishly following guidance if more robust processes are available and reliable. In my view the 10m reference height is simply a means to an end – the end in this case being to relate the background noise measurements to the wind speed and hence the noise generated by the turbines. I cannot see that the method adopted by the appellant undermines this principle.

[19] Pages 47-49
[20] Document 40
[21] ETSU-R-97 page 85

Propagation

99. There is agreement between the parties that an example of a relevant area not covered by ETSU-R-97 is that concerned with the propagation of sound outdoors. In this case the appellant has used one of the International Standards series – ISO 9613-2 (Part 2: General method of calculation)[22]. Its purpose is to enable noise levels in the community to be predicted from sources of known sound emission.

100. The DBJRG have drawn my attention to its limitations. In particular it is claimed the use of the ISO is inappropriate where there is both wind *and* a temperature inversion; it is limited to conditions where the wind is between 1 and 5m/s measured between a height of 3 and 11m; and the method of calculating the ground effect is applicable only where the ground is approximately flat – either horizontally or with a constant slope. The document also identifies an uncertainty of +/- 3 dB over distances between 100 and 1000m. I acknowledge the existence of these limitations in relation to the use of the ISO, but it on the basis of this propagation model that the appellant predicts the turbine generated noise at the 6 receptor sites would, with one exception, be within the criteria derived from ETSU-R-97.

101. The predicted margins are as follows:

- at Halse Farm the downwind turbine noise would be below the night-time limit by at least 8.5 dB, and below the day-time limit by at least 7 dB;
- at Lower Itton the equivalent margins are 5 dB and 1 dB;
- at Ham Farm the equivalent margins are 5.5 dB and 0.5 dB;
- at Broadnymett the equivalent margins are 8 dB and 4 dB;
- at Coxmoor the equivalent margins are 9.5 dB and 6.5 dB;
- the exception is Crooke Burnell. Here the equivalent night-time margin is 6.5 dB, but the downwind predicted noise *exceeds* the day-time limit by a maximum of 1 dB. However, the predicted noise would fall below the 40 dB L_{A90} limit referred to in ETSU-R-97[23]. The house is also occupied by a financially involved participant where ETSU-R-97 indicates an even higher lower limit of 45 dB(A)[24].

102. In response to the DBJRGs criticisms, the appellant has cited a paper given at the Third International Meeting on Wind Turbine Noise in Denmark in June 2009 – Wind Farm Noise Predictions and Comparisons with Measurements[25]. This is said to confirm the predictions derived from the propagation model. Be that as it may, much rests on the comparisons between the sites considered in the paper and the current appeal site.

[22] CD68
[23] Page 63
[24] Page 66
[25] CD155

103. Three sites were considered, but I agree with the DBJRG that they all appear to be at odds with the current appeal site. Site A is described as being located on a relatively high plateau characterised by moderately undulating terrain and minimal vegetation – a mixture of grassland and peat bog. The land was effectively frozen during the survey. Site B is located on flat terrain with minimal vegetation. It too is surrounded by peat bog and was water logged during the survey. Site C is lightly undulating but effectively flat in acoustic terms. There is minimal vegetation but with large areas of forestry further away. At Site A, a 110° arc of downwind propagation was used, but ISO 9613-2 specifies a maximum angle of +/-45°. At Sites B and C, two datasets were produced using 30° and 90° arcs, but at all sites the study focussed on the periods in which all the two speed turbines were generating in the high speed mode[26]. It is only at Site C that a ground factor of G=0.5 was used – as with the current appeal case – and the graphs indicate that the measured noise levels are generally higher than the predicted levels. Finally, I note in the conclusions to the paper that further study is considered to be desirable, including in more complex terrain profiles and using variable speed machines. In my view the three sites studied certainly appear to be radically different from the land in the immediate vicinity of and surrounding the current appeal site. For the reasons expressed by the DBJRG I have attributed little weight to the paper, and I am concerned that the propagation model appears to have been used outside the terms of its limitations.

104. The utility and accuracy of the propagation model is further complicated by doubts over the identity of the actual machine which would be used. For understandable commercial reasons the prospective developer is reluctant to specify a particular manufacturer or model other than as a candidate. There are a number of turbine manufacturers producing machines of similar dimensions and appearance, but exhibiting differing sound power characteristics.

105. Both the appellant and DBJRG have provided evidence of the different sound power levels emitted by the candidate machine – a 2MW Vestas V90 – and others. There are evident differences between the machines. The information provided by the parties indicates a difference at cut-in speed (4m/s) of about 4 dB. With a wind speed of between 8 and 12m/s DBJRG's figures show a difference of 1.5 dB (on the basis of 4 machines), while the appellant shows a difference of about 1 dB at 12 m/s (on the basis of 3 machines). It is in this context that the DBJRG has referred to the significance of the compatibility of the application for planning permission and the ES in *R v. Rochdale MDC* [2000][27]. I acknowledge that the differences between machines constitutes an additional element of uncertainty, but I do not believe it would be sufficient to undermine any permission granted. Similarly, I understand wear and tear, particularly of the blades, would also have an effect, together with variations implicit in the warranty of machines. It would however endow any conditions designed to regulate noise at receptor sites all the more important.

106. As is recorded in paragraph 2 of DoE Circular 11/95 : *The Use of Conditions in Planning Permissions,* the power to impose conditions when granting planning permission is very wide. Amongst other matters however, conditions

[26] The candidate turbine in the current appeal is a variable speed machine.
[27] Document 36

should only be imposed where they are necessary. The appellant observes that the candidate turbine is capable of meeting the noise limits specified in ETSU-R-97, but simultaneously records that it is prepared to accept planning conditions to the same effect. Largely as a result of the complexities involved, the draft conditions are painstakingly elaborate, but in my view their acknowledged necessity by the appellant does not inspire confidence. I recognise however that conditions to regulate noise at receptor locations derive, at least in part, from the uncertainties to which I have referred and the need to secure compatibility between the planning application, any planning permission and the ES for the scheme. I consider the draft conditions later in this decision.

Day-time lower limit

107. I have already referred to the threshold as advised in ETSU-R-97 for the day-time lower limit – it lies within the range of 35-40 dB(A). Although in comparison with day-time the desirability of more stringent limits at night-time is generally acknowledged – in PPG24 for example, ETSU-R-97 adopts the rather surprising approach that external day-time noise limits should lie somewhere between that required to forestall sleep disturbance *outside* the adjacent noise-sensitive building (ie 35 dB(A)), and the higher level that would still avoid sleep disturbance *inside* (ie 43 dB(A)).

108. The actual value chosen should depend on three considerations: the number of dwellings in the neighbourhood of the wind farm; the effect of noise limits on the kWh generated; and the duration and level of exposure. Both night-time and day-time lower limits are therefore both sleep-related, and closer to each other than the limits included in PPG24. One effect of the structure of the limits is that, subject to the upper limit (of 5 dB above background) and notwithstanding the ability to regulate noise emissions by reducing the rotational speed of the blades, compliance with the day-time lower limit should ensure that the night-time lower limit would be comfortably met. In this case a value of 37.5 dB(A) was agreed with the council[28].

109. The purpose of the variable day-time lower limit is to allow some flexibility to take account of the numbers of dwellings in the vicinity; the proportion of time background noise levels were very low; and the effect of limitations on the power generated. In accordance with the implications of these considerations, it appears the design of the proposed wind farm has been driven by the ETSU-R-97 noise limits on one hand and the maximisation of power generation on the other. I agree with DBJRG that the adoption of 37.5 dB as the day-time lower limit appears not to have been the subject of detailed assessment. The level was agreed between the appellant and the council early in the process, and the rationale for the adoption of this level is unclear to me.

110. What is evident however is that the effect of the three factors is to render rural locations with low population densities but higher background noise levels the most attractive destinations for wind energy schemes. Based on the appellant's data, DBJRG has assessed that Ham Farm and Crooke Burnell have background noise levels below 30 dB for 44% of time. The comparable

[28] Although she uses a different day-time lower limit and ground hardness assumption, the principle is usefully (and clearly) illustrated in Dr Hoare's Figures 5, 6 and 7. However, I see no reason to dispute the ground hardness assumption adopted by the appellant.

proportions for Lower Itton, Broadnymett and Coxmoor are 25%, 21% and 16% respectively.

111. On the basis of their duration and the level of exposure, DBJRG suggests the day-time lower limit should be set at 35 dB. I agree that these are relatively long periods, but I note the comment in ETSU-R-97 that the approach is difficult to formulate precisely and a degree of judgement should be exercised. I saw on my visits that that there are only a limited number of dwellings in the vicinity of the appeal site. On the basis of these considerations, and notwithstanding the low background noise levels, I raise no objection to the adoption of 37.5 dB as the day-time lower limit.

Amplitude modulation

112. Evidence was submitted at the inquiry by the residents of dwellings close to existing wind farms. Particular reference was made to the adverse effect of amplitude modulation (AM) – the modulation of aerodynamic noise at blade passing frequency. Under the heading of 'penalties for the character of the noise' in ETSU-R-97[29] the phenomenon is described as blade swish, and it records that it has been considered by some to have a characteristic that is irregular enough to attract attention. The noise levels recommended in the report take account of the phenomenon, but it is acknowledged that further research may be required to enable proper measurements and assessments to be made.

113. According to the appellant, the precise causes of high levels of modulation are not clearly understood, but five possible contributory factors are identified. They are: close separation distances between turbines in a line where such a line points towards noise-sensitive buildings; unusual topography; the ratio of blade length to tower height; high levels of wind shear; and specific turbine types.

114. DBJRG also refers to very stable atmospheric conditions as a possible contributory factor. ETSU-R-97 records that the modulation in blade noise can result in a variation in the overall noise level by up to 3 dB(A) close to the turbine. Receptor locations close to reflective surfaces may result in an increase in the modulation depth by as much as +/- 6 dB(A). It is reported on behalf of DBJRG that such greater modulations can occur at distances in excess of 900m from the closest relevant turbine. In some cases the noise experienced can possess intrusive impulse characteristics.

115. One of the potential contributory factors referred to by both parties is the proximity of turbines. The same matter was referred to in evidence submitted on behalf of CPRE. In its section on the technology of wind turbines the Companion Guide to PPS22 provides an example of turbine spacing of around 6 times the rotor diameter (540m) where the machines are in line with the prevailing wind direction, and the General Specification of the Vestas V90[30] itself specifies a distance of 5 rotor diameters (450m). In contrast, the appellant observes that a typical minimum is 3 rotor diameters. In this case the layout of the proposed wind farm is such that the majority of the turbines would be aligned in two lines on a south-west/north-east orientation, with T2,

[29] Page 68
[30] CD150, paragraph 1.4

T7, T4 and T5 forming a northern group and T1, T8 and T6 forming a southern group. The average separation distance of turbines within each group would be 377m and 452m respectively. The possibility of energy loss through wind shadowing by upstream machines referred to in the Companion Guide is essentially a matter of the prospective developer, but the layout would appear to lend itself to the possibility of high levels of downstream turbulence.

116. Because of concern about the presence and impact of AM the Government commissioned research into the matter from the University of Salford[31]. The research essentially takes the form of a survey of local authorities with wind farms in their areas. The survey indicated that 27 out of the 133 wind farms operational at the time had received formal complaints about noise at some point in their history. Only in 4 cases however was AM considered to be a factor, although it was a possibility in another 8 cases. DBJRG has expressed misgivings about the survey and the interpretation of its results, but the study also includes a discussion of the possible causes of greater than expected AM. Amongst other matters the report records that sound generation by turbulence is still not completely understood, and there are no existing models by which it can be predicted. In some situations AM noise seems to travel a considerable distance from the turbines, but further studies are needed to explain and predict the observed noise levels. Topographical effects may also result in turbines being 'unsure' about the direction of the wind, or the wind may be blowing in different directions at different heights. The report concludes that the incidence of AM and the numbers of people affected are too small to make a compelling case for further research. On the other hand such research would be prudent to improve understanding.

117. In its consideration of the report the Government concluded[32] there was not a compelling case for more work into AM at the time (2007), however the matter would be kept under review. In its observations on AM the appellant records that recent examples of high levels have been at sites incorporating Repower MM82 turbines. Although it is said that this make of turbine is not proposed for the current site, as I understand the position, no commitments have been made either for or against any specific make or model. On the basis of the evidence I have received I conclude that the possibility of a greater than expected impact from AM would be possible. In circumstances where the result of unforeseen consequences is sleep disturbance, I am in no doubt that, in the event of the appeal succeeding, a condition to regulate the phenomenon is both necessary and reasonable. I discuss this matter later in this decision.

Conclusion on Noise

118. The parties are effectively in agreement that the utility of ETSU-R-97 is questionable in some respects, and I have also been quite critical in a number of respects. This is perhaps inevitable when the processing of the application and the appeal has taken such a long time. Both the manner in which the advice is applied and the basis of the methodology have changed since the application was submitted, and I agree with DBJRG that there are some notable uncertainties inherent in the process. Notwithstanding the endorsement which the report enjoys through its citation in paragraph 22 of PPS22, I believe it

[31] CD103
[32] CD109

would be misguided not to amend and refine the procedure it adopts when this will improve the value of the exercise. In my view, this is what the appellant has sought to do without loosing sight of the essential purposes of the document.

119. It is important in this context to record that its purpose is two-fold. It seeks to protect the living conditions of residents who would be near wind turbines, but it also aims to avoid placing unreasonable restrictions on wind energy development. It does not set out, for example, to render wind turbines inaudible at nearby dwellings. I have considered the matters raised by DBJRG and others in the light of the contents, purposes and general principles of ETSU-R-97, as improved in current practice.

120. In my view the appellant has carried out a detailed and comprehensive assessment of the noise environment in the vicinity of the appeal site. An assessment has also been made of the impact the proposed wind farm would have on the locality. No doubt more exhaustive surveys and assessments could have been undertaken over more extended time periods and meteorological conditions, and a number of the uncertainties identified by DBJRG could be reduced. I fear however that the application of the practice of acoustics to the noise generated by wind turbines is such that they could never be entirely extinguished, and in this case some of the day-time margins – especially at Ham Farm and Lower Itton – are very small.

121. It is in the light of these inherent uncertainties that I conclude the living conditions of local residents would not be unreasonably affected provided the necessary and appropriately worded conditions were imposed. If the appellant's predictions are correct there would be no need for the conditions to be enforced, but it is important that the council is able to take the necessary action if it became expedient to do so. In my view the uncertainties which have been identified serve to accentuate the necessity for the imposition of conditions on any permission granted. I conclude on this basis the proposed development would not conflict with the provisos included in both structure plan Policies CO12 and CO16 and local plan Policies PS10 and BE18.

122. The possibility was raised at the inquiry that I should consider whether the scheme gave rise to a likely violation under Articles 3 and 8 of the European Convention on Human Rights. Article 3 is the prohibition of torture, and Article 8 is the right to respect for private and family life. The matter is raised in the context the possibility of sleep deprivation. I recognise that allowing the appeal would inevitably result in some interference at the homes of residents in the surrounding area. I do not believe the turbines would be inaudible. However, this consideration must be balanced against the rights and freedoms of others, and I am satisfied that if the development, subject to conditions, goes ahead, its effect would not be disproportionate.

Other Matters

123. A number of additional matters have been raised during the processing of this case which in my view do not constitute main issues. These include the potential impact of the proposal on tourism, health, safety and agriculture.

Tourism

124. Although the effect of the proposed development on the potential of the locality as a tourist destination was considered at the previous inquiry, Visit Devon – a non-profit making, public-private partnership – was not formed until 2008. It fully supports the need for renewable energy projects in the South West, but it is particularly concerned about the number, size and scale of the turbines in an otherwise undeveloped area so close to the Dartmoor National Park. My attention has been drawn in particular to two tourism based businesses at Staddon Farm and Nichols Nymet House.

125. Both properties lie on the south facing slope of the ridge between North Tawton and Bow. The appeal site lies to the south of both at a distance of about 2kms. Staddon Farm is the base for the organisation and sale of horse-riding holidays – usually at destinations abroad. I understand there was a prospect that similar holidays could have been instigated locally, taking advantage of the proximity of the land to Dartmoor. However, the prospect of the proposed development has resulted in a decision being postponed.

126. Nichols Nymet House includes a bed and breakfast business with three holiday cottages in a converted stable block. One of the most important aspects of the destination is its peace and tranquillity – characteristics which it is feared it would be impossible to identify in the event of the development proceeding.

127. There can be no dispute that the operation of the proposed wind farm would be evident from both properties, from their immediate surroundings, and from the surrounding roads, bridleways and footpaths – making an allowance for the additional height of those on horse-back. I recognise the development would significantly affect the way in which the area is seen and perceived by those on holiday, but I am unconvinced that it would result in serious harm to actual or potential businesses. Notwithstanding their visibility, I believe it would be to exaggerate their influence to suggest that they could also undermine or compromise the viability of otherwise successful business enterprises. Although the visual effects would be felt in a relatively wide area, the change to the character of the landscape would be comparatively localised. On this basis I do not believe the proposed development would be a threat to local tourism.

Health

128. A number of local residents and others have expressed concern about the possible health impacts of the proposed turbines. However, many of these concerns are based on the possible consequences of sleep deprivation and/or the purported emission of low frequency noise from the turbines. I have referred to the first of these matters in a preceding section of this decision. I again acknowledge that the possibility of sleep disturbance – given especial prominence by the criteria adopted in ETSU-R-97 – would indeed be a serious consequence, albeit one confined to a limited number of noise-sensitive properties. As far as low frequency noise is concerned however, the Companion Guide to PPS22 records that there is no evidence that ground transmitted low frequency noise from wind turbines is at a sufficient level to be harmful to human health.

129. A number of representations have been made in relation to the possible effects of shadow flicker and reflected light. It is recognised that in some circumstances the former can trigger an epileptic reaction, and both can be irritating. However, the Companion Guide to PPS22 records that the phenomenon should not apply to the slower moving new generation of turbines, and in any event the Statement of Common Ground includes a draft condition designed to overcome the problem. It is not possible to entirely eliminate reflected light, but there is no indication that it might be the cause of a similar reaction.

Safety

130. Evidence submitted on behalf of CPRE refers to the potential for wind turbines to present a source of high risk to the public. Possible causes refer to blade failure, fire, structural failure, ice and lightning strikes. Others have referred to the possibility of driver distraction and the inadequacy of the local roads to accommodate large delivery vehicles. The latter matters are also addressed by the Companion Guide to PPS22. I acknowledge that the implementation of the scheme would necessitate some minor road alterations. These are essentially matters between the appellant and the local highway authority. As far as the possible distraction of drivers is concerned, I saw on my visits that the local network does not carry substantial volumes of traffic and the turbines would be set well back from roads and junctions. I see no objection to the project on these grounds.

131. I acknowledge that the EIA Regulations refer to the risk of accidents in the selection criteria for the screening of Schedule 2 development, but in my view the ES is not deficient in its consideration of the safety implications of the development or the associated risk assessment. Modern wind turbines are undeniably large structures, and, as with any man-made machine, they can be subject to failure from time to time.

132. However, both the ES and the Companion Guide to PPS22 record that properly designed and maintained wind turbines are a safe technology. I have no reason to doubt that the turbines would be certified to withstand extreme conditions. The technology itself is fairly simple, and this in itself must reduce the risk of accidents. I understand the turbines will include lightning conductors, and the possibility of the icing of the blades would result in the turbine being shut-down.

133. The Companion Guide to PPS22 records that maximum safety can be achieved by ensuring the turbines are set-back from roads and railways by at least fall over distance. I understand however that two of the proposed turbines (T6 and T8) would be within 100m and 90m respectively of the railway line which crosses the appeal site. However, in my view the likelihood of a collapse is extremely remote.

Agriculture

134. Representations were made at the inquiry to the effect that the proposal had had a divisive effect on the agricultural community. The earthmoving operations necessary to construct the wind farm would also adversely affect the hydrology of the land and possibly sterilise large areas. The scheme would not be as reversible as the appellant suggests.

135. I do not dispute that wind energy schemes can have a divisive effect on communities where substantial or rapid change has not been characteristic of the recent past. However, in this respect such proposals do not differ from other schemes where one area of land is favoured over another. It is a matter which in my view falls outside the remit of the planning mechanism.

136. In relation to the second matter, the ES includes a hydrological assessment of the scheme. Attention is drawn to the different hydrological regimes in the areas of the site which drain into the Den Brook and into the unnamed stream to the south. I understand that in part this is due to different soil types. Amongst other matters the turbines positions have been identified in order to avoid watercourses, but the ES recognises the likely need for drainage and treatment. I have no reason to suppose that best practice would not be applied to the excavation of foundations or the other operations involved, and I agree with the view expressed in the ES that the hydrological effect of the scheme would be minimal.

Conclusion on the first main issue

137. I therefore conclude in relation to the first main issue that the project would be a cause of some harm in terms of its visual effect on the landscape – especially from some vantage points to the north and north-east of the site. The scheme would also result in a significant change to the landscape character of the surrounding area. I found there would be no harm however in relation to the historic environment or with respect to local ecology. In relation to possible noise interference, I am concerned that this is a matter where there are significant uncertainties surrounding the generation and propagation of wind turbine noise. In contrast, I am reasonably confident about the background noise surveys. In my view these conclusions can only accentuate the importance and necessity of appropriately worded conditions to any permission granted in order to secure compliance with the limits included in ETSU-R-97. I have found no harm resulting from the other matters raised.

Renewable Energy Policy

138. I turn now to the second main issue, under the terms of which it is necessary to consider the position of the scheme in relation to the range of policies which specifically refer to the generation and supply of energy from renewable resources. A number of the key principles included in paragraph 1 of PPS22 are relevant. Sub-paragraph (ii) records that regional spatial strategies and local development documents should contain policies designed to promote and encourage, rather than restrict, the development of renewable energy resources. Sub-paragraph (iv) indicates that the wider environmental benefits of proposals for renewable energy projects, whatever their scale, should be given significant weight in the determination of planning applications. Similarly, sub-paragraph (vi) recognises that small-scale projects can provide a valuable contribution to the overall outputs of renewable energy, and applications should not therefore be refused simply because the level of output would be small.

139. The thrust in favour of the adoption and growth of renewable energy is reiterated in numerous international and national statements and policies – largely in response to concerns about climate change and its effects. Most

latterly, paragraph 11 of the Supplement to PPS1: *Planning and Climate Change* (2007) records that authorities should have regard to the contents of the Supplement as a material consideration which may supersede the policies of the development plan. *The UK Renewable Energy Strategy*[33] (2009) refers to the legally-binding target to ensure that 15% of our energy comes from renewable sources by 2020. The strategy's lead scenario is that more than 30% of our electricity should be generated from renewables by 2020 – up from about 5.5% today. I acknowledge nevertheless that notwithstanding the new imperative, the need for a balance to be struck between the requirement for sites and their local impact remains central to decision making. I note also the council's point that the strategy does not seek to establish sectoral or technology targets. On the contrary, the Government has sought to introduce a raft of measures including a reduction in demand and use, and the securing of diverse and secure energy supplies. The development of onshore wind energy remains but one part of a wide range of measures.

140. The most directly relevant policy included in RPG 10 (2001) is Policy RE 6 (Energy Generation and Use). Amongst other matters, it encourages a minimum of 11-15% of electricity production to be from renewable energy sources by 2010; it has full regard for the recommendations and background information included in the *Renewable Energy Assessments and Targets for the South West* (2001)[34]; and it also records that development plans should specify the criteria against which renewable energy projects will be assessed, balancing the benefits of developing more sustainable forms of energy against the environmental impacts, in particular on national and international designated sites.

141. The draft revised RSS including the Secretary of State's proposed changes was issued in 2008. Policy RE1 includes renewable energy targets for 2010 and 2020. The 2010 minimum target is 509-611 MW installed onshore capacity, of which about 151 MW would be in Devon. The equivalent regional cumulative target for 2020 is 850 MW. Policy RE4 (Meeting the targets through development of new resources) records that in considering individual applications, local planning authorities will take account of the wider environmental, community and economic benefits of proposals, whatever their scale. They should also be mindful that schemes should not have cumulative negative impacts, and proposals in protected areas should be of an appropriate scale and not compromise the objectives of designation. The draft strategy has now reached an advanced stage and its contents therefore enjoy significant weight.

142. Policy CO12 is the most directly relevant policy of the *Devon Structure Plan 2001 to 2016* (2004). It repeats the sub-regional target of 151 MW by 2010, but, as I have already reported, it renders schemes subject to consideration of their impact on the qualities and special features of the landscape and upon the conditions of those living and working nearby. It also identifies priority search areas in the Key Diagram. Although the appeal site does not fall within such an area this does not in my view seriously undermine the consideration which should be given to other sites.

[33] Document 35
[34] CD 11

143. Policy PS10 of the *West Devon Borough Local Plan Review* (2005) is similar to the equivalent policy in the structure plan. It offers support to renewable energy projects provided they have no significant adverse effects on the qualities and special features of the natural landscape or townscape, on nature conservation, or on the conditions of those living and working nearby.

144. It is therefore evident that the stance adopted in both the development plan and emerging policy is essentially supportive of the renewable energy schemes, subject to a number of provisos which I have considered in the preceding sections of this decision. At the inquiry the appellant and the council came to an agreement listing the capacity of the operational, consented and pending renewable energy schemes in Devon. This records a total installed capacity of 32.8 MW, and consented schemes of 82.75 MW. Three appeals are pending (including the current case) providing 44 MW; applications are pending providing 31.1 MW; and pre-planning discussions are underway for an additional four schemes providing 64 MW. The parties agreed that the deficit for the 2010 Devon target is therefore 118.2 MW. As far as the RSS targets are concerned, the installed capacity is now 154.84 MW and the deficit for the 2010 target is therefore 354-456 MW. The deficit in terms of the 2020 target is 695.16 MW.

145. Paragraphs 2-5 of PPS22 indicate the importance which is attached to the targets for increasing renewable energy capacity. Paragraph 3 states that they should be recorded as a minimum amount of installed capacity, although they may also be expressed as a percentage of electricity consumed or supplied. Progress should be monitored and targets should be revised upwards if they are met. The latter provision is however subject to the region's renewable energy resource potential, and the capacity of the environment for such development. Achievement of the target should not be used in itself as a reason for refusing planning permission for further projects, and the prospect of offshore generation should not be used as a justification for lower targets for onshore projects.

146. My attention was drawn by the council to paragraphs 14-16 of the Supplement to PPS1. These are concerned with the performance of the RSS in mitigating climate change. It is noted that strategic targets form part of the framework for planning decisions. However, they should be used as a strategic tool for shaping policy, and not applied directly to individual planning applications. It is on this basis that the council argues the strategic targets are peripheral to the consideration of the merits of the appeal proposal.

147. I have considered the applicability to this case of the performance management measures and strategic targets referred to in the Supplement to PPS1. The Supplement is concerned with the broader issue of climate change and the reduction of carbon emissions, whereas PPS22 has a significantly more focused purpose. It is concerned only with the contribution which renewable energy schemes can make to the wider environmental objective. Nevertheless, as an addition to PPS1 the Supplement has an overarching status in relation to the delivery of sustainable development. It is specifically noted that, where there is any difference in emphasis on climate change between the Supplement and the other PPS/Gs in the series, this is intentional and the Supplement takes precedence. In addition, paragraph 11 of the Supplement records that it may

supersede the policies of the development plan. The Supplement (2007) also post-dates PPS22 (2004) and its Companion Guide (2004).

148. I therefore agree with the council that the content of the Supplement appears to diminish the extent to which the deficit in relation to the renewable energy targets can have a significant bearing on this case. However, my view is tempered by the wider remit of the Supplement, and by the evident weight with which they – the renewable energy targets – are promoted in PPS22. Indeed, paragraph 3.13 of Chapter 3 of the Companion Guide specifically states that targets are important because they have to be followed through into local development frameworks and the development control process. Even within the context of the appeal, there are few who doubt or question the legitimacy of the targets in terms of either climate change or the attractions of renewable energy, and in my view, a poor performance must add some weight to the benefit of a project which would serve to decrease the size of the deficit. In this case it appears the 2010 renewable energy target for Devon will be only be about 22% achieved, and the equivalent proportion for the region will be between 25 and 30%. I recognise that with the addition of the consented schemes the Devon proportion would rise to about 77%, but evidence submitted on behalf of the appellant notes that lead-in times can be long. Even though the appeal scheme could not now make a contribution to the 2010 target, if the project was implemented with the other consented schemes, the proportion would rise to just over 88%. However, it seems inevitable therefore that the targets will not be achieved, and, though by no means determinative, I conclude this state of affairs must make its own contribution to the benefit of the project.

149. I have taken account of the council's concern that both the output of the proposed wind farm and the predicted emissions saved have been exaggerated. The council has referred to the predicted long-term mean annual capacity factor for the proposed wind farm of 25.2% - equivalent to 39.77 GWh/annum. These figures are indeed less than those included in the ES in 2005. Similarly, I accept that the savings in terms of reduced CO_2 emissions are now much reduced – from 860g/kWh to 430g/kWh. However, as the council observes, although these benefits would be notably less than those originally predicted in the ES, the targets are expressed in terms of installed capacity. Even on the basis of their recalculated levels, the scheme would still make a significant and valuable contribution. I note in this context that the Companion Guide to PPS22 reports that capacity factors in the UK generally fall anywhere between 20 and 50%, with 30% being typical.

150. The council has also drawn my attention to a challenge in 1999 to the decision in respect of an unsuccessful appeal for a wind farm in County Durham - *National Wind Power Ltd v. SSETR* [1999][35]. In that case the judge held that the decision-maker could take account of both the absolute and relative contributions of the scheme then under consideration – that is, the installed capacity and the anticipated actual output. It appears in the current case that a similar argument formed part of the challenge in respect of the first appeal decision. However, the point was essentially overtaken by other events before the decision was quashed. I do not dispute the point made by the council, but

[35] Document 56

I note that the capacity of the proposed development would fall within the national average.

151. I have considered the council's point that the appellant has failed to demonstrate the necessary regard for the location of the scheme as required in paragraph 1(viii) of PPS22. However, I have no reason to doubt that the process described in paragraphs 2.1.1 to 2.5.2 of the ES were carried out as recorded. This reports how sites were sought in the areas of West Devon, North Devon and Mid Devon west of the M5 motorway. A total of 47 potential sites were reduced to 16 for a variety of reasons. These were subject to more detailed scrutiny and subsequently reduced to 11. Of these, 6 appeared to be large enough to permit the siting of at least 5 turbines, and the site at Den Brook was the largest. In my view this process described a comprehensive procedure by which the site was identified, and I agree with the appellant that there is no requirement to pursue a sequential process.

152. I conclude in relation to the range of national and development plan policies against which renewable energy schemes fall to be considered, that the scheme would make a limited but valuable contribution to the reduction of CO_2 emissions. It thus complies with the purpose of Policy RE 6 of RPG 10 and the subsequent emerging equivalent policies of the RSS. Subject to the matters I have considered under the heading of the first main issue, it accords with the purposes of structure plan Policy CO12 and local plan Policy PS10.

Conditions

153. I turn now to consider the draft conditions which were submitted to and discussed at the inquiry. The draft conditions cited are those attached at Document 65. I have considered the conditions in the light of both the preceding parts of this decision and the contents of DoE Circular 11/95: *The Use of Conditions in Planning Permissions.* I have considered the draft noise conditions separately.

154. The standard period in which development is to be commenced is 3 years. I acknowledge however that in relation to a commercial wind energy scheme a longer time would be necessary because of the long lead-in times involved. A period of 4 years would be appropriate.

155. Draft condition 2 limits the life of the wind farm to 25 years and makes provisions for the after-care of the site. Both the council and DBJRG consider the limited removal of the concrete turbine bases would be insufficient. However, in my view the removal of concrete to a depth of 1m below ground level would be sufficient for the re-establishment of agriculture. The costs of restoration would fall to the then owner or operator of the site.

156. There was no objection to draft condition 3 concerning the removal of the temporary construction compound and two temporary meteorological masts.

157. The purpose of draft condition 4 is to secure the removal of turbines which, for any reason, stop working for a continuous period of 12 months. This is indeed a rather long period, but I have no reason to doubt the appellant's contention that lead-in times for spare parts can be significant. I have nevertheless clarified the meaning of 'operational', and, in the interests of precision, I have removed the flexibility included in the original draft.

158. There was no objection to draft condition 5 concerning the preparation of a construction method statement.

159. Draft condition 6 regulates the external finish and colour of the proposed turbines and buildings. The CPRE favoured a white finish, but both the council and the appellant would prefer a more subdued finish. Paragraph 3.2.15 of the ES specifies a pale grey colour with a semi-matt finish. In my view this would appear less stark than white, and I have specified it accordingly.

160. There was no objection to draft condition 7 concerning the direction of rotation of the proposed turbines.

161. The purpose of draft condition 8 is to allow some flexibility in the siting of turbines to take account of, for example, ground conditions. Both the council and DBJRG drew attention in this context to the effect of *R v. Rochdale MBC,* and the danger that an assessment made on the basis of submitted drawings may be undermined by an excess of flexibility. The appellant also expressed some sympathy for this view, but felt the matter could be left to the council. In my view the condition fails the test of precision included in Circular 11/95. The proposed siting of the turbines is capable of being clearly and precisely defined on the ground on the basis of the submitted drawings, and in the event of adverse ground conditions a revised application may be necessary. It follows that I consider draft condition 8 should be omitted. Departing from the 50m micrositing flexibility included in Figure 3.1A of the ES also largely resolves the concern expressed in English Nature's Technical Information Note about the proximity of turbines to hedgerows.

162. There was no objection in principle to draft condition 9 concerning ecological mitigation and compensation measures, nor draft condition 10 concerning archeaology.

163. Draft condition 11 seeks to establish a means of regulating the possible incidence of shadow flicker. In my view a clause requiring the implementation of the scheme is both necessary and reasonable.

164. The purpose of draft condition 13 is to secure a scheme to investigate and alleviate any electro-magnetic interference with radio or television reception. There was no objection.

165. Neither the council nor the appellant were enthusiastic about a lighting scheme for the proposed turbines. However, the area is one which is subject to low altitude training and in my view a condition is both necessary and reasonable. I have constructed a condition based on draft condition 18 which in my view would have only a limited adverse effect on local amenity.

166. There was no fundamental objection to draft condition 15 concerning off-site highway works, nor draft condition 16 concerning working times and practices during the construction phase.

167. Draft condition 17 specifies the type of turbine and their maximum height.

168. The council has suggested an additional condition preventing the commencement of the proposed development unless and until a connection to the national grid is approved by the council. In the appellant's view such a condition would fail the test of relevance included in Circular 11/95. The local

electricity distribution company would in any event have to obtain approval for the route. This matter if referred to in the Companion Guide to PPS22[36]. From the appellant's viewpoint it is self-evidently a prerequisite of the scheme for which a separate mechanism applies. I therefore see no need to add a condition which would duplicate the requirement.

Noise conditions

169. The draft conditions cited are those included in Document 66. Draft noise conditions were discussed at the inquiry, including the submissions made by DBJRG. I have considered in the first instance the draft conditions agreed between the appellant and the council.

170. In ETSU-R-97 it is suggested[37] that the need to regulate noise emissions from wind turbines is too complicated to be the subject of conditions imposed on a planning permission. In view of this the contents of a section 106 Agreement under the above Act are drafted together with supplementary guidance notes. However, more recently the contents of the draft Agreement have effectively been translated into a number of conditions, but including the necessary guidance notes. Notwithstanding the endorsement of ETSU-R-97 conferred by PPS22, the advice of ODPM Circular 05/05: *Planning Obligations* is that, where possible, conditions are preferable to obligations[38].

171. The draft conditions essentially seek to: (a) establish rating levels for noise immissions at 7 noise-sensitive dwellings; (b) specify a procedure for considering complaints about turbine noise; (c) provide for the disclosure of information; and (d) devise a scheme for the measurement of immissions in a range of different wind speeds and directions with the purpose of demonstrating compliance with the rating levels. In the event that noise immission levels are exceeded, the development will have failed to comply with (a). The council would then have the option of pursuing the matter by means of either a Breach of Condition Notice or an Enforcement Notice.

172. In relation to draft noise condition 1, DBJRG observes: that 'rating level' is not defined; that 'properties' should read 'dwellings'; that 'lawfully exist[ing]' is not defined; and that 'nearest' is not defined. 'Rating level' is defined in the Glossary to PPG24, and I raise no objection to 'dwellings' being substituted for 'properties'. I consider the meanings of 'nearest' and 'lawfully exist[ing]' are clear in both their geographical and planning senses, but I have omitted the final phrase in the interests of precision.

173. Draft noise condition 1 refers to Tables 1 and 2. These tables record the various levels at the receptor sites at different wind speeds. Table 1 refers to the night-time hours, and Table 2 to the remainder. DBJRG observes that it is neither practical nor useful to refer to fractions of decibels, but, in contrast, the wind speeds should refer to fractions. I accept the appellant's view however that the limits are specified in relation to wind speed integer levels having been derived from a polynomial curve. I raise no issue with the detail inherent in the noise limits as these too would be mathematically derived.

[36] Page 183, paragraph 99
[37] Page 91
[38] Paragraph B51

174. In relation to draft noise condition 2, DBJRG observes: that the council should be able to investigate noise immissions in the absence of a complaint; that the consultant's report should include all relevant data in an electronic format; and that the 28 day period is excessively rapid. I see no practical benefit in the council being able to instigate an investigation without a complaint. The data sought by DBJRG would be available under the provisions of draft noise condition 3, but I agree that 28 days could be too short a period to take account of different meteorological conditions. I have therefore increased the period to 56 days.

175. In relation to draft noise condition 3, DBJRG observes that locations for the data cited are not defined. However, the data is from each turbine so the locations would be known. In the interests of consistency I have increased the period specified to 56 days.

176. In relation to draft noise condition 4, DBJRG observes: that there is a need for a consultant to be appointed at the expense of the developer to advise the council; and that the council's satisfaction should be agreed in writing. I agree with both suggestions. I have also altered 'developer' to 'wind farm operator' in the interests of consistency with draft noise condition 2.

177. The council has suggested, with the support of DBJRG, that a fifth noise condition would be necessary seeking details of the actual wind turbine design and technical specification which it is intended to install. Notwithstanding the case of *R v. Rochdale MBC* to which I have previously referred, the appellant considers such a requirement is unnecessary. One of the purposes of the planning system is to seek to anticipate and forestall adverse impacts on the living conditions of neighbours. To this end details of design and technical specifications are a useful source of information, but absolute predictability is neither possible nor necessary. It is in order to minimise the effect of uncertainty that conditions would be necessary and reasonable. What would matter in the current case would be that the noise immissions at the receptor locations would not exceed the specified limits. The design and technical specification of the turbine would be irrelevant.

178. The DBJRG also made some observations on the schedule of Notes which supplement the draft noise conditions. In relation to Note 2(a) it is suggested that other meteorological criteria should be added – wind shear level, frozen ground and cloud cover. I agree that these are important variables. At Note 2(b) the need to specify adjacent rain gauges and to avoid atypical data points should be specified. I have included references to both these matters. At Note 2(c) a 3rd order polynomial is recommended. The appellant's preference is for a 2nd order polynomial. In my view either would be sufficient for its purpose, and I have therefore retained the Note as drafted.

179. It is in Note 4 that the conditions reach their conclusion. The DBJRG holds that the Note should require that any offending turbine is switched off. I acknowledge that this would be a logical conclusion of the process, but it would clearly constitute a serious step which should only be taken after due consideration of all the circumstances. It would be a matter for the council in the first instance. In this respect I agree with the appellant that such action falls to be specified in either a Breach of Condition Notice or an Enforcement Notice. I anticipate that the scheme required by draft noise condition 4 would

inevitably involve switching off selected turbines for temporary periods in order to permit the necessary evaluation.

180. The DBJRG has provided an alternative noise condition[39] and a reasoned justification[40] to those agreed between the appellant and the council. I have considered the alternative but I can see no obvious advantage over the draft conditions and their supplementary notes discussed above.

181. However, as is evident from my consideration of the possible noise impact of the proposed wind farm, I am concerned about the effect of greater than anticipated AM[41] arising at the site. At my instigation DBJRG has drafted a condition designed to regulate this possibility[42] and prepared a reasoned justification[43], and this has been the subject of a response by the appellant[44].

182. The appellant objects in principle to the inclusion of a condition designed to regulate AM on the grounds that excessive AM is rare; stable atmospheric conditions are rare at the appeal site; it is not recommended in ETSU-R-97; and there is insufficient knowledge to achieve the necessary balance between the preservation of amenity without causing profound damage to the UK wind industry.

183. In my opinion these misgivings are either overstated or misleading. I do not see that the rarity of the circumstance constitutes a valid reason to object to such a condition. If it is unlikely, then it is equally unlikely that it would be necessary to enforce the condition. On the basis of the evidence I have heard I am satisfied that the phenomenon is not fully taken into account in ETSU-R-97, and the condition proposed is of a precautionary nature. I would have more sympathy with the appellant's view had the purpose of ETSU-R-97 been merely the preservation of amenity, but it is not. From the viewpoint of wind farm neighbours the most important purpose of ETSU-R-97 would be more accurately described as the preservation of sleep. Taking account of both this and the uncertainties to which I have already referred, it is for these reasons that in my opinion the imposition of conditions is both necessary and reasonable.

184. The appellant complains that the condition drafted by DBJRG contains subjective elements, but I cannot see this. I fear the psycho-acoustic approach suggested by the appellant would be likely to be significantly more subjective. The possibility of a penalty approach is suggested similar to that included in ETSU-R-97 for a tonal component and as cited in Note 3. However, I have received no details of an appropriate sliding scale. I do accept nevertheless that the proposed condition would benefit from redrafting in order to clarify its content and purpose. I have amended it to this effect.

Overall conclusion

185. Paragraph 1(i) of PPS22 states that renewable energy developments should be capable of being accommodated throughout England in locations where the

[39] Document 46
[40] Document 49
[41] That is, greater than anticipated in ETSU-R-97.
[42] Document 45
[43] Document 50
[44] Documents 54 and 53

technology is viable and environmental, economic, and social impacts can be addressed satisfactorily. Similarly, and notwithstanding the extensive landscape protection policies which are integral to the planning system, paragraph 19 effectively requires that proposals are considered on a case by case basis. In the identification of the main issues in this case I have sought to balance the requirement that any adverse effects on the locality should be weighed against the widely accepted benefits of renewable energy generation. As is so often the case with planning decisions, the effects of both the development proposed and the policies of the development plan pull in different directions.

186. As far as the effect of the scheme on the character and appearance of the surrounding area is concerned, I have concluded that although the development would result in the creation of a localised zone in which the turbines would dominate the landscape character, this would diminish quite rapidly. I see no significant objection to the proposed development in relation to its effect on the historic environment. In visual terms however, I believe there would be locations to the north of the appeal site which would be harmed by the development. In contrast, I have concluded there would be no equivalent effect in relation to the local ecology. The effect of the scheme on the noise environment was the subject of much evidence and occupied a significant proportion of the inquiry. The issue is the subject of specific guidance, but I am concerned that with the growth of knowledge and the advent of larger commercial machines, ETSU-R-97 is not now as applicable as previously. However, subject to some important conditions, I have concluded that the effect of the scheme is likely to fall within the limits which were designed, in part, for the protection of wind farm neighbours. I have also taken account of other matters which I did not consider constituted main issues but which were raised by contributors to the inquiry.

187. In conclusion, the harm I have identified is fairly limited. In respect of the landscape protection provisions of the development plan there is conflict with structure plan Policy CO1, local plan Policy NE10, and Policy EN 1 of RPG 10. The protection of the landscape is also a component of Policy RE 6 of RPG 10, of structure plan Policy CO12, and of local plan Policy PS10. The purpose of these policies is to support the exploitation of renewable energy, but they require in each case that a balance is struck. The latter policies also require that account is taken of the living conditions of nearby residents. The purpose of structure plan Policy CO16 and local plan Policy BE18 is more specific – to protect existing residents from noise pollution. This is also one of the purposes of ETSU-R-97. I have concluded that, subject to conditions to regulate its impact, the scheme would conflict with neither Policy CO16 nor Policy BE18, and that the conflict with the landscape policies to which I have referred is sufficiently limited to be outweighed by the purposes of structure plan Policy CO12, local plan Policy PS10, and Policy RE 6 of RPG 10. It is for the reasons given above that I have concluded the appeal should be allowed.

Andrew Pykett

INSPECTOR

APPEARANCES

FOR THE LOCAL PLANNING AUTHORITY:

Mr Peter Wadsley	of Counsel, instructed by the Solicitor to West Devon Borough Council
He called:	
Ms Frances Griffith BA FSA MIFA	Devon County Archaeologist
Mr Mark Holland BA(Hons) DipLA CMLI	Chris Blandford Associates
Mrs Jane Hart BA MSc MRTPI	Chief Planning Officer, West Devon Borough Council

FOR THE APPELLANT:

Mr Marcus Trinick	Partner, Eversheds LLP
He called:	
Mr Colin Goodrum BSc(Hons) DipLA MLI	LDA Design
Mr David Stewart MA(Cantab) DipTP MRTPI	David Stewart Associates
Dr Stephen Holloway BSc(Hons) PhD MIEEM CEnv	Andrew McCarthy Associates
Dr Janet Barlow BSc(Hons) MSc PhD	Department of Meteorology, University of Reading
Dr Andrew McKenzie BSc(Hons) PhD MIOA	Hayes McKenzie Partnership

FOR THE DEN BROOK JUDICIAL REVIEW GROUP Ltd:

Mr Reuben Taylor	of Counsel, instructed by Ms Susan Ring of Richard Buxton Solicitors
He called:	
Ms Sarah Reynolds BSc(Hons) DipLD MA MLI	The Landscape Partnership
Mrs Pamela Coles	Local resident
Mr Ivan Buxton	Wildlife warden
Mrs Jane Davis RN RM RHV MA	Resident of Deeping St Nicholas, Lincolnshire
Mrs Clair Hodgson BA	Local resident
Dr Lee Hoare PhD	Data analyst
Mr Michael Stigwood FRSPA MIOA	MAS Environmental

FOR THE CAMPAIGN TO PROTECT RURAL ENGLAND:

Mr T J W Hale	Chairman, Devon CPRE
He called himself and:	
Mr James Paxman BA	Chief Executive, Dartmoor Preservation Association
Dr P A W Bratby BSc PhD ARCS	Energy consultant

WRITTEN STATEMENTS AND LETTERS BY INTERESTED PERSONS

OBJECTORS

Mr Justin Whittaker
Cllr James McInnes
Dr & Mrs K E Whitaker
Mr Nick Jewell
Ms Lesley Jewell
Mr David Gribble
Mr Luke de Haan
Mr George Livingstone-Learmouth
Ms Ruth Harvey
Cllr Paul Rogers
Ms Christine Lovelock
Ms Brenda Ware, for Bow Parish Council
Mr J K Welsbey, for Zeal Monachorum Parish Council
Ms Nicola Poultney, for Visit Devon
Mr Martin Quick
Mr Q Morgan Edwards
Mr Tony Wood
Ms Muriel Goodman
Ms Alix Quested
Ms Maggie Greaves
Mr P F Coles
Mr Peter Green, for Bow and District Historical Society
Mr Michael Addison
Ms Alison Thornton
Mr Colin Stabler
Ms Christine Stabler
Ms Anne Ramsey
Ms Carol Hughes
Cllr Jenny Rosser
Ms Maureen Thomson
Mr Peter Hadden

SUPPORTERS

Mr C D Bell
Ms Nan Pratt
Mr John Vincent
Mr Francis George Macnaughton
Ms Eva Ritchie
Dr Steve Ritchie
Ms Deborah Marshall, with Dan Marshall and Kira Moore
Mrs M B Williams

DOCUMENTS SUBMITTED DURING THE INQUIRY

1 Statement of Common Ground, including draft conditions
2 Bundle of supporting statements and letters, submitted by the appellant
3 Opening Statement by Mr Trinick for the appellant
4 Opening Statement by Mr Wadsley for the council
5 Opening Statement by Mr Hale for the CPRE
6 Opening Statement by Mr Taylor for DBJRG
7 Letter of support dated 15 July 2009 from the Mortenhampstead Action Group for Sustainability
8 Answer to RES Development's rebuttal of Zeal Monachorum Parish Council's paper on the impact of the proposed wind farm at Den Brook
9 Viewpoint Assessment and Effects, submitted for DBJRG
10 Wireframe Views, Viewpoints J K N Q U V and Y, submitted for the appellant
11 Landscape & Visual Impact significance tables, submitted for DBJRG
12 Photograph N, submitted for DBJRG
13 Agreed note on photograph viewpoints, including wireframes for Viewpoints G W and X, submitted for DBJRG and the appellant
14 Map showing photograph locations wider setting, submitted for DBJRG
15 Installed Renewable Energy Capacity Targets and Operational, Consented, Appeal Pending, Applications Pending and Pre-Planning Proposals in Devon, submitted for the council and the appellant
16 Note – height of cheese factory at North Tawton, submitted for the council
17 Note – Area of Great Landscape Value and the wind farm character zone, submitted for the council
18 Plan showing areas of impact, submitted for the appellant
19 Letter of support dated 25 July 2009 from Exeter Friends of the Earth
20 Note – CPRE Tranquility mapping, submitted for CPRE

21 Two large biomass proposals in the South West Region, submitted by the council
22 Pages 1-4 Climate Change Act 2008, submitted by CPRE
23 BWEA Statistics 2008, submitted by the council
24 Letter and enclosures dated 30 July 2003, Scheduled Ancient Monuments: West Devon, submitted by the council
25 Note – Wind shear model used to calculate wind speed at turbine hub height, Submitted by the appellant
26 Draft non-noise conditions: Comments of DGJRB
27 Additional draft condition, submitted by the council
28 Note – grid connection wayleaving, submitted by the appellant
29 Extract from Option Agreement, submitted by CPRE
30 Chapter 7, Draft Revised RSS for the South West incorporating the Secretary of State's Proposed Changes, July 2008, submitted by the council
31 *The UK Low Carbon Transition Plan,* submitted by the council
32 Exchange of letters dated 21 August and 1 October 2009 between Mr Philip Mulligan and Lord Hunt of Kings Heath, submitted by the appellant
33 Plan showing proximity of North Wyke and Halse Farm, submitted by the appellant
34 *Derbyshire Dales District Council and Peak District National Park Authority v. Secretary of State for Communities and Local Government and Carsington Wind Energy Limited* [2009], submitted by the appellant
35 *The UK Renewable Energy Strategy,* submitted by the appellant
36 *R v. Rochdale MBC* [2000], submitted by DBJRG
37 CPRE Policy Position Statement *Onshore Wind Turbines,* submitted by the appellant
39 Den Brook Wind Farm – Planning Conditions 2009, submitted by the appellant
40 Draft Statement of Common Ground (Noise)
41 Email dated 6 October 2009 and Draft Noise Conditions
42 Diagram, submitted by the appellant
43 Number 10 official website extract, submitted by DBJRG
44 *Night Noise Guidelines for Europe,* World Health Organization, submitted by DBJRG
45 Draft noise condition for Amplitude Modulation, submitted by the DBJRG
46 Draft noise condition for Wind Farm noise, submitted by the DBJRG
47 Den Brook Wind Farm – Planning Conditions 2009
48 Third International Meeting on Wind Turbine Noise, Aalborg, Denmark, submitted by the DBJRG
49 Rationale for general noise level condition for Wind Farm noise, Den Brook, submitted by the DBJRG
50 Rational to the Den Brook excess Amplitude Modulation condition, submitted by the DBJRG
51 MAS Errata, submitted by the DBJRG
52 Den Brook Wind Turbines – Human Rights Issues, submitted by Mr Hadden

53 Comments on DBJRG's draft noise condition for Amplitude Modulation, submitted by the appellant
54 Comments on DBJRG's draft noise condition for Wind Farm noise, submitted by the appellant
55 *North Wiltshire District Council v. Secretary of State for the Environment and Clover* [1992], submitted by the council
56 *National Wind Power v. The Secretary of State for the Environment, Transport and the Regions and others* [1999], submitted by the council
57 Closing Submission by Mr Hale
58 Closing Submissions by Mr Taylor
59 Closing Statement by Mr Wadsley
60 Closing Submissions by Mr Trinick (read by Mr Paul Maile)
61 Appeal Decision dated 1 December 2006, submitted by the appellant
62 Appeal Decision dated 15 January 2008 APP/V3310/A/2031158, submitted by the appellant
63 *The impact of wind farms on the tourist industry in the UK,* submitted by the appellant
64 Letter dated 15 November 2006 from English Heritage, submitted by the appellant
65 Draft conditions, final version, submitted by the appellant
66 Draft noise conditions, final version, submitted by the appellant
67 Email dated 11 November 2009 concerning lighting specification, submitted by the council

Schedule of Conditions

1. The development hereby permitted shall begin not later than 4 years from the date of this decision.

2. Other than in respect of the temporary construction compound and the 2 temporary meteorological masts shown in figures 3.1, 3.9 and 3.10 of the Environmental Statement (Volume III), the permission hereby granted is for the proposed development to be retained for a period of not more than 25 years from the date that electricity from the development is first supplied to the grid, this date to be notified in writing to the local planning authority. By no later than the end of the 25 year period the turbines shall be decommissioned and all related above ground structures shall be removed from the site. Six months before the due date for the decommissioning of the turbines, a scheme for the restoration of the site shall be submitted and approved in writing by the local planning authority. The scheme shall make provision for the removal of all the above-ground elements, plus 1m of the concrete turbine base below ground level, and all associated equipment before its return to agricultural use. The scheme shall include details of the phasing of the works. Upon approval, the restoration scheme shall be implemented in accordance with the phasing details, the turbines having been removed not later than the due date.

3. The temporary construction compound and the 2 temporary masts referred to in condition 2 above shall be removed within 2 years of the date that electricity is first supplied to the grid, and the ground shall be restored to its previous condition within 6 months thereafter.

4. If any turbine hereby permitted ceases to generate electricity for a continuous period of 12 months all its above-ground elements plus 1m of the concrete turbine base below ground level, save for the access tracks, shall be removed within the ensuing period of not more than 6 months.

5. No work shall commence on site until a Construction Method Statement including details of all on site construction, drainage, mitigation, restoration and reinstatement works, together with details of their timetabling has been submitted to and approved in writing by the local planning authority. This shall detail the following:

    - The construction of the access into the site from A3072 and the creation and maintenance of associated visibility splays, as illustrated in figures 3.1 and 10.5 of the Environmental Statement (Volume III);
    - The nature and use of access by rail, including any improvement works (eg signals, passing loop) for the purposes of transporting construction materials and turbine components to or from the site;
    - The formation of the construction compound;
    - The construction of the crane pads;
    - The carrying out of foundation works;
    - The construction of the sub-station and control building;

- The erection of the meteorological masts;
- The arrangements to be made for the cleaning of the site entrances and the adjacent public highway;
- The formation of the access tracks and any areas of hardstanding;
- The post-construction restoration/reinstatement of the working areas;
- The measures to be taken to avoid any damage to on-site archaeological remains that are to remain in-situ.

Construction shall only take place in accordance with the methods as approved.

6. No development shall take place until details of the following have been submitted to, and approved in writing by, the local planning authority:

    (a) The external finish and colour of the proposed turbines, which shall be pale grey with a semi-matt finish; and
    (b) The materials to be used in the construction of the external surfaces of the proposed buildings.

    The development shall be carried out in accordance with the approved details, and there shall be no subsequent change to the finish or coloration of the turbines.

7. All the turbine blades shall rotate in the same direction.

8. Before the commencement of the development hereby permitted a scheme of illumination of the most northerly (T5), southerly (T3), and westerly (T10) turbines shall be submitted to and approved in writing by the local planning authority. The scheme shall provide for 25 candela omni-directional lighting in the horizontal plane (360°). In the vertical plane the lighting shall be limited to the sector between 15° below and 30° above the horizon. The lighting shall be night vision goggle compatible or infra-red lighting on the hubs of the turbines. The scheme shall be implemented as approved by the date that electricity is first supplied to the grid.

9. Before development commences a scheme shall be submitted to and approved in writing by the local planning authority for the ecological mitigation and compensation measures proposed within the site incorporating the principles set out in Tables 6.15 and 6.16 of the Environmental Statement (Volume II) and the amended habitat mitigation plan set out in Figure 6.21 Rev 0.1. The scheme, as approved, shall be implemented throughout the construction and operational phases of the development.

10. The development hereby permitted shall not commence until a programme of archaeological work has been implemented in accordance with a written scheme of investigation submitted to and approved in writing by the Local Planning Authority.

11. The development hereby permitted shall not commence until a scheme to avoid the incidence of shadow flicker at any dwelling or other sensitive property has been submitted to and approved in writing by the local planning authority. The scheme shall be implemented as approved and as necessary.

12. The development hereby permitted shall not commence until a scheme to secure the investigation and alleviation of any electro-magnetic interference to television and radio reception, caused by the operation of the wind turbines, has been submitted to and approved in writing by the local planning authority. The procedure set out in the approved scheme shall be followed at all times.

13. The development hereby permitted shall not commence until a detailed Construction Management Scheme for off-site highways works has been submitted to and approved in writing by the local planning authority. This shall include a Traffic Management Plan for the routing of construction traffic to and from the site, addressing in particular the movement of abnormal loads, the arrangements to be made for any Highways Act Agreement that may be required, and the re-instatement of off-site works not needed to be retained after the construction phase. The development shall be carried out in accordance with the approved scheme.

14. Notwithstanding the statement prepared in accordance with condition 5 above, construction work shall take place only between the hours of 07:00 and 19:00 on Monday to Friday inclusive, 07:00 and 13:00 on Saturdays with no such working on a Sunday or local or national public holiday. Outside these hours, development at the site shall be limited to turbine erection, maintenance, dust suppression and the testing of plant and equipment or construction work that is not audible from any noise-sensitive property outside the site. The receipt of any materials or equipment for the construction of the site, other than turbine blades, nacelles and towers, is not permitted outside the said hours.

15. The development hereby permitted is confined to 3-bladed horizontal axis wind turbines with a maximum height to the blade tip of 120m above ground level.

16. The rating level (as defined in the Glossary of PPG24: *Planning and Noise*) of noise immissions from the combined effects of the wind turbines (including the application of any tonal penalty), when assessed in accordance with the attached Guidance Notes, shall not exceed the values set out in the attached Tables 1 and 2 below. Noise limits for dwellings which lawfully existed at the date of this permission but not listed in the Tables attached shall be those at the nearest location listed in the Tables.

17. At the request of the local planning authority following a complaint the wind farm operator shall, at its expense, employ a consultant approved

by the local planning authority, to assess the level of noise emissions from the wind farm at the complainant's property following the procedures described in the attached Guidance Notes. A report of the assessment shall be provided in writing to the local planning authority within 56 days of a request under this condition unless this period is extended by the local planning authority in writing.

18. Wind speed, wind direction and power generation data for each wind turbine shall be continuously logged and provided to the local planning authority at its request and in accordance with the attached Guidance Notes within 56 days of such a request.

19. No wind turbine shall generate electricity to the grid until the local planning authority, as advised by a consultant approved by the local planning authority at the expense of the operator, has approved in writing a scheme submitted by the wind farm operator providing for the measurement of noise immissions from the wind turbines. The objective of the scheme (which shall be implemented as approved) shall be to evaluate compliance with condition 16 in a range of wind speeds and directions and it shall terminate when compliance with condition 16 has been demonstrated to the satisfaction of and agreed in writing by the local planning authority.

20. At the request of the local planning authority following the receipt of a complaint the wind farm operator shall, at its expense, employ a consultant approved by the local planning authority, to assess whether noise immissions at the complainant's dwelling are characterised by greater than expected amplitude modulation. Amplitude modulation is the modulation of the level of broadband noise emitted by a turbine at blade passing frequency. These will be deemed greater than expected if the following characteristics apply:

a) A change in the measured $L_{Aeq,\ 125\ milliseconds}$ turbine noise level of more than 3 dB (represented as a rise and fall in sound energy levels each of more than 3 dB) occuring within a 2 second period.

b) The change identified in (a) above shall not occur less than 5 times in any one minute period provided the $L_{Aeq,\ 1\ minute}$ turbine sound energy level for that minute is not below 28 dB.

c) The changes identified in (a) and (b) above shall not occur for fewer than 6 minutes in any hour.

Noise immissions at the complainant's dwelling shall be measured not further than 35m from the relevant building, and not closer than within 3.5m of any reflective building or surface, or within 1.2m of the ground.

21. No wind turbine shall generate electricity to the grid until the local planning authority, as advised by a consultant approved by the local planning authority at the expense of the operator, has approved in writing a scheme submitted by the wind farm operator providing for the measurement of greater than expected amplitude modulation immissions generated by the wind turbines. The objective of the scheme (which shall be implemented as approved) shall be to evaluate compliance with condition 20 in a range of wind speeds and directions and it shall

terminate when compliance with condition 20 has been demonstrated to the satisfaction of and agreed in writing by the local planning authority.

SCHEDULE OF GUIDANCE NOTES RELATING TO CONDITIONS 16 - 18

These notes (or any superseding equivalent UK adopted procedure) are to be read with conditions 16 - 18. They further explain these conditions and specify the methods to be deployed in the assessment of complaints about noise immissions from the wind farm.

NOTE 1

(a) Values of the $L_{A90,10min}$ noise statistic should be measured at the complainant's property, using a sound level meter of IEC 651 Type 1, or BS EN 61672 Class 1, standard (or the equivalent relevant UK adopted standard in force at the time of the measurements) set to measure using a fast time weighted response. This should be calibrated in accordance with the procedure specified in BS 4142: 1997 (or the equivalent relevant UK adopted standard in force at the time of the measurements).

(b) The microphone should be mounted at 1.2 - 1.5m above ground level, fitted with a two layer windshield or suitable equivalent approved by the local authority, and placed outside the complainant's dwelling. Measurements should be made in "free-field" conditions, so that the microphone should be placed at least 3.5m away from the building facade or any reflecting surface except the ground.

(c) The $L_{A90,10min}$ measurements should be synchronised with measurements of the 10-minute arithmetic average wind speed and with operational data from the turbine control systems of the wind farm.

(d) The wind farm operator shall continuously log arithmetic mean wind speed and arithmetic mean wind direction data in 10 minute periods from the hub height anemometer on the site to enable compliance with the conditions to be evaluated. Such data shall be 'standardised' to a reference height of 10m as described in ETSU-R-97 at page 120 using a reference roughness length of 0.05m.

NOTE 2

(a) The noise measurements should be made so as to provide not less than 20 valid data points as defined in Note 2 paragraph (b). Such measurements should provide valid data points for the range of wind speeds, wind directions, wind shear levels, frozen ground, cloud cover, times of day and power generation requested by the local planning authority. In specifying such conditions the local planning authority shall have regard to those conditions which were most likely to have prevailed during times when the complainant alleges there was disturbance due to noise. At its request the wind farm operator shall provide all of the data collected under condition 17 to the local planning authority.

(b) Valid data points are those that remain after all periods during rainfall have been excluded as informed by a rain gauge sited adjacent to the measurement location. Additional atypical data as agreed by the local planning authority shall also be removed.

(c) A least squares, "best fit" curve of a maximum 2nd order should be fitted to the data points and define the rating level at each integer speed.

NOTE 3

Where, in the opinion of the local planning authority noise immissions at the location or locations where assessment measurements are being undertaken contain a tonal component, the following rating procedure should be used.

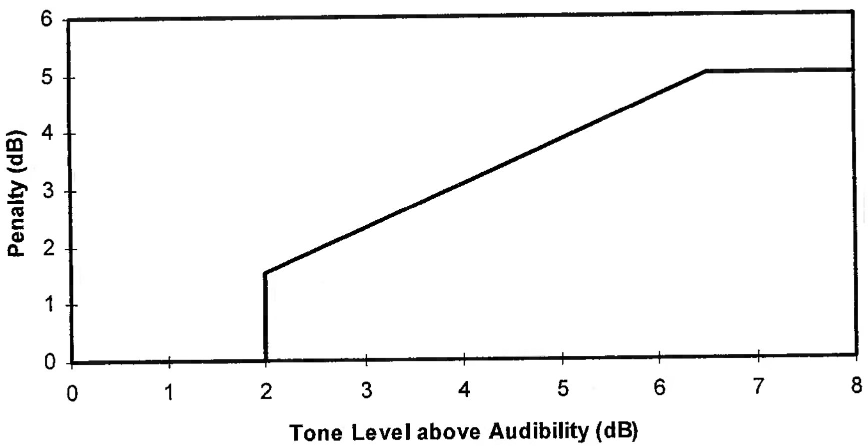
(a) For each 10-minute interval for which $L_{A90,10min}$ data have been obtained as provided for in Note 1 a tonal assessment is performed on noise immissions during 2 minutes of each 10 minute period. The 2 minute periods should be regularly spaced at 10 minute intervals provided that uninterrupted clean data are available. Where clean data are not available, the first available uninterrupted clean 2 minute period out of the affected overall 10 minute period shall be selected. Any such deviations from standard procedure shall be reported.

(b) For each of the 2-minute samples the margin above or below the audibility criterion of the tone level difference, Delta L_{tm}, should be calculated by comparison with the audibility criterion given in paragraph 2.1 on pages 104-9 of ETSU-R-97.

(c) The margin above audibility is plotted against wind speed for each of the 2-minute samples. For samples for which the tones were below the audibility criterion or no tone was identified, substitute a value of zero audibility.

(d) A linear regression should then be performed to establish the margin above audibility at the assessed wind speed for each integer wind speed. If there is no apparent trend with wind speed then a simple arithmetic average shall be used.

(e) The tonal penalty is derived from the margin above audibility of the tone according to the figure below. The rating level at each wind speed is the arithmetic sum of the wind farm noise level, as determined from the best fit curve described in Note 2, and the penalty for tonal noise.



NOTE 4

If the rating level is above the limit set out in the conditions, measurements of the influence of background noise should be made to determine whether or not there is a breach of condition. This may be achieved by repeating the steps in Note 2, with the wind farm switched off, and determining the background noise at the assessed wind speed, L_3. The wind farm noise at this speed, L_1, is then calculated as follows where L_2 is the measured level with turbines running but without the addition of any tonal penalty:

$$L_1 = 10\log\left[10^{L_2/10} - 10^{L_3/10}\right]$$

The rating level is re-calculated by adding the tonal penalty (if any) to the derived wind farm noise L_1. If the rating level lies at or below the values set out in the conditions then no further action is necessary. If the rating level exceeds the values set out in the conditions then the development fails to comply with the conditions.

TABLES OF NOISE LIMITS RELATING TO CONDITION 16

Table 1: Between 23:00 and 07:00 hours (Noise Level in dB $L_{A90,\ 10min}$)

	Standardised Wind Speed at 10 m height (m/s)											
Location	1	2	3	4	5	6	7	8	9	10	11	12
Halse Farm	43.0	43.0	43.0	43.0	43.0	43.0	43.0	45.4	48.9	52.0	54.4	55.8
Itton Manor	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	45.4	48.7	51.7	54.2
Ham Farm	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	47.2	52.7
Crooke Cottage	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	45.9	49.7
Crooke Burnell	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	45.9	49.7
Broadnymett	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.1	46.8	50.6	54.4	58.0
Coxmoor	43.0	43.0	43.0	43.0	43.0	43.0	43.0	45.6	49.5	53.3	56.9	59.9

Table 2: At all other times (Noise Level in dB $L_{A90,\ 10min}$)

	Standardised Wind Speed at 10 m height (m/s)											
Location	1	2	3	4	5	6	7	8	9	10	11	12
Halse Farm	37.5	37.5	37.5	37.5	38.0	40.5	43.6	46.9	50.1	53.0	55.4	56.9
Itton Manor	37.5	37.5	37.5	37.5	37.5	37.5	40.1	43.1	46.0	48.7	50.7	52.0
Ham Farm	37.5	37.5	37.5	37.5	37.5	37.5	37.5	37.9	40.2	42.8	45.3	47.6
Crooke Cottage	37.5	37.5	37.5	37.5	37.5	37.5	37.5	37.9	40.6	43.5	46.6	49.7
Crooke Burnell	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.6	43.5	46.6	49.7
Broadnymett	37.5	37.5	37.5	37.5	37.5	37.6	40.4	43.5	46.6	49.7	52.4	54.7
Coxmoor	37.5	37.5	37.5	37.5	37.5	38.8	42.2	45.9	49.7	53.3	56.4	58.7

3 December 2009

Sarah Holmes
Bond Pearce LLP
Ballard House
West Hoe Road
Plymouth
PL1 3AE

Our Ref: APP/F2415/A/09/2096369/NWF
Your Ref: SCH1/DET1/347662.17

Dear Madam

TOWN AND COUNTRY PLANNING ACT 1990 – SECTION 78
APPEAL BY NUON UK LTD: LAND TO THE NORTH-EAST OF SWINFORD
APPLICATION REF: 08/00506/FUL

1. I am directed by the Secretary of State to say that consideration has been given to the report of the Inspector, Mr John Woolcock, BNatRes (Hons) MURP DipLaw MPIA MRTPI, between 14 and 31 July 2009 into your client's appeal for non-determination of an application by Harborough District Council for the construction and operation of a wind farm consisting of eleven 125 m turbines, control building, temporary construction compound, anemometer mast, vehicular access, accommodation works and tracks at land north-east of Swinford, Leicestershire, in accordance with application number 08/00506/FUL.
2. On 12 February 2009 the appeal was recovered for the Secretary of State's determination, in pursuance of section 79 of, and paragraph 3 to Schedule 6 to, the Town and Country Planning Act 1990 because the appeal relates to proposals of major significance for the delivery of the Government's Climate Change Programme and Energy Policies.

Inspector's recommendation and summary of the decision

3. The Inspector recommended that the appeal be allowed and planning permission granted, subject to conditions. For the reasons given below, the Secretary of State agrees with the Inspector's conclusions and with his recommendation. A copy of the Inspector's report (IR) is enclosed. All references to paragraph numbers, unless otherwise stated, are to that report.

Procedural matters

4. In reaching this position the Secretary of State has taken into account the Environmental Statement which was submitted under the Town and Country Planning (Environmental Impact Assessment) (England and Wales) Regulations 1999, and the Inspector's comments at IR187-188. The Secretary of State is content that the Environmental Statement complies with the above regulations

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and that sufficient information has been provided for him to assess the environmental impact of the appeal before him.

Matters arising after the close of the inquiry

5. Following the close of the inquiry the Secretary of State received a number of representations about the application scheme. These are listed at Annex A. The Secretary of State has given careful consideration to these representations, but does not consider that they raise any new issues that would either affect his determination of this appeal, or require him to refer back to the parties for further representations prior to reaching his decision. Copies of the correspondence can be made available on written request to the address at the foot of the first page of this letter.

Policy considerations

6. In deciding the appeal, the Secretary of State has had regard to section 38(6) of the Planning and Compulsory Purchase Act 2004 which requires that proposals be determined in accordance with the development plan unless material considerations indicate otherwise.

7. In this case, the development plan comprises the Regional Spatial Strategy (RSS) for the East Midlands (the *East Midlands Regional Plan*) published on 12 March 2009 and saved policies of the Harborough District Local Plan (LP), adopted in 2001. The Secretary of State considers that the development plan policies most relevant to the appeal are those set out by the Inspector at IR20-23.

8. Other material considerations which the Secretary of State has taken into account include Planning Policy Statement (PPS) 1: *Delivering Sustainable Development*; Planning Policy Statement: *Planning and Climate Change* (supplement to PPS1); PPS 7: *Sustainable Development in Rural Areas*; PPS9: *Biodiversity and Geological Conservation*; Planning Policy Guidance (PPG)13: *Transport*; PPG15: *Planning and the Historic* Environment; PPG16: *Archaeology and Planning*; PPS22 and its companion Guide: *Renewable Energy,* along with the Government's subsequent statement regarding the findings of the Salford University report into Aerodynamic Modulation of Wind Turbine Noise (published by BERR in August 2007); PPG24: *Planning and Noise*; Circular 11/95: *Planning Conditions*; and Circular 05/2005: *Planning Obligations.*

9. The Secretary of State has also taken into account draft PPS15: *Planning for the Historic Environment,* published for consultation in July 2009. However, as this document is still at consultation stage and may be subject to change, he affords it little weight.

10. In determining the application the Secretary of State has had regard to the various listed buildings and structures in the vicinity of the appeal site. In accordance with section 66 (1) of the Planning (Listed Buildings and Conservation Areas) Act 1990, the Secretary of State has paid special regard to the desirability of preserving the listed structures or their setting or any features of special architectural or historic interest which they may possess. He has also had regard to potential impacts on the Swinford Conservation Area. As required by section 72 (1) of the Planning (Listed Buildings and Conservation Areas) Act 1990, he has paid special attention to the desirability of preserving or enhancing the character or appearance of this area.

Main issues

11. The Secretary of State considers that the main issues in this case are as set out by the Inspector at IR186.

Landscape and visual impact

12. For the reasons set out at IR189-191, the Secretary of State agrees with the Inspector that the proposal would result in some visual harm to the local landscape (IR191), and would be at odds with national guidance in PPS7 (IR225). However, the Secretary of State does not consider that the proposal would have an unacceptable adverse effect on the integrity of either the Lutterworth Lowlands LCA or the Laughton Hills LCA (IR191). In respect of the assessment of possible cumulative impacts, the Secretary of State considers that some significant negative effects would result if the Yelvertoft and Lilbourne wind farms were constructed in addition to the appeal scheme, but that the effects would not add unduly to the harm to the local landscape identified above (IR192).

Cultural heritage

13. The Secretary of State agrees with the Inspector's reasoning and conclusions on cultural heritage matters at IR193-204. The Secretary of State has had special regard to the desirability of preserving the setting of the Grade 1 listed Stanford Hall. As he agrees with the Inspector that the skyline in views from the Hall and its surround is not a historic skyline for the purposes of applying the guidance in PPG15 (IR195), he also agrees with him that the proposal would not conflict with LP Policy EV/16 and on this basis would accord with relevant guidance on listed buildings in PPG15 (IR196). The Secretary of State also agrees with the Inspector that turbine WT9 would to some degree have a detrimental effect on the setting of the historic parkland associated with Stanford Hall and that this weighs against the appeal (IR200). Like the Inspector, the Secretary of State does not consider that the proposal would have an unacceptable adverse effect on the setting of deserted medieval village within the appeal site, and finds no conflict with guidance in PPG16 in this respect (IR202). Nor does he consider that the proposal would adversely affect the settings of other listed buildings or harm either of the conservation areas considered in IR 203-204.

Noise

14. For the reasons set out at IR205-210 the Secretary of State agrees with the Inspector that the proposal would not cause an unacceptable degree of noise disturbance, and so would not conflict with PPG24 (IR211). Like the Inspector he is satisfied, subject to the imposition of appropriate planning conditions that the scheme would minimise increases in ambient noise levels for this type of development and so would also accord with the guidance in PPS22 (IR211).

Archaeological remains

15. For the reasons set out at IR212 the Secretary of State agrees with the Inspector that there is nothing to indicate that an unacceptable effect on archaeological remains would weigh against permitting the proposal.

Nature conservation

16. For the reasons set out at IR213, the Secretary of State agrees with the Inspector that, subject to the imposition of appropriate conditions, there is no reason that harm to wildlife or nature conservation would significantly weigh against the proposal.

Living conditions for local residents

17. For the reasons set out at IR214-215 the Secretary of State does not consider that the proposal would have an unacceptable effect on nearby dwellings that would adversely affect the living conditions of occupiers. Like the Inspector, he considers that shadow flicker is a matter which could be reasonably dealt with by the imposition of appropriate conditions (IR216).

Other considerations

18. The Secretary of State agrees with the Inspector's reasoning and conclusions in respect of the matters considered at IR217-223. He agrees that the reversibility of the scheme should not be an influential factor in determining this appeal (IR222). Like the Inspector, he does not consider that other issues raised by objectors substantially weigh against allowing the appeal (IR233).

Relationship to development plan and national policy on renewable energy

19. The Secretary of State agrees with the Inspector's assessment of the proposal in respect of development plan policy at IR225-227. As indicated at paragraph 13 above, he agrees with the Inspector that there is no conflict with the aims of LP Policy EV/16. He also agrees that conflict with the development plan would be limited to LP policies EV/5 and EV/18 (IR225) and RSS policies 27 and 31 (IR226). The Secretary of State sees no significant conflict with RSS Policy 26 because, as the Inspector identifies, this policy implies a balancing exercise (IR226). However, the scheme would generate renewable energy that would make a significant contribution towards achieving the targets set out in RSS policy 40 (IR227). Like the Inspector, the Secretary of State considers that the appeal scheme would make an important contribution to reducing the current shortfall against the regional target (IR235).

20. The Secretary of State agrees with the Inspector that an overall balance in favour of the scheme renders the proposal compliant with RSS8, when read as a whole. For this reason the Secretary of State considers that the scheme accords with the development plan as a whole and agrees that the scheme also accords with PPS22 and the Energy White Paper (IR240).

21. The Secretary of State agrees with the Inspector's reasoning and conclusions at IR228-231 in respect of compliance with national planning policy in PPS22 and the support the proposal gains from the Energy White Paper and Stern Report.

Planning balance

22. For the reasons given at IR233-236, the Secretary of State agrees with the Inspector that the significant benefits of renewable energy generation in this case outweigh the limited harm to the local landscape and to the setting of the registered historic parkland, and the resultant policy conflict. He therefore agrees that the planning balance here falls in favour of granting planning permission (IR237).

Conditions

23. The Secretary of State has considered the proposed conditions and the Inspector's comments on these at IR238. He is satisfied that the conditions recommended in the Inspector's schedule are reasonable and necessary and meet the tests of Circular 11/95.

Overall Conclusions

24. The Secretary of State considers that there would the limited harm to the local landscape and to the setting of the registered historic parkland, both of which conflict with policy and weigh against the proposal, but that there are no other material considerations that substantially weigh against it. However, he considers that the significant benefits in terms of renewable energy generation outweigh the limited harms. He concludes that the proposal is in overall accordance with the development plan and complies with national policy in PPG15, PPG16 and PPS22. Overall, the Secretary of State concludes that the planning balance falls in favour of allowing the appeal and that there are no material considerations of sufficient weight which count against the proposal to determine the appeal other than in accordance with the development plan.

Formal decision

25. Accordingly, for the reasons given above, the Secretary of State agrees with the Inspector's recommendation. He hereby allows your client's appeal and grants planning permission for the construction and operation of a wind farm consisting of eleven 125 m turbines, control building, temporary construction compound, anemometer mast, vehicular access, accommodation works and tracks at land north-east of Swinford, Leicestershire in accordance with application number 08/00506/FUL dated 7 April 2008, subject to conditions set out at Annex B.

26. An applicant for any consent, agreement or approval required by a condition of this permission for agreement of reserved matters has a statutory right of appeal to the Secretary of State if consent, agreement or approval is refused or granted conditionally or if the Local Planning Authority fail to give notice of their decision within the prescribed period.

27. This letter does not convey any approval or consent which may be required under any enactment, bye-law, order or regulation other than section 57 of the Town and Country Planning Act 1990.

28. This letter serves as the Secretary of State's statement under regulation 21(2) of the Town and Country (Environmental Impact Assessment) (England and Wales) Regulations 1999.

Right to challenge the decision

29. A separate note is attached setting out the circumstances in which the validity of the Secretary of State's decision may be challenged by making an application to the High Court within six weeks from the date of this letter.

30. A copy of this letter has been sent to Harborough District Council and all parties who appeared at the inquiry.

Yours faithfully

Julian Pitt
Authorised by Secretary of State to sign in that behalf

Annex A

Post inquiry correspondence

14 August 2009	R D Waggin
20 September 2009	Darren Bassett
21 September 2009	Martin K Kilbane
1 November 2009	Mr G Wardell
8 November 2009	Dawn Money
16 November 2009	Dave Havergill

Annex B: Schedule of conditions relating to application 08/00506/FUL

1. The development hereby permitted shall be begun before the expiration of five years from the date of this permission. Written confirmation of the date of the first export of electricity to the grid from the wind farm hereby permitted shall be provided to the local planning authority within one month of the date of this taking place.

2. The planning permission hereby granted is for a period from the date of this decision until the date occurring 25 years after the date of the first export of electricity to the grid from the wind farm hereby permitted, when the use shall cease and the turbines, control building, temporary construction/decommissioning compound and anemometer mast shall be removed from the site in accordance with Condition 17.

3. Each turbine and its site track shall be provided in the position indicated on Figure 4.1 subject to a micro-siting allowance of 50m. Any variation of the indicated position on Figure 4.1, within the micro-siting allowance, shall only be permitted following prior written approval by the local planning authority.

4. No development hereby permitted shall commence until full details of the turbines including their colour, finish, air safety lighting and the warranted sound power level have been submitted to and approved in writing by the local planning authority. The development shall thereafter be carried out in accordance with the approved details.

5. Prior to the erection of any of the turbines hereby permitted, details of the control building, temporary construction compound and anemometer mast, shall be submitted to and approved in writing by the local planning authority. The development shall thereafter be carried out in accordance with the approved details.

6. No development shall commence until a scheme for the investigation and alleviation of electromagnetic interference, including to television reception, caused by the turbines hereby permitted, has been submitted to and approved in writing by the local planning authority. The approved mitigation measures shall be carried out in accordance with a timescale approved in writing by the local planning authority.

7. No development shall commence until a scheme for the investigation and alleviation of shadow flicker caused by the turbines hereby permitted, has been submitted to and approved in writing by the local planning authority. The approved mitigation measures shall be carried out in accordance with a timescale approved in writing by the local planning authority.

8. Prior to the commencement of any works a Construction Method Statement shall be submitted to and approved in writing by the local planning authority. This shall include details relating to:

(i) The control of noise and vibration emissions from construction activities including groundwork and the formation of infrastructure, along with arrangements to monitor noise emissions from the development site during the construction phase.

(ii) The control of dust including arrangements to monitor dust emissions from the development site during the construction phase.

(iii) Measures for controlling pollution/sedimentation and responding to any spillages/incidents during the construction phase.

(iv) Measures to control mud deposition offsite from vehicles leaving the site.

(v) The location and size of temporary parking, lay down and compound areas.

(vi) The control of surface water drainage from parking and hard-standing areas including the design and construction of oil interceptors (including during the operational phase).

(vii) The use of impervious bases and impervious bund walls for the storage of oils, fuels or chemicals on-site.

(viii) Replanting plans for turbine bases and crane operation areas subsequent to construction.

(ix) Details of the reinstatement of any areas of the site which may have been disturbed during construction.

(x) The means by which users of public rights of way would be protected during the construction period.

Development shall be carried out in compliance with the approved Construction Method Statement, unless otherwise approved in writing by the local planning authority in advance.

9. All construction and decommissioning works shall be carried out only between the hours of 07:00 to 19:00 Monday to Friday, 07:00 to 16:00 Saturdays and at no times on Sundays and Bank Holidays unless prior written approval has been obtained from the local planning authority. Notwithstanding the hours stated above, the local planning authority may approve in writing deliveries outside these hours on prior application from the developer.

10. No development shall take place until a habitat management plan, including long term ecological objectives, management regime and maintenance schedules has been submitted to and approved in writing by the local planning authority. The plan shall include for the provision of 300 m of new hedging together with the replacement of any hedgerows and trees lost as a result of the development. It shall also include provision for the management of existing ponds and the provision and maintenance of rough grassland. The approved habitat management plan shall be implemented within the first twelve months following the cessation of construction and shall be reviewed at five yearly intervals. Changes to the habitat management plan shall only be made with the prior approval in writing by the local planning authority. The measures included within the approved habitat management plan shall continue throughout the lifetime of the planning permission hereby granted.

11. No development shall take place within the application area until the applicant has secured the implementation of a programme of archaeological work, comprising a staged programme of archaeological mitigation which shall include, as necessary, provision for exploratory trenching, preservation in situ of archaeological remains

and/or appropriate excavation and recording. This work shall be undertaken in accordance with a written scheme of investigation which has been submitted to and approved in writing by the local planning authority.

12. The temporary access to facilitate delivery of the turbine components shall be implemented in accordance with Drawing No. 22991 – R01 Rev B, unless otherwise approved in writing by the local planning authority in advance. The development shall only proceed in accordance with the approved details.

13. Before the development hereby permitted commences, a Transport Management Plan shall be submitted to and approved in writing by the local planning authority. The Transport Management Plan shall include details of:

(i) The management and routing of construction traffic.
(ii) Delivery times.
(iii) Internal compound and wheel washing arrangements.
(iv) The timing of and means by which the temporary access and road shown hatched grey on drawing number 22991 – R01 Rev B will be stopped up. The sub-base of both the access and the road may be retained during the life of the permission and both the access and the road may be temporarily reopened and used with the prior written approval of the local planning authority.

The Transport Management Plan shall be implemented for the whole of the construction period.

14. Notwithstanding the details submitted, prior to commencement of the development hereby permitted, details of the vehicular access to the site shall be submitted to and approved in writing by the local planning authority. This shall include details about the siting, geometry, visibility splays, surfacing and any gates. Vehicular access to the site shall be implemented in accordance with the approved details prior to commencement of development.

15. Prior to commencement of development, details of parking facilities for maintenance, servicing or repair vehicles for the 25 year duration of the facility hereby permitted shall be submitted to and approved in writing by the local planning authority. These facilities shall be fully implemented prior to the first use of the turbines and retained for the duration of this planning permission.

16. Prior to the commencement of development, details of post-construction monitoring of bird and bat strike to be conducted shall be submitted to and approved in writing by the local planning authority. The aforementioned monitoring shall then be carried out in accordance with the approved details, and the results shall be submitted to the local planning authority in accordance with an approved timescale.

17. Not less than one year prior to the expiry of this planning permission a Decommissioning Method Statement shall be submitted for the written approval of the local planning authority. This shall include details of all site decommissioning works, including how wind turbines and ancillary equipment would be dismantled and removed from the site, the depth to which wind turbine foundations shall be removed below ground level, along with details of site restoration and a timetable of works. The Decommissioning Method Statement shall be carried out as approved.

18. Prior to the commencement of development, details shall be provided to the local planning authority of the bond or other financial provision to be put in place to cover all decommissioning and site restoration costs on the expiry of this planning permission. No work shall commence on the site until documentary evidence that the proposed bond or other financial provision is in place has been provided and written confirmation has been given by the local planning authority that the proposed bond or other financial provision is satisfactory. The applicant, or their agent or successors in title shall ensure that the approved bond or other financial provision is maintained throughout the duration of this consent and the bond or other financial provision will be subject to a five yearly review from the commencement of the development, to be conducted by a competent independent professional approved in writing by the local planning authority who has relevant experience within the wind energy sector, and provided to the applicant, or their agent or successors in title, the landowner(s) and the local planning authority.

19. The rating level of noise emissions from the combined effects of the wind turbines (including the application of any tonal penalty) when calculated in accordance with the attached Guidance Notes 1-4 shall not exceed the noise values set out in Tables 1 & 2 within the Guidance Notes. Noise limits for properties within 2 km of a wind turbine, which lawfully exist or have planning permission for construction at the date of this planning permission, but are not listed in these tables, shall be those of the nearest location listed in Tables 1 & 2.

20. Within 28 days from the receipt of a written request from the local planning authority following a complaint to it, the wind farm operator shall, at its own expense, employ an independent consultant approved in writing by the local planning authority to assess the level of noise emissions from the wind farm at the complainants property following the procedure described in the attached Guidance Notes. Details of the assessment and its results as to whether a breach of the noise limits in Condition 19 has been established shall be reported to the local planning authority as soon as the assessment is completed.

21. Upon notification in writing from the local planning authority of an established breach of the noise limits in Condition 19 the wind farm operator shall, within 28 days propose a scheme to the local planning authority to mitigate the breach to prevent its future occurrence, including a timetable for its implementation. Following the written approval of the scheme by the local planning authority it shall be activated forthwith and thereafter retained.

22. Wind speed, wind direction and power generation data for each wind turbine shall be continuously logged and provided to the local planning authority at its request and in accordance with the attached Guidance Notes within 28 days of such a request. Such data shall be retained for a period of 5 years.

23. Prior to the commencement of development, details of a nominated representative for the development to act as a point of contact for local residents (in connection with conditions 19 - 24) together with the arrangements for notifying and approving any subsequent change in the nominated representative shall be submitted to and approved in writing by the local planning authority. The nominated representative shall have responsibility for dealing with any noise complaints made

during construction, operation and decommissioning of the wind farm and liaison with the local planning authority.

24. On the written request of the local planning authority, following a complaint to it considered by the local planning authority to relate to regular fluctuation in the turbine noise level (amplitude modulation), the wind farm operator shall at its expense employ an independent consultant approved in writing by the local planning authority to undertake the additional assessment outlined in Guidance Note 5 to ascertain whether amplitude modulation is a contributor to the noise complaint as defined in Guidance Note 5. If the said assessment confirms amplitude modulation to be a contributor as defined in Guidance Note 5, the local planning authority shall request that within 28 days of the completion of the noise recordings referred to in Guidance Note 5, the developer shall submit a scheme to mitigate such effect. Following the written approval of the scheme and the timescale for its implementation by the local planning authority the scheme shall be activated forthwith and thereafter retained.

25. No lighting, symbols, signs or logos or other lettering, other than those required for health and safety, traffic management or aviation safety, shall be displayed on any part of the turbines or any other building or structures without the prior written approval of the local planning authority.

26. All cables within the development site between turbines and from the turbines to the substation shall be set underground.

27. The number of turbines shall not exceed 11. The blade tip height of turbines shall not exceed 125 m in height. The hub height of the turbines shall not exceed 84 m and shall not be less than 76 m.

28. All turbine blades shall rotate in the same direction.

29. If any of the wind turbines hereby permitted ceases to operate for a continuous period of 6 months then, unless otherwise approved in writing by the local planning authority, a scheme for the decommissioning and removal of the wind turbine and any other ancillary equipment and structures relating solely to that turbine, shall be submitted to and approved in writing by the local planning authority within 3 months of the end of the 6 month cessation period. The scheme shall include details for the restoration of the site. The scheme shall be implemented and site restoration completed within 12 months of the date of its approval by the local planning authority.

30. No development shall commence on site until the Ministry of Defence has been provided with the following information:

(i) The date of commencement of the construction.
(ii) The height above ground level and the location of the tallest structure.
(iii) The maximum extension height of any construction equipment.
(iv) Details of site lighting.

GUIDANCE NOTES RELATING TO NOISE CONDITIONS

These notes are to be read with the planning conditions covering operational noise. They further explain these conditions and specify the methods to be deployed in the assessment of any complaints about noise emissions from the wind farm.

NOTE 1

(a) Values of the $L_{A90,10min}$ noise statistic should be measured at the complainant's property, using a sound level meter of IEC 651 Type 1, or BS EN 61672 Class 1, standard (or the equivalent relevant UK adopted standard in force at the time of the measurements) set to measure using a fast time weighted response. This should be calibrated in accordance with the procedure specified in BS 4142: 1997 (or the equivalent relevant UK adopted standard in force at the time of the measurements).

(b) The microphone should be mounted at 1.2 - 1.5 m above ground level, fitted with a two layer windshield or suitable equivalent approved in writing by the local planning authority, and placed outside the complainant's dwelling. Measurements should be made in "free-field" conditions, so that the microphone should be placed at a location approved in writing by the local planning authority and at least 3.5 m away from the building facade or any reflecting surface except the ground.

(c) The $L_{A90,10min}$ measurements should be synchronised with measurements of the 10-minute arithmetic average wind speed and with operational data from the turbine control systems of the wind farm.

(d) The wind farm operator shall continuously log arithmetic mean wind speed and arithmetic mean wind direction data in 10 minute periods from the on-site anemometry mast to enable compliance with the conditions to be evaluated. Such data shall be measured at a height of 10 metres, corrected for the difference between the mast location used for the baseline measurements based on a correlation exercise approved in writing by the local planning authority, and at hub height.

NOTE 2

(a) The noise measurements should be made so as to provide not less than 100 valid data points as defined in Note 2 paragraph (b). Such measurements should provide valid data points for the range of wind speeds, wind directions, times of day and power generation approved in writing by the local planning authority. In specifying such conditions the local planning authority shall have regard to those conditions which were most likely to have prevailed during times when the complainant alleges there was disturbance due to noise. At its request the wind farm operator shall provide all of the data collected under Conditions 20 and 22 to the local planning authority.

(b) Valid data points are those that remain after all periods during rainfall have been excluded.

(c) A least squares, "best fit" polynomial curve of a maximum 2nd order should be fitted to the data points and define the rating level at each integer wind speed.

NOTE 3

Where, in the opinion of the local planning authority noise emissions at the location or locations where assessment measurements are being undertaken contain a tonal component, the following rating procedure should be used.

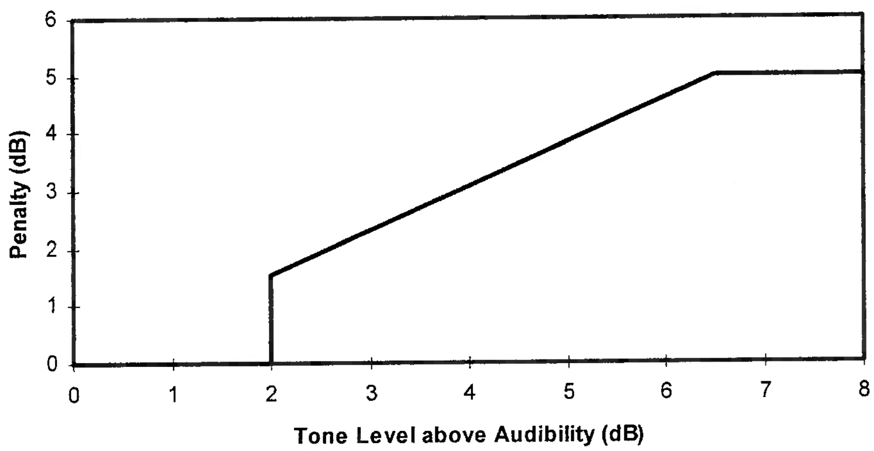
(a) For each 10-minute interval for which $L_{A90,10min}$ data have been obtained as provided for in Note 1 a tonal assessment is performed on noise emissions during 2 minutes of each 10 minute period. The 2 minute periods should be regularly spaced at 10 minute intervals provided that uninterrupted clean data are available. Where clean data are not available, the first available uninterrupted clean 2 minute period out of the affected overall 10 minute period shall be selected. Any such deviations from standard procedure shall be reported.

(b) For each of the 2-minute samples the margin above or below the audibility criterion of the tone level difference, Delta L_{tm}, should be calculated by comparison with the audibility criterion given in Section 2.1 on pages 104-109 of ETSU-R-97.

(c) The margin above audibility is plotted against wind speed for each of the 2-minute samples. For samples for which the tones were below the audibility criterion or no tone was identified, substitute a value of zero audibility.

(d) A linear regression should then be performed to establish the margin above audibility at the assessed wind speed for each integer wind speed. If there is no apparent trend with wind speed then a simple arithmetic average shall be used.

(e) The tonal penalty is derived from the margin above audibility of the tone according to the figure below. The rating level at each wind speed is the arithmetic sum of the wind farm noise level, as determined from the best fit curve described in Note 2, and the penalty for tonal noise.



NOTE 4

If the rating level is above the limit set out in the conditions, measurements of the influence of background noise should be made to determine whether or not there is a breach of condition. This may be achieved by repeating the steps in Note 2, with the wind farm switched off, and determining the background noise at the assessed wind speed, L_3. The wind farm noise at this speed, L_1, is then calculated as follows where L_2 is the measured level with turbines running but without the addition of any tonal penalty:

$$L_1 = 10\log\left[10^{L_2/10} - 10^{L_3/10}\right]$$

The rating level is re-calculated by adding the tonal penalty (if any) to the derived wind farm noise L_1. If the rating level lies at or below the values set out in the conditions then no further action is necessary. If the rating level exceeds the values set out in the conditions then the development fails to comply with the conditions.

NOTE 5

Amplitude Modulation (AM) is the regular variation of the broadband aerodynamic noise caused by the passage of the blades through the air at the rate at which the blades pass the turbine tower. ETSU-R-97, "The Assessment and Rating of Noise from Wind Turbines", assumes that a certain level of AM (blade swish) is intrinsic to the noise emitted by the wind turbine and may cause regular peak to trough variation in the noise of around 3 dB and up to 6 dB in some circumstances. The noise assessment and rating framework recommended in ETSU-R-97 fully takes into account the presence of this intrinsic level of AM when setting acceptable noise limits for wind farms.

Where the local planning authority considers the level of AM may be at a level exceeding that envisaged by ETSU-R-97, they may require the operator to appoint an approved independent consultant to carry out an assessment of this feature under Condition 24. In such circumstances, the complainant(s) shall be provided with a switchable noise recording system by the independent consultant and shall initiate recordings of the turbine noise at times and locations when significant amplitude modulation is considered to occur. Such recordings shall allow for analysis of the noise in one-third octave bands from 50Hz to 10kHz at intervals of 125 milliseconds. The effects of amplitude modulation are normally associated with impacts experienced inside properties or at locations close to the property, such as patio or courtyard areas. For this reason the assessment of the effect necessarily differs from the free-field assessment methodologies applied elsewhere in these Guidance Notes.

If, over a period of 6 months, commencing at a time of the first occasion at which the local planning authority records an amplitude modulation event, the complainant fails to record 5 occurrences of significant amplitude modulation, in separate 24 hour periods, then its existence as a contributor to the noise complaint shall be excluded. If, however, the independent consultant, on analysis of the noise recordings, identifies that amplitude modulation is a significant contributor to the noise complaint then the local planning authority shall be informed in writing.

TABLES OF NOISE LIMITS

Table 1: Between 23:00 and 07:00 hours (Noise Level in dB $L_{A90,\ 10min}$):

	Wind speed at 10 m height (m/s) at on-site anemometry mast									
Location	3	4	5	6	7	8	9	10	11	≥12
Botney Lodge	43	43	43	43	45	47	50	53	56	59
Top Barn Farm	43	43	43	43	45	47	50	53	56	59
Hill Top Farm	43	43	43	43	45	47	50	53	56	59
Hill Farm	49	49	49	50	51	53	54	56	59	61
Shawell Lodge Farm	49	49	49	50	51	53	54	56	59	61
Melbourne Lodge	43	44	45	47	48	50	52	54	56	58
Poplar's Farm	43	44	45	47	48	50	52	54	56	58
Thornhill Stud	43	44	45	47	48	50	52	54	56	58
London Lodge	43	44	45	47	48	50	52	54	56	58
Orchard Farm	43	44	45	47	48	50	52	54	56	58
Penfoland	47	48	50	51	52	52	53	54	55	56
Denyer's Barn	47	48	50	51	52	52	53	54	55	56
Swinford Lodge	47	48	50	51	52	52	53	54	55	56
Kilworth Road	47	48	50	51	52	52	53	54	55	56
Un-Named Property*	47	48	50	51	52	52	53	54	55	56
Warren Farm	44	45	46	48	49	51	53	56	58	61
Lutterworth Road	44	45	46	48	49	51	53	56	58	61
Misterton Grange	44	45	46	48	49	51	53	56	58	61

Table 2: At all other times (Noise Level in dB $L_{A90,\ 10min}$):

	Wind speed at 10 m height (m/s) at on-site anemometry mast									
Location	3	4	5	6	7	8	9	10	11	≥12
Botney Lodge	40	41	43	45	47	50	52	55	57	60
Top Barn Farm	40	41	43	45	47	50	52	55	57	60
Hill Top Farm	40	41	43	45	47	50	52	55	57	60
Hill Farm	56	57	58	59	60	61	62	64	65	67
Shawell Lodge Farm	56	57	58	59	60	61	62	64	65	67
Melbourne Lodge	47	47	48	50	51	53	54	56	58	60
Poplar's Farm	47	47	48	50	51	53	54	56	58	60
Thornhill Stud	47	47	48	50	51	53	54	56	58	60
London Lodge	47	47	48	50	51	53	54	56	58	60
Orchard Farm	47	47	48	50	51	53	54	56	58	60
Penfoland	51	51	52	53	54	55	56	57	58	59
Denyer's Barn	51	51	52	53	54	55	56	57	58	59
Swinford Lodge	51	51	52	53	54	55	56	57	58	59
Kilworth Road	51	51	52	53	54	55	56	57	58	59
Un-Named Property*	51	51	52	53	54	55	56	57	58	59
Warren Farm	49	50	51	52	53	55	56	58	60	62
Lutterworth Road	49	50	51	52	53	55	56	58	60	62
Misterton Grange	49	50	51	52	53	55	56	58	60	62

* Unoccupied un-named property west of Lutterworth Road

Department for Communities and Local Government

Ms Kee Evans
Eversheds LLP
1 Callaghan Square
Cardiff
CF10 5BT

Our Refs:
Appeal A: APP/X1545/A/12/2174982
Appeal B: APP/X1545/A/12/2179484
Appeal C: APP/X1545/A/12/2179225

13 February 2014

Dear Madam

TOWN AND COUNTRY PLANNING ACT 1990 (SECTION 78)
APPEALS BY RES UK & IRELAND LTD:

APPEAL A - TURNCOLE FARM, THE MARSHES, DENGIE, SOUTHMINSTER - APPLICATION REF: FUL/MAL/10/01070

APPEAL B - LOWER BURNHAM ROAD AND FAMBRIDGE ROAD, NEAR COLD NORTON, ESSEX - APPLICATION REF: FUL/MAL/12/00119

APPEAL C - TURNCOLE FARM, THE MARSHES, DENGIE, SOUTHMINSTER - APPLICATION REF: FUL/MAL/11/00879

1. I am directed by the Secretary of State to say that consideration has been given to the report of the Inspector, John Woolcock BNatRes(Hons) MURP DipLaw MPIA MRTPI, who held a public local inquiry between 23 April and 8 May 2013 into your appeals against a decision of Maldon District Council to refuse planning permission for:

   Appeal A: Wind Farm Development consisting of seven three-bladed, horizontal-axis wind turbines, each up to 126.5 m maximum height to blade tip, with associated electricity transformers, underground cabling, access tracks, road widening works, crane hard-standings, control building, substation compound, communications mast and anemometry mast for a period of twenty-five years. Also temporary works including a construction compound, laydown area, rotor assembly pads, turning heads, welfare facilities and four guyed anemometry masts, in accordance with application reference FUL/MAL/10/01070, dated 14 February 2011.

   Appeal B: Permanent road widening works for the purpose of facilitating access for abnormal load deliveries to the proposed wind farm at Turncole Farm. The new highway created will be fenced or similar to allow access to the abnormal

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loads only and not all traffic. The works will take place at the two road junctions between Lower Burnham Road and Fambridge Road near Cold Norton. The works will result in a change of use from residential and agricultural land to form new highway. Works in accordance with application reference FUL/MAL/12/00119, dated 8 February 2012.

Appeal C: Permanent road widening works and replacement of Twizzlefoot bridge for the purpose of facilitating access for abnormal load deliveries to the proposed wind farm at Turncole Farm. The works will result in a change of use from agricultural land to form new highway. Works in accordance with FUL/MAL/11/00879, dated 5 October 2011.

2. On 5 June 2013, the appeals were recovered for the Secretary of State's determination, in pursuance of section 79 of, and paragraph 3 to Schedule 6 to, the Town and Country Planning Act 1990, because they relate to proposals of major significance for the delivery of the Government's climate change programme and energy policies.

Inspector's recommendation and summary of the decision

3. The Inspector recommended that all the appeals be allowed and planning permission be granted subject to conditions. For the reasons given below, the Secretary of State agrees with the Inspector's conclusions and agrees with his recommendation. A copy of the Inspector's report (IR) is enclosed. All references to paragraph numbers, unless otherwise stated, are to that report.

Procedural matters

4. In reaching this position, the Secretary of State has taken into account the Environmental Statement (ES) and Supplemental Environmental Information (SEI) which was submitted under the Town and Country Planning (Environmental Impact Assessment) (England and Wales) Regulations 1999 and the Inspector's comments on the ES and SEI at IR2 and 119. The Secretary of State considers that the ES and SEI comply with the above regulations and that sufficient information has been provided for him to assess the environmental impact of the proposals. Given that the appeals are linked, he agrees with the Inspector that they should be either all allowed or all dismissed (IR119).

5. Following the close of the inquiry, on 9 January 2014 the Secretary of State wrote to the main parties to invite them to consider whether any amendments would be appropriate to the noise condition that was considered at the inquiry. On 3 February the Secretary of State received a noise condition agreed upon by the appellant and the Council, and a representation from the Rule 6 party. These representations were circulated to the parties for final comment.

6. A list of all the responses received from parties is set out at Annex A to this letter. The Secretary of State has taken account of all these responses in his consideration of the appeals before him. As the responses were circulated to the main inquiry parties, he does not consider it necessary to summarise the responses here or attach them to this letter. Copies of the correspondence can be obtained upon request to the address at the bottom of the first page of this letter.

Matters arising after the close of the inquiry

7. Following the close of the inquiry, The Department of Communities and Local Government (DCLG) published the 'Planning Practice Guidance for Renewable and Low Carbon Energy' (PPGRLCE) in July 2013, and cancelled 'Planning for Renewable Energy: A Companion Guide to Planning Policy Statement 22'. The Planning Inspectorate invited comments on the PPCRLCE (IR6). In reaching his decision on these appeals, the Secretary of State has taken into account the PPGRLCE and the parties' responses to this.

8. In December 2013, Renewable UK published new research and a proposed planning condition covering the regulation of Other Amplitude Modulation, with accompanying guidance notes. However this has not yet been reflected in an update to the current good practice guidance that accompanies ETSU-R-97 and has not been endorsed by Government.

Policy considerations

9. In deciding the appeals, the Secretary of State has had regard to section 38(6) of the Planning and Compulsory Purchase Act 2004 which requires that proposals be determined in accordance with the development plan unless material considerations indicate otherwise.

10. In this case, following the revocation of the Regional Spatial Strategy for the East of England, the adopted development plan for the area comprises only the saved policies of the Maldon Local Plan 2005 (IR7). The Secretary of State considers that the local plan policies listed in Annex 1 of the IR are the most relevant policies to these appeals.

11. The Secretary of State notes that the Council is reviewing its Local Plan, but as this is still at consultation draft stage and is liable to change, he attributes it little weight.

12. Other material considerations which the Secretary of State has taken into account include the National Planning Policy Framework (the Framework); the National Policy Statements (NPS) for Energy (EN-1) and Renewable Energy (EN-3); the Community Infrastructure Levy (CIL) Regulations 2010 as amended; and Circular 11/95: The Use of Conditions in Planning Permissions. The Secretary of State has also taken into account Ministerial Written Statements on renewable energy published in June 2013 by the Secretary of State for Energy and Climate Change and by the Secretary of State for Communities and Local Government. He has not taken into account Planning for Renewable Energy: A Companion Guide to PPS22, as this was cancelled by the PPGRLCE.

13. The Secretary of State has had regard to the fact that on 28 August 2013 Government opened a new national planning practice guidance web-based resource. However, given that the guidance has not yet been finalised, he has attributed it limited weight.

Main issues

Renewable energy benefits

14. The Secretary of State agrees with the Inspector's assessment of the renewable energy benefits of the scheme at IR196-198. He agrees that it would make a

significant contribution to meeting national targets and reducing greenhouse gas emissions, and that this consideration weighs heavily in favour of the proposal.

Landscape character and appearance

15. The Secretary of State agrees with the Inspector's overall assessment and reasoning in regard to landscape and visual impacts at IR121-145. He agrees that the scheme duration of 25 years would be a substantial period for those who would have to endure any adverse effects and that the reversibility of the scheme should not be an influential factor in determining these appeals (IR127). He notes that the Inspector considers that the impact of the proposal on landscape character, when taken cumulatively with the previously permitted Middlewick wind farm, would be of moderate to minor significance (IR128-134). Additionally, the proposal would have an adverse effect on visual amenity, both by itself and cumulatively, of major/moderate significance from some vantage points, but more generally of moderate significance, reducing to minor or negligible with distance (IR135-145). Like the Inspector, the Secretary of State considers that the overall adverse effect on the landscape character and visual amenity of the area would be of moderate significance, and that this consideration weighs against the proposal and brings it into conflict with the aims of several Maldon Local Plan Policies (IR145).

Living conditions

16. The Secretary of State has given careful consideration to the Inspector's assessment of the impacts on the living conditions of local residents at IR146-176. Regarding outlook, he agrees with the Inspector that the proposed Turncole turbines, either by themselves or cumulatively with other existing or proposed turbines, would not result in an overwhelming and oppressive impact on the outlook from nearby dwellings or their associated amenity space that would result in unsatisfactory living conditions. Likewise, he agrees that the limited removal of roadside vegetation along the route proposed for abnormal indivisible loads would not harm the residential amenity of nearby occupiers (IR161). Consequently he agrees with the Inspector's judgement that the proposal would not unacceptably affect amenities and the use of land and buildings which ought to be protected in the public interest (IR162).

17. Regarding noise and disturbance, the Secretary of State agrees with the Inspector that a lower fixed day-time cumulative limit of 40 dB would properly accord with the provisions set out in ETSU-R-97 (IR169). He agrees that wind turbine noise and some disturbance during construction and decommissioning would, to some extent, detract from the tranquillity of the area, but that subject to the suggested condition the scheme could operate within acceptable ETSU-R-97 limits (IR170-173).

18. Regarding the issue of Amplitude Modulation (AM), the Secretary of State has considered the representations made in response to his request for further information and the suggested additional conditions put forward by the appellant and SIEGE. He is persuaded that there is a need for an additional condition to protect the living conditions of nearby residents from unacceptable AM. He agrees with the view expressed in the appellant's representation of 10 February that, given the wider debate that is presently taking place concerning the most appropriate form that a fit for purpose AM noise condition should take, it would not be appropriate at this stage to choose between the condition put forward in the appellant's earlier response of 3 February and the alternative form of an AM noise

condition advanced in a technical report provided by SIEGE with its response of 3 February and endorsed in the Council's representation of 10 February (an 'updated' Den Brook condition). The Secretary of State agrees with the noise condition proposed in the applicant's representation of 10 February and considers that it is the most appropriate in current circumstances, because this condition will allow a properly endorsed AM noise assessment and rating methodology to be appropriately incorporated into an AM scheme to be agreed by the Council, taking account of any further advice forthcoming from the UK Institute of Acoustics and/or Government prior to commencement of operation of the development. For these reasons the Secretary of State has added Condition 25 in Annex B to this letter.

19. Overall, with the addition of Condition 25, the Secretary of State agrees with the Inspector that the evidence indicates that the combined effects of the proposed turbines on the outlook of nearby occupiers, along with operational noise in compliance with ETSU-R-97 limits, likely shadow flicker, health fears, and any disturbance or disruption during construction, operation or decommissioning, would not have a significant adverse effect on the living conditions of local residents. As a result, there would be no conflict with those parts of relevant Local Plan policies that aim to protect the amenity of neighbouring properties and their occupiers (IR176).

Heritage assets

20. In determining these appeals, the Secretary of State has had regard to its potential impacts on listed buildings, with particular regard to the desirability of preserving those buildings or their settings, as required by section 66(1) of the Planning (Listed Buildings and Conservation Areas) Act 1990. He has given careful consideration to the Inspector's assessment of impacts on listed buildings and archaeological features at IR177-182. The Secretary of State agrees that the evidence indicates that the proposed turbines would not significantly affect views that are important to the setting of heritage assets and that there would be no conflict with relevant Local Plan policies on landscape features and buildings of historic importance. The less than substantial harm to heritage assets that would result from the solus and cumulative effects of the proposed development would be a matter to be weighed against the benefits of the scheme in accordance with the provisions of the Framework (IR183).

Other Matters

21. The Secretary of State agrees with the Inspector's reasoning and conclusions on air safety at IR184-186, nature conservation and biodiversity at IR187-189, highway safety at IR190 and other considerations at IR191-195, including an alternative delivery route for abnormal loads.

Conditions

22. The Secretary of State has considered the Schedule of Conditions at the end of the Inspector's report and national policy as set out in Circular 11/95 and the Framework. He is satisfied that the proposed conditions, and also Condition 25 that he has added for the reasons above, are reasonable and necessary and would meet the tests of Circular 11/95 and paragraph 206 of the Framework.

Planning balance and overall conclusions

23. The Secretary of State has given careful consideration to the Inspector's balancing exercise and consideration of policy matters at IR199-204, and his overall conclusions at IR212-214. He agrees with the Inspector that the benefits of renewable energy should be given significant weight. The Secretary of State also agrees that the proposed wind farm would have an adverse effect on landscape character and visual amenity of overall moderate significance, but that the adverse effects on the living conditions of those residing in the area would not be significant. He also agrees that there would be some harm to local amenity, but that this would largely be attributable to the effects on the local landscape and visual amenity of the area, which should not be double-counted. The proposal would have only a minor adverse effect on cultural heritage. Subject to the imposition of appropriate conditions the wind farm would not unduly affect air safety, biodiversity or highway safety (IR199-200).

24. The proposal would conflict with saved Local Plan policies on landscape and visual impact. However the Framework provides that due weight should be given to relevant policies in existing plans according to their degree of consistency with the Framework (IR201). In this case, the Local Plan does not include criteria-based policies to enable the assessment of renewable energy schemes. Furthermore, whilst the Special Landscape Area designation in which the proposal is situated is indicative of a valued landscape, the Plan does not set criteria-based policies against which proposals for any development on or affecting such landscape areas would be judged. This is not consistent with the Framework (IR203). Having had particular regard to paragraph 98 of the Framework, the Secretary of State considers that the landscape and visual amenity impacts of the proposal would be acceptable in this case, as would other impacts subject to the relevant conditions. He agrees with the Inspector that the planning balance falls in favour of the proposal and that it would be sustainable development to which the presumption in favour set out in Framework would apply (IR204).

Formal decision

25. Accordingly, for the reasons given above, the Secretary of State agrees with the Inspector's overall conclusions at IR212-213 and his recommendation at IR215. He hereby grants planning permission for the construction and operation of a wind farm and associated highway works, as described in paragraph 1 above, for an operation period of 25 years in accordance with application references FUL/MAL/10/01070, FUL/MAL/12/00119 and FUL/MAL/11/00879, dated 14 February 2011, 8 February 2012 and 5 October 2011, respectively, subject to the conditions at Annex B of this letter.

26. An applicant for any consent, agreement or approval required by a condition of this permission has a statutory right of appeal to the Secretary of State if consent, agreement or approval is refused or granted conditionally or if the local planning authority fails to give notice of their decision within the prescribed period.

27. This letter does not convey any approval or consent which may be required under any enactment, bye-law, order or regulation other than that required under section 57 of the Town and Country Planning Act 1990.

28. This letter serves as the Secretary of State's statement under Regulation 21(2) of the Town and Country Planning (Environmental Impact Assessment) (England and Wales) Regulations 1999.

Right to challenge the decision

29. A separate note is attached setting out the circumstances in which the validity of the Secretary of State's decision may be challenged by making an application to the High Court within six weeks from the date of this letter.

30. A copy of this letter has been sent to Maldon District Council. A notification letter has been sent to all other parties who asked to be informed of the decision.

Yours faithfully

Julian Pitt

Authorised by Secretary of State to sign in that behalf

ANNEX A

Post-inquiry representations

In response to the Secretary of State's letter of 9 January 2014:

Maldon District Council (3 February 2014)
RES UK & Ireland Limited (3 February 2014)
Southminster Inhabitants Environmental Group Enterprise (SIEGE) (3 February 2014)

In response to the Secretary of State's emails of 3 and 4 February 2014:

Maldon District Council (10 February 2014)
RES UK & Ireland Limited (10 February 2014)
SIEGE (10 February 2014)

ANNEX B: CONDITIONS

Application Reference FUL/MAL/10/01070 / Appeal A: APP/X1545/A/12/2174982

1) The development hereby permitted shall begin not later than five years from the date of this decision.

2) This permission shall expire 25 years from the date when electrical power is first exported from any of the wind turbines hereby permitted to the electricity grid network, excluding electricity exported during initial testing and commissioning ("First Export Date"). Written confirmation of the First Export Date shall be provided to the local planning authority no later than one calendar month after the event.

3) The development hereby permitted shall be carried out in accordance with the following approved plans: Planning Application Boundary (Site Location Plan) Drawing No.02340D2908-05, Turbine Layout with Micro-siting Drawing No.02340D2107-05 and Infrastructure Layout Drawing No.02340D1001-14.

4) If any wind turbine fails for a continuous period of 12 months to supply electricity to the local electricity grid network, then, unless otherwise approved in writing by the local planning authority that wind turbine and ancillary development solely related to it shall be taken down and removed from the site and the land shall be reinstated in accordance with a reinstatement scheme approved in writing by the local planning authority (which shall include a timetable for the removal of the turbine(s) and the reinstatement of the land). The developer shall submit the reinstatement scheme to the local planning authority not later than 28 days after the expiry of the twelve month period provided for in this condition, and the scheme shall be implemented as approved.

5) No later than twelve months before the expiry of this permission a scheme for the decommissioning and the restoration of the site shall be submitted to the local planning authority for approval in writing. The scheme shall make provision for the removal of the wind turbines and their associated ancillary equipment to a depth up to one metre below ground and the reinstatement of the site. The scheme shall include proposals for the management and timing of the works, measures to be taken to safeguard and where possible enhance wildlife habitats and a traffic management plan and shall be implemented as approved.

6) No development shall commence until a Construction Method Statement has been submitted to and approved in writing by the local planning authority. The construction of the development shall only be carried out in accordance with the approved Construction Method Statement, unless otherwise approved in writing by the local planning authority. The Construction Method Statement shall address the following matters:
   (a) A Site Environmental Management Plan to include details of measures to be taken during the construction period to protect wildlife, habitats and hydrology; an ecological survey; an investigation and monitoring scheme to oversee and direct construction works; and details of soil handling, storage and restoration.
   (b) Details of the timing of works and methods of working for cable trenches and foundation works.
   (c) Details of the timing of works and construction of the substation/control buildings and anemometry masts.

(d) Dust management.
(e) Pollution control: protection of water courses and ground water and soils, bunding of fuel storage areas, sewage disposal.
(f) Disposal of surplus materials.
(g) Construction noise management plan including identification of access routes, locations of materials lay-down areas, details of equipment to be employed, operations to be carried out, mitigation measures and a scheme for the monitoring of noise.
(h) Details of a site evacuation/flood management plan.
(i) Temporary site illumination.
(j) The construction of the access into the site and the creation and maintenance of visibility splays.
(k) Wheel cleaning facilities.
(l) Arrangements for keeping the site entrance and adjacent public road clean.
(m) Post-construction restoration and reinstatement of the working areas.

The approved Construction Method Statement shall be implemented and maintained for the duration of the construction works.

7) No development shall commence until a scheme providing for works in the public highway (reflecting the works shown on Figures 3.1 and 3.2 of submitted Supplementary Environmental Information) to enable abnormal indivisible loads (AIL) to access the site has been submitted to and approved in writing by the local planning authority. The scheme shall be implemented as approved and shall:
(a) Make provision to ensure that the use of the improvement works at the junction of Marsh Road with Church Road/Southminster Road Burnham-on-Crouch is restricted to these AIL only.
(b) Include an arboricultural method statement which shall address management and safeguarding of all trees along the AIL route.

8) No development shall commence until a Construction Traffic Management Plan has been submitted to and approved in writing by the local planning authority. The plan, which shall be implemented as approved, shall apply to all construction traffic and shall include, but shall not be limited to:
(a) A pre and post construction road survey, and a programme and methodology for any repairs as a consequence of any damage caused by construction traffic following the completion of construction.
(b) Provisions for the routeing of traffic to and from the site.
(c) Proposal for the timing of traffic movements.
(d) Proposal for the management of traffic movements at junctions with, and pedestrian crossings of, the public highway.
(e) Provisions of signs warning of construction traffic.
(f) The removal and replacement of street furniture, road verges, or other items within the public.
(g) Arrangements to ensure that construction traffic does not use the junction of Marsh Road with Church/Southminster Road Burnham on Crouch when children are scheduled to arrive at or leave Ormiston Academy or St. Mary's Primary school.

9) No AIL movements shall take place until all works have been completed in accordance with the permissions granted pursuant to Appeal References APP/X1545/A/12/2179484 and APP/X1545/A/12/2179225.

10) The hours of operation of the construction phase of the development and any traffic movements to or from the site associated with the construction of the development hereby permitted shall be limited to 0700 hours to 1900 hours on Mondays to Saturdays. No work shall take place on Sundays or Bank Holidays, except for any works previously approved in writing by the local planning authority. Construction works so approved shall not be audible from the boundary of any dwelling. Any emergency works carried out outside the hours provided for in this condition shall be notified in writing to the local planning authority within seven working days of occurrence.

11) Notwithstanding the provisions of Condition 10, delivery of abnormal indivisible loads may take place outside the hours specified subject to not less than 24 hours prior notice of such traffic movements being given to the local planning authority.

12) All cabling on the site between the wind turbines and the site sub-station shall be installed underground.

13) The turbines shall have a semi matt finish and a pale grey colour. Prior to the erection of any turbine its exact finish and colour along with details of the dimensions, finish and colour of any external transformer units and the proposed meteorological and communications masts shall be submitted to and approved in writing by the local planning authority. No name, sign, symbol or logo shall be displayed on any external surfaces of the turbines or any external transformer units or the masts other than those required to meet statutory requirements. The development shall be carried out as approved and thereafter be retained in accordance with the approved details.

14) The height of each of the wind turbines shall not exceed 126.5 metres to the tip of the blades when the turbine is in the vertical position. The hub height of the wind turbines shall be between 77 metres and 87 metres. In each case the height shall be as measured from natural ground conditions immediately adjacent to the turbine base.

The wind turbines shall be erected at the following coordinates:

Turbine ID	X	Y
T1	597864	197734
T2	598203	197889
T3	598408	197589
T4	598756	197686
T5	599047	197452
T6	599442	197280
T7	599420	197663

Notwithstanding the locations of the turbines and other infrastructure shown on Figure 4.2 of the Environmental Statement the turbines may be located within the micro-siting areas shown on Figure 4.1 of the Environmental Statement. The consequential realignment of the associated infrastructure shall also be permitted.

15) All wind turbine blades shall rotate in the same direction.

16) No wind turbine or anemometry mast shall be externally lit except for a PIR activated light above the door to turbines and substation to aid engineers accessing the site during dusk or darkness, temporary lighting required during

the construction period or during maintenance, unless otherwise previously approved in writing by the local planning authority.

17) No development of the substation shall commence until details of the appearance, surface materials and dimensions of the proposed substation have been submitted to and approved in writing by the local planning authority. The details of the compound and substation shall reflect what is shown in Figures 4.7 and 4.8 of the Environmental Statement and shall not exceed the total area shown in those figures unless otherwise approved in writing by the local planning authority. The development shall be carried out as approved.

18) No development shall commence until a scheme reflecting the Ecological Mitigation and Enhancement Strategy contained in Chapters 6 and 14 of the Environmental Statement has been submitted to and approved in writing by the local planning authority. The scheme shall be implemented as approved.

19) No development shall take place until the applicant has secured the implementation of a programme of archaeological work in accordance with a written scheme of investigation which has been submitted to and approved in writing by the local planning authority.

20) No development shall take place on site until a scheme to secure the investigation and alleviation of any electro-magnetic interference to TV and radio reception caused by the operation of the turbines has been submitted to and approved by the local planning authority. The scheme shall provide for the investigation by a qualified independent television engineer of any complaint of interference with television reception at a dwelling (defined for the purposes of this condition as a building within use Class C3 of the Use Classes Order) which lawfully exists or had planning permission at the date of this permission where such a complaint is notified to the developer by the local planning authority within 12 months of the First Export Date. Where impairment is determined by the qualified independent television engineer to be attributable to the wind farm, details of the mitigation works which have been approved in writing by the local planning authority shall be implemented in accordance with the approved scheme.

21) Prior to the erection of any wind turbine a scheme providing for the avoidance of shadow flicker at any dwelling lawfully existing or with planning permission at the date of this permission shall be submitted to and approved in writing by the local planning authority. The approved scheme shall be implemented and thereafter retained.

22) Prior to the commencement of the development an ornithological post construction monitoring scheme (to include but not be limited to corpse searching) for a period of five years to commence when all of the wind turbines have been erected shall be submitted to and approved in writing by the local planning authority. The scheme shall include a methodology for the carrying out of the monitoring and shall make provision for annual reports of that monitoring to be submitted to the local planning authority. The monitoring scheme shall be implemented as approved.

23) No development shall take place until details of a scheme to mitigate any adverse effects of the development on the Primary Surveillance Radar at Southend Airport which shall include the arrangements for the implementation of the scheme, have been submitted to and approved in writing by the local

planning authority. No turbine shall be erected until the scheme has been implemented in accordance with the approved details.

24) The level of noise immissions from the combined effects of the wind turbines within this development (including the application of any tonal penalty) when calculated in accordance with the attached Guidance Notes, shall not exceed the values for the relevant integer wind speed set out in the attached Table 1. Noise limits for dwellings which lawfully exist or have planning permission for construction at the date of this consent but are not listed in the Tables attached shall be those of the physically closest location listed in the Tables unless otherwise approved in writing by the local planning authority. The coordinate locations to be used in determining the location of each of the dwellings listed in Table 1 shall be those listed in Table 2.

The wind farm operator shall continuously log power production, wind speed and wind direction, all in accordance with Guidance Note 1(d). These data shall be retained for a period of not less than 12 months. The wind farm operator shall provide this information to the local planning authority on its request within 28 days of receipt in writing of such a request. The data shall be supplied in comma separated values in electronic format unless otherwise approved in writing by the local planning authority.

Within 28 days from receipt of a written request from the local planning authority following a complaint to the local planning authority from an occupant of a dwelling which lawfully exists or has planning permission at the date of this permission, the wind farm operator shall, at the wind farm operator's expense, employ an independent consultant approved in writing by the local planning authority to assess the level of noise immissions from the wind farm at the complainant's property in accordance with the procedures described in the attached Guidance Notes. The written request from the local planning authority shall set out at least the date, time and location that the complaint relates to and any identified atmospheric conditions, including wind direction.

The wind farm operator shall provide to the local planning authority the independent consultant's assessment of the said complaint in accordance with the attached Guidance Notes within the later of two months of the date of the written request of the local planning authority above or two months following the approval of the local planning authority of the independent consultant and the approval of rain gauge location(s) under Guidance Note 1e, unless the time limit is extended in writing by the local planning authority. All data collected for the purposes of undertaking the compliance measurements shall be made available to the local planning authority on its request within 28 days of receipt in writing of such a request.

Table 1: Noise limits expressed in dB $L_{A90,10\text{-}minute}$ as a function of the standardised wind speed (m/s) at 10 metre height as determined within the site averaged over 10 minute periods

Location	Standardised wind speed at 10 m height in m/s								
	4	5	6	7	8	9	10	11	12
West Wycke Farm	38.0	38.0	38.0	38.0	38.0	40.3	45.2	50.7	50.7
Great West Wycke Farmhouse	38.0	38.0	38.0	38.0	39.7	44.3	49.1	53.3	53.3
1 Redward Cottages	38.0	38.0	38.0	38.0	39.7	44.3	49.1	53.3	53.3
New Bungalow	38.0	38.0	38.0	38.0	39.7	44.3	49.1	53.3	53.3
Turncole Farm	44.8	44.6	44.3	44.1	44.0	44.0	48.6	54.3	54.3
Broadward Farm	44.9	44.7	44.6	44.4	44.4	44.3	45.5	50.8	50.8
Poultry Farm	38.0	38.0	38.0	38.0	39.7	44.3	49.1	53.3	53.3
3 East Wick Cottages	38.0	38.0	38.0	38.0	38.0	41.6	45.7	48.5	48.5
Montsale Bungalow	38.0	38.0	37.9	37.2	36.7	43.4	48.8	53.5	53.5
West Wycke Bungalow	38.0	38.0	38.0	38.0	38.0	40.3	45.2	50.7	50.7
Old Montsale Farm	38.0	38.0	38.0	38.0	38.9	44.0	49.0	53.6	53.6
Wraywick Farm	38.0	38.0	37.4	36.4	35.7	39.2	45.3	50.7	50.7
Deal Hall	38.0	38.0	38.0	38.0	39.5	44.2	49.1	53.6	53.6
New Montsale	38.0	38.0	38.0	38.0	39.2	44.1	49.0	53.6	53.6
Middlewick Cottage	38.0	38.0	38.0	38.0	39.7	43.3	48.5	53.4	53.4
Middle wick	38.0	38.0	38.0	37.6	37.2	43.5	48.8	53.5	53.5
Court Farm	38.0	38.0	38.0	37.4	36.9	43.4	48.8	53.5	53.5
Wraywick Cottage	38.0	38.0	38.0	38.0	38.0	40.6	45.7	50.9	50.9
Dammerwick Farmhouse	38.0	38.0	38.0	38.0	38.0	40.5	45.3	50.7	50.7
Newmans Farm	38.0	38.0	38.0	38.0	38.0	40.4	45.3	50.7	50.7
8 Dammerwick Cottages	38.0	38.0	38.0	38.0	38.0	40.5	45.3	50.7	50.7
Brook Farmhouse	38.0	38.0	38.0	38.0	38.0	40.5	45.3	50.7	50.7
1 East Wick Cottages	38.0	38.0	38.0	38.0	38.0	41.6	45.7	48.5	48.5
2 Coney Hall Cottages	38.0	38.0	38.0	38.0	38.0	41.6	45.7	48.5	48.5
Coney Hall	38.0	38.0	38.0	38.0	38.0	41.6	45.7	48.5	48.5

Table 2 Coordinate locations of the properties listed in Table 1.

House Name	British National Grid Coordinates	
	Easting	Northing
West Wycke Farm	597924	196919
Great West Wycke Farmhouse	598490	196714
1 Redward Cottages	598532	196564
New Bungalow	598818	196666
Turncole Farm	599105	198347
Broadward Farm	598483	198639
Poultry Farm	598944	196651
3 East WickCottages	600254	196617
Montsale Bungalow	600456	198210
West Wycke Bungalow	597954	196928
Old Montsale Farm	600729	197742
Wraywick Farm	598431	199214
Deal Hall	601025	197108
New Montsale	600712	197419
Middlewick Cottage	600712	198664
Middle wick	601275	198759
Court Farm	601408	199092
Wraywick Cottage	598135	198948
Dammerwick Farmhouse	596297	196913
Newmans Farm	596221	197420
8 Dammerwick Cottages	596029	196953
Brook Farmhouse	595815	197145
1 East WickCottages	600105	196506
2 Coney HallCottages	600877	196576
Coney Hall	600901	196689

Note to Table 2: The geographical coordinate references are provided for the purpose of identifying the general location of dwellings to which a given set of noise limits applies.

25) No generation of electricity to the grid from the wind turbines shall take place until a Scheme for the regulation of amplitude modulation has been submitted to and approved in writing by the local planning authority. The scheme should be implemented as approved.

Guidance Notes for Noise Conditions

These notes are to be read with and form part of Condition 24. They further explain the noise conditions and specify the methods to be employed in the assessment of complaints about noise immissions from the wind farm. Reference to ETSU-R-97 refers to the publication entitled The Assessment and Rating of Noise from Wind Farms (1997) published by the Energy Technology Support unit (ETSU) for the Department of Trade and Industry (DTI).

Guidance Note 1

(a) Values of the $L_{A90,10\text{-minute}}$ noise statistic should be measured at the complainant's property, using a sound level meter of EN 60651/BS EN 60804 Type 1, or BS EN 61672 Class 1 quality (or the equivalent UK adopted standard in force at the time of the measurements) set to measure using the fast time weighted response as specified in BS EN 60651/BS EN 60804 or BS EN 61672-1 (or the equivalent UK adopted standard in force at the time of the measurements). This should be calibrated in accordance with the procedure specified in BS 4142: 1997 (or the equivalent UK adopted standard in force at the time of the measurements). Measurements shall be undertaken in such a manner to enable a tonal penalty to be applied in accordance with Guidance Note 3.

(b) The microphone should be mounted at 1.2-1.5 metres above ground level, fitted with a two-layer windshield or suitable equivalent approved in writing by the local planning authority, and placed outside the complainant's dwelling. Measurements should be made in "free field" conditions. To achieve this, the microphone should be placed at least 3.5 metres away from the building facade or any reflecting surface except the ground at the approved measurement location. In the event that the consent of the complainant for access to his or her property to undertake compliance measurements is withheld, the wind farm operator shall submit for the written approval of the local planning authority details of the proposed alternative representative measurement location prior to the commencement of measurements and the measurements shall be undertaken at the approved alternative representative measurement location.

(c) The $L_{A90,10\text{-minute}}$ measurements should be synchronised with measurements of the 10-minute arithmetic mean wind speed and operational data logged in accordance with Guidance Note 1(d), including the power generation data from the turbine control systems of the wind farm.

(d) To enable compliance with the conditions to be evaluated, the wind farm operator shall continuously log arithmetic mean wind speed in metres per second and wind direction in degrees from north at hub height for each turbine and arithmetic mean power generated by each turbine, all in successive 10-minute periods. Unless an alternative procedure is previously approved in writing by the local planning authority, this hub height wind speed, averaged across all operating wind turbines, shall be used as the basis for the analysis. Each 10 minute arithmetic average mean wind speed data measured at hub height shall be 'standardised' to a reference height of 10 metres as described in ETSU-R-97 at page 120 using a reference roughness length of 0.05 metres. It is this standardised 10 metre height wind speed data which is correlated with the noise measurements and referred to in Table 1. All 10-minute periods shall commence on the hour and in 10- minute increments thereafter synchronised with Greenwich Mean Time and adjusted to British Summer Time where necessary.

(e) Prior to the commencement of measurements the wind farm operator shall submit for the approval in writing of the local planning authority details of the proposed location of a data logging rain gauge which shall be installed during the course of the assessment of the levels of noise immissions. The data logging rain gauge shall record rainfall over successive 10-minute periods synchronised with the periods of data recorded in accordance with Note 1(d).

Guidance Note 2

(a) The noise measurements should be made so as to provide not less than 20 valid data points as defined in Guidance Note 2 paragraph (b).

(b) Valid data points are those measured in the conditions specified by the local planning authority under noise condition 24, but excluding any periods of rainfall measured in the vicinity of the sound level meter.

(c) For those data points considered valid in accordance with Guidance Note 2(b), values of the $L_{A90,10\text{-minute}}$ noise measurements and corresponding values of the 10-minute wind speed, as derived from the standardised ten metre height wind speed averaged across all operating wind turbines using the procedure specified in Guidance Note 1(d), shall be plotted on an XY chart with measured $L_{A90,10min}$ noise level on the Y-axis and the standardised mean wind speed on the X-axis. A least squares, "best fit" curve of an order deemed appropriate by the independent consultant (but which may not be higher than a second order polynomial) should be fitted to the data points and define the wind farm noise level at each integer wind speed.

Guidance Note 3

Where noise immissions at the location or locations where compliance measurements are being undertaken contain or are likely to contain a tonal component, a tonal penalty is to be calculated and applied using the following rating procedure.

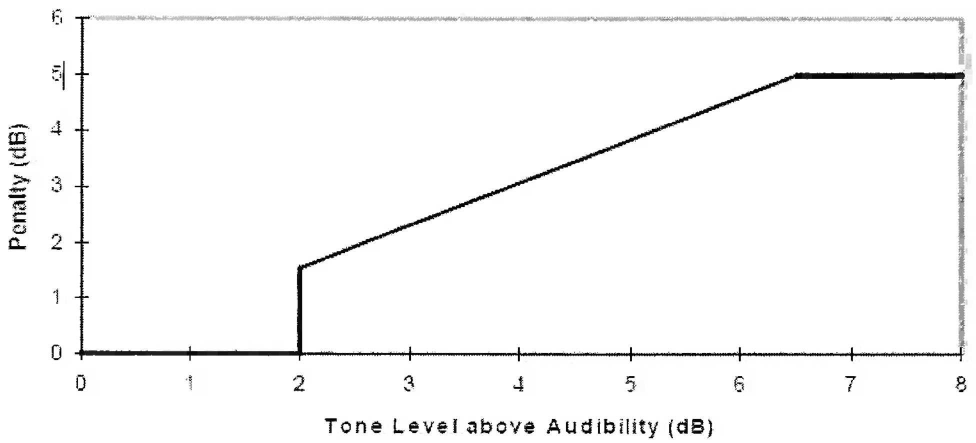
(a) For each 10-minute interval for which $L_{A90,10\text{-minute}}$ data have been determined as valid in accordance with Guidance Note 2 a tonal assessment shall be performed on noise immissions during 2 minutes of each 10-minute period. The 2-minute periods should be spaced at 10-minute intervals provided that uninterrupted uncorrupted data are available ("the standard procedure"). Where uncorrupted data are not available, the first available uninterrupted clean 2-minute period out of the affected overall 10-minute period shall be selected. Any such deviations from the standard procedure, as described in Section 2.1 on pages 104-109 of ETSU-R-97, shall be reported.

(b) For each of the 2-minute samples the tone level above or below audibility shall be calculated by comparison with the audibility criterion given in Section 2.1 on pages 104 -109 of ETSU-R-97.

(c) The tone level above audibility shall be plotted against wind speed for each of the 2-minute samples. Samples for which the tones were below the audibility criterion or no tone was identified, a value of zero audibility shall be substituted.

(d) A least squares "best fit" linear regression line shall then be performed to establish the average tone level above audibility for each integer wind speed derived from the value of the "best fit" line at each integer wind speed. If there is no apparent trend with wind speed then a simple arithmetic mean shall be used. This process shall be repeated for each integer wind speed for which there is an assessment of overall levels in Guidance Note 2.

(e) The tonal penalty is derived from the margin above audibility of the tone according to the figure below.



Guidance Note 4

If the wind farm noise level (including the application of any tonal penalty as per Guidance Note 3) is above the limit set out in the conditions, measurements of the influence of residual noise shall be made in accordance with a methodology that has been previously submitted to and approved in writing by the local planning authority to determine whether or not there is a breach of condition. This may be achieved by repeating the steps in Guidance Notes 1 & 2 with the wind farm switched off in order to determine the residual noise, L_3, at the assessed wind speed. The wind farm noise at this wind speed, L_1, is then calculated as follows, where L_2 is the measured wind farm noise level at the assessed wind speed with turbines running but without the addition of any tonal penalty:

$$L_1 = 10 \log \left[10^{L_2/10} - 10^{L_3/10} \right]$$

The wind farm noise level is re-calculated by adding the tonal penalty (if any) to the wind farm noise.

Application Reference FUL/MAL/12/00119 / Appeal B: APP/X1545/A/12/2179484

1) The development hereby permitted shall begin not later than five years from the date of this decision.

2) The development hereby permitted shall be carried out in accordance with the following approved plans: Planning Application Boundary Drawing No.02340D2909-01 and Delivery Analysis Drawing No.02340D2414-01 Sheets 1 and 2, except in respect of the detail shown on Sheet 2 which shall be approved pursuant to Condition 3 below.

3) No development shall commence until a scheme has been submitted to and approved in writing by the local planning authority detailing:

(a) The works required to implement the permission, along with a timetable for implementation.

(b) Proposals to restore land outside the carriageway of the public highway (including new or replacement planting of trees and hedges).

(c) The maintenance of the restoration works for a period of five years from their completion.

(d) The method statement providing for works to manage and safeguard trees during implementation of the works.

The scheme shall be implemented as approved.

4) No development under this permission shall take place prior to the commencement of development of the wind farm granted planning permission under Appeal Reference: APP/X1545/A/12/2174982.

Application Reference FUL/MAL/11/00879 / Appeal C: APP/X1545/A/12/2179225

1) The development hereby permitted shall begin not later than five years from the date of this decision.

2) The development hereby permitted shall be carried out in accordance with the following approved plans: Planning Application Boundary Drawing No.02340D2513-05 Sheets 1 and 2, Bridge Proposed Adjacent to Twizzlefoot Bridge Drawing No.02340D2413-06 Sheets 1 and 2, except in respect of the detail shown on Drawing No.02340D2413-06 which shall be approved pursuant to Condition 3 below.

3) No development shall commence until a scheme has been submitted to and approved in writing by the local planning authority detailing:

(a) The works required to implement the permission, along with a timetable for implementation.

(b) Proposals to restore land outside the carriageway of the public highway (including new or replacement planting of trees and hedges).

(c) The maintenance of the restoration works for a period of five years from their completion.

The scheme shall be implemented as approved.

4) No development under this permission shall take place prior to the commencement of development of the wind farm granted planning permission under Appeal Reference: APP/X1545/A/12/2174982.

The Planning Inspectorate

Report to the Secretary of State for Communities and Local Government

by John Woolcock BNatRes(Hons) MURP DipLaw MPIA MRTPI

an Inspector appointed by the Secretary of State for Communities and Local Government

Date: 21 October 2013

Town and Country Planning Act 1990

Maldon District Council

appeals by

RES UK & Ireland Ltd

Inquiry held on 23-26 and 30 April, 1, 2 and 8 May 2013

Appeal A: Turncole Farm, The Marshes, Dengie, Southminster CM0 7JJ
Appeal B: Lower Burnham Road and Fambridge Road, Near Cold Norton, Essex CM3 6NW
Appeal C: Turncole Farm, The Marshes, Dengie, Southminster CM0 7JJ

Report APP/X1545/A/12/2174982, 2179484 and 2179225

CONTENTS PAGE

ABBREVIATIONS

AIL	Abnormal indivisible loads
BS4142	*Method for rating industrial noise affecting mixed residential and industrial areas*
BS5837	*Trees in relation to design, demolition and construction*
CD	Inquiry Core Document
CLVIA	Cumulative landscape and visual impact assessment
DNO	Distribution Network Operator
EA	Environment Agency
EH	English Heritage
EIA	Environmental Impact Assessment
EN-1	*Overarching National Policy Statement for Energy*
EN-3	*National Policy Statement for Renewable Energy Infrastructure*
ES	Environmental Statement
ETSU-R-97	*The Assessment and Rating of Noise from Wind Farms*, ETSU-R-97, Energy Technology Support Unit
Framework	*National Planning Policy Framework*
GHG	Greenhouse Gases
GPG	*A Good Practice Guide to the Application of ETSU-R-97 for the Assessment and Rating of Wind Turbine Noise,* Institute of Acoustics, 20 May 2013.
GLVIA	*Guidelines for Landscape and Visual Impact Assessment, Third Edition,* Landscape Institute
ID	Inquiry Document – document submitted during the Inquiry
LP	Maldon District Replacement Local Plan 2005
MoD	Ministry of Defence
NATS	National Air Traffic Services
NE	Natural England
NPSE	*Noise Policy Statement for England*
MoD	Ministry of Defence
OAM	Other Amplitude Modulation
PPS22	now replaced *Planning Policy Statement 22: Renewable Energy*
PPS22CG	now cancelled *Planning for Renewable Energy – A Companion Guide to PPS22*
RE	Renewable energy
RSPB	Royal Society for the Protection of Birds
SEI	Supplementary Environmental Information
SIEGE	Southminster Inhabitants Environmental Group Enterprise
SLA	Special Landscape Area
SoCG	Statement of Common Ground between the Council and the appellant
SPA	Special Protection Area
SSSI	Site of Special Scientific Interest
T1-T7	Proposed wind turbines 1 to 7 in appeal scheme
VP	View Point
ZTV	Zone of Theoretical Visibility

Appeal A: APP/X1545/A/12/2174982
Turncole Farm, The Marshes, Dengie, Southminster CM0 7JJ

- The appeal is made under section 78 of the Town and Country Planning Act 1990 against a refusal to grant planning permission.
- The appeal is made by RES UK & Ireland Ltd against the decision of Maldon District Council.
- The application Reference FUL/MAL/10/01070, dated 14 February 2011, was refused by notice dated 25 October 2011.
- The development proposed is "Wind Farm Development consisting of seven three-bladed, horizontal-axis wind turbines, each up to 126.5 m maximum height to blade tip, with associated electricity transformers, underground cabling, access tracks, road widening works, crane hardstandings, control building, substation compound, communications mast and anemometry mast for a period of twenty-five years. Also temporary works including a construction compound, laydown area, rotor assembly pads, turning heads, welfare facilities and four guyed anemometry masts."

Appeal B: APP/X1545/A/12/2179484
Lower Burnham Road and Fambridge Road, Near Cold Norton, Essex CM3 6NW

- The appeal is made under section 78 of the Town and Country Planning Act 1990 against a refusal to grant planning permission.
- The appeal is made by RES UK & Ireland Ltd against the decision of Maldon District Council.
- The application Reference FUL/MAL/12/00119, dated 8 February 2012, was refused by notice dated 16 May 2012.
- The development proposed is "permanent road widening works for the purpose of facilitating access for abnormal load deliveries to the proposed wind farm at Turncole Farm. The new highway created will be fenced or similar to allow access to the abnormal loads only and not all traffic. The works will take place at the two road junctions between Lower Burnham Road and Fambridge Road near Cold Norton. The works will result in a change of use from residential and agricultural land to form new highway."

Appeal C: APP/X1545/A/12/2179225
Turncole Farm, The Marshes, Dengie, Southminster CM0 7JJ

- The appeal is made under section 78 of the Town and Country Planning Act 1990 against a refusal to grant planning permission.
- The appeal is made by RES UK & Ireland Ltd against the decision of Maldon District Council.
- The application Reference FUL/MAL/11/00879, dated 5 October 2011, was refused by notice dated 23 May 2012.
- The development proposed is "permanent road widening works and replacement of Twizzlefoot bridge for the purpose of facilitating access for abnormal load deliveries to the proposed wind farm at Turncole Farm. The works will result in a change of use from agricultural land to form new highway."

Summary of Recommendations:

Appeal A: APP/X1545/A/12/2174982
The appeal be allowed, and planning permission granted subject to conditions.

Appeal B: APP/X1545/A/12/2179484
The appeal be allowed, and planning permission granted subject to conditions.

Appeal C: APP/X1545/A/12/2179225
The appeal be allowed, and planning permission granted subject to conditions.

Preliminary matters

1. The appeals were recovered, by letter dated 5 June 2013, for determination by the Secretary of State because the appeals relate to proposals of major significance for the delivery of the Government's climate change programme and energy policies. This report briefly sets out the respective cases of the parties and deals more fully with their submissions in the Conclusions section, citing documents before the Inquiry, and submitted after its close, where appropriate.

2. The planning application for the scheme in Appeal A was accompanied by an Environmental Statement (ES). Supplementary Environmental Information (SEI) was submitted on 26 July 2012. The ES and SEI were advertised in accordance with the Environmental Impact Assessment (EIA) Regulations.[1] Following the submission of the SEI the Council issued updated reasons for refusal in January 2013.[2] The ES and SEI reasonably comply with the relevant provisions of the EIA Regulations, and the Environmental Information, as defined in the EIA Regulations, has been taken into account in this report and its recommendations.

3. On application Southminster Inhabitants Environmental Group Enterprise (abbreviated to 'SIEGE' in this report), which currently has a membership of about 700 people, was granted Rule 6(6) status pursuant to the Town and Country Planning (Determination by Inspectors) (Inquiries Procedure) (England) Rules 2000, which then applied. SIEGE participated fully in the Inquiry, opposing the proposed development.

4. The Institute of Acoustics published *A Good Practice Guide to the Application of ETSU-R-97 for the Assessment and Rating of Wind Turbine Noise* (GPG) after the close of the Inquiry.[3] This was endorsed as a supplement to *ETSU-R-97*.[4] The parties were given the opportunity to comment.[5]

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[1] In Appeal A the Town and Country Planning (Environmental Impact Assessment) (England and Wales) Regulations 1999 continue to apply in accordance with the transitional arrangements for the Town and Country Planning (Environmental Impact Assessment) Regulations 2011.
[2] CD20.
[3] ID41.
[4] ID41.1.
[5] Only the appellant responded, which is at ID41.2.

5. The High Court judgment in *Anita Colman and SoS for CLG and North Devon DC and RWE* also came after the Inquiry had closed.[6] The parties commented on this by email.[7]

6. Written statements to Parliament on onshore wind were published on 6 June 2013.[8] The parties were given the opportunity to comment.[9] The Department for Communities and Local Government subsequently published *Planning practice guidance for renewable and low carbon energy* on 29 July 2013 (PPG).[10] There is nothing to indicate that the written statements to Parliament were withdrawn with the publication of the PPG. Comments about the PPG were invited from the parties.[11]

Planning policy

7. Following the revocation of the Regional Spatial Strategy for the East of England and of all remaining structure plan policies, the adopted development plan for the area comprises saved policies of the Maldon District Replacement Local Plan 2005 (LP).[12] I deal with relevant policies in more detail later in this report, but highlight that the three appeal sites lie within a Special Landscape Area (SLA), as designated by LP Policy CC7.[13] They also lie within the defined Coastal Zone pursuant to LP Policy CC11.[14] Maldon District Council's emerging Local Development Plan is at preferred options consultation stage and so cannot be given much weight in determining these appeals.[15]

8. Paragraph 3 of the *National Planning Policy Framework* (hereinafter the *Framework*) states that national policy statements are a material consideration in decisions on planning applications. I deal in more detail later with the *Framework*. However, it replaced *Planning Policy Statement 22: Renewable Energy* (PPS22). Footnote 17 to paragraph 97 of the *Framework* states that in assessing the likely impacts of potential wind energy development in determining such planning applications the approach in the *National Policy Statement for Renewable Energy Infrastructure* (EN-3), read with the relevant sections of the *Overarching National Policy Statement for Energy* (EN-1), should be followed. In accordance with paragraph 1.2.1 of EN-1 and paragraph 1.2.3 of EN-3 there are no reasons here why these national planning statements should not apply in the interests of consistency, notwithstanding that the appeal scheme falls below the 50 MW threshold for national infrastructure projects.

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[6] *Anita Colman and SoS for CLG and North Devon DC and RWE* [2013] EWHC 1138 (Admin) Case No:CO/12831/2012 at ID42.
[7] ID42.1, ID42.2 and ID42.3.
[8] ID43a, ID43a.1 and ID43b.
[9] ID43.1 and ID43.2.
[10] ID44.
[11] Submissions from the main parties are at ID44.1, ID44.2 and ID44.3. The appellant's response to the Council's and SIEGE's submissions are at ID44.4.
[12] CD23a.
[13] The SLA is shown on ES Figure 5.2. Appeal sites A and C lie within the Dengie Marshes SLA.
[14] The Coastal Zone is shown on ES Figure 5.3. The designation arose from the Coastal Protection Belt in the now revoked Essex & Southend-on-Sea Replacement Structure Plan. This applied stringent restrictions on development at ID31.
[15] ID23.

9. *Planning Practice Guide to PPS5: Planning for the Historic Environment* remains extant, but it is guidance about implementing PPS5 *Planning for the Historic Environment*, which was replaced by the *Framework*. *Planning for Renewable Energy – A Companion Guide to PPS22* (PPS22CG) was cancelled by the PPG. The PPG was foreshadowed in the written statements to Parliament dated 6 June 2013. It is a material consideration in determining these appeals and there are no reasons why it should not generally be followed. Paragraph 15 of the PPG sets out a number of matters which it is important to be clear about in considering planning applications. Particular planning considerations that relate to wind turbines are included in PPG paragraphs 29-45. More details about how these apply in this case are included in the relevant sections of this report.

The appeal sites and surrounds [16]

10. The proposed Turncole wind farm site comprises large open agricultural fields primarily used for crops. It lies about 2.6 km south-east of Southminster, and about 2.7 km north-east of Burnham-on-Crouch, on the Dengie peninsula. Other settlements in the area include Stoneyhills, which is about 2.8 km to the west, and Asheldham and Dengie, which are smaller dispersed settlements some 3.5 km to 3.8 km north of the site.[17] The nearest national designations are the Crouch and Roach Estuaries Site of Special Scientific Interest (SSSI) to the south, and the Essex Coast Environmentally Sensitive Area to the south-west. The closest international designations are the Crouch and Roach Estuaries Special Protection Area (SPA), Special Area of Conservation and Ramsar site.[18] There are a number of listed buildings and archaeological sites in the locality which are identified in the ES.[19]

11. There are 27 dwellings within 2 km of the proposed wind farm.[20] It was clarified at the Inquiry that the occupiers of both Turncole Farm and Broadward Farm have a financial interest in the proposed wind farm. Footpaths in the locality include St Peter's Way long distance footpath, which runs in an east-west direction approximately 6 km at its nearest point to the north of the proposed wind farm. Footpaths FP18 and FP24 are the closest to the appeal site in Appeal A at a distance of about 1 km.[21] Sustrans cycle routes lie approximately 14 km and 15 km from this appeal site at their nearest points.[22]

12. There are other wind turbines in the wider locality.[23] A turbine 36.4 m to blade tip is located at Southminster Hall, about 1.9 km north-west of the proposed Turncole wind farm.[24] The first two of 10 permitted 121 m to blade tip turbines at Bradwell-on-Sea were constructed at the time of the Inquiry, some 8 km to the north of the proposed Turncole wind farm.[25] These were permitted on appeal in

[16] Based on SoCG and evidence at the Inquiry.
[17] The location is shown at ES Figure 1.1.
[18] SAC/SPA/Ramsar sites and SSSI are shown on ES Figure 3.2 and ES Figure 6.10.
[19] Shown on ES Figure 7.2.
[20] These are shown on ES Figure 5.14.
[21] The nearest public footpaths are shown on ES Figure 5.14.
[22] Sustrans routes and St Peter's Way are shown on ES Figure 5.1.
[23] SoCG Table 1 sets out details about existing and permitted wind turbines within 25 km of the proposed Turncole wind farm. Locations for some are shown on ES Figure 5.10.
[24] Southminster Hall is shown on ES Figure 5.14.
[25] ID29.

2010.[26] Middlewick wind farm, about 1.3 km north of the proposed Turncole wind farm, has planning permission for 9 turbines, each 125 m to blade tip.[27] In that case the main parties agreed that a joint day and night-time lower noise limit of 38 dB $L_{A90,10\ min}$ for properties not financially involved with the Middlewick wind farm could be adopted.[28] This joint limit was justified on the grounds that it would prevent a sudden increase in acceptable noise limits during the night-time and to prevent excessive night-time noise levels above background levels.[29] Construction of Middlewick wind farm had not commenced at the time of the Inquiry, but all preconditions have been discharged.[30] At a distance of some 22 km to 23 km there are offshore wind farms at Gunfleet Sands and Kentish Flats. At a similar distance there are also five turbines at Earls Hall Farm, which is about 1 km to the west of Clacton-on-Sea.[31]

13. In terms of landscape character the proposed wind farm site is located in National Character Area 81: Greater Thames Estuary.[32] The key characteristics of this area include extensive open space dominated by the sky, within a predominantly flat, low-lying landscape, with a strong feeling of remoteness and wilderness on the open beaches and salt marshes, on the reclaimed farmed marshland and also on the mudflats populated by a large and varied bird population.[33] It adds that hedges are absent from the large, rectilinear fields, and that generally tree cover is limited to farmsteads and dwellings on higher, drier pockets of ground. Character Area 111: Northern Thames Basin lies to the west of Area 81. This is a more diverse landscape, which includes broad plateau areas mainly in agricultural use, along with broad and smaller river valleys.[34] In the *Essex Landscape Character Assessment* the site is identified within the Dengie and Foulness Coast (F3), and described as a large scale, flat landscape with wide views, with a remote tranquil character, arable farmland intersected by ditches with only a few hedgerows.[35]

14. At a more local level appeal sites A and C are located within Landscape Character Area D8 Dengie Drained Estuarine Marsh.[36] Key characteristics of this area include low drained land of mostly arable farmland intersected by linear ditches and dykes, with restricted access and isolated farms, along with a sense of huge sky, sound of birds, tranquillity and panoramic views across the marshland and out to sea. There is evidence that tranquillity increases significantly to the east of the settlements at Southminster and Burnham-on-Crouch.[37] The consented Middlewick wind farm site lies within Area D8. To the east of Area D8 lies Area C3 Dengie Flats Estuarine Marsh/Mudflats, some 3 km from the Appeal A site, which is an inter-tidal landscape. The character of Area C3 is influenced by the

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[26] ID20.
[27] Granted planning permission on appeal in 2011 at CD58.
[28] References to all noise levels in this report do not repeat the $L_{A90,10\ min}$ descriptor, e.g 38 dB $L_{A90,10\ min}$ would be specified simply as 38 dB.
[29] CD58 paragraph 38 and Condition 40.
[30] Council's response to Inspector's question.
[31] Inspector's site visit – location is shown on ES Figure 3.2.
[32] Shown on ES Figure 5.4.
[33] CD95.
[34] CD96.
[35] CD89 and ES Figure 5.5.
[36] CD91. These local landscape character areas are shown on SEI Figure 5.1.
[37] ID9.

changing colours of the sea and sky. To the north and west, at a distance of about 2 km from the proposed Turncole wind farm, lies Landscape Character Area E2 Tillingham and Latchingdon Coastal Farmland. This is gently undulating farmland, locally quite steep, behind the coastal marshland. Features cited as key characteristics in Area E2 include right-angled bends in lanes which reflect ancient field patterns, and that Dutch elm disease has made elm loss noticeable in hedgerows. Settlements north of Burnham-on-Crouch lie within Area E2. Appeal site B lies within a transition area between Drained Estuarine Marsh and Coastal Farmland character areas. Bradwell wind farm and Bradwell Power Station lie within landscape character Area D7 Bradwell Drained Estuarine Marshes, which lies about 6 km from the proposed Turncole wind farm. This is the same character type as Area D8.

15. Appeal sites A and C lie within the Maldon peninsula regional seascape unit as devised for the ES.[38] This is wedged between the River Blackwater to the north and the River Crouch to the south, and is described in the ES as a highly distinctive and surprisingly isolated seascape consisting of a peninsula, which at its narrowest is no more than 6 km wide. My site visits confirmed the findings in the ES that, although a coastal landscape, the area is defined by land and sky and the flatness of the terrain rather than the sea itself, with the wide expanse of mudflats at low tide visually separating the sea from the land.[39]

Proposed development [40]

16. It was clarified at the opening of the Inquiry that the three appeal schemes relate to a single proposal, and that if the appeals were to succeed it would be necessary to link the resultant planning permissions by conditions. The proposed development includes seven wind turbines (T1-T7) with a maximum height to blade tip of 126.5 m. Proposed infrastructure layout is shown on ES Figure 4.2, with indicative turbine elevations depicted at ES Figure 4.3.[41] During construction and commissioning temporary works would include a construction compound and anemometry masts. The construction phase of the proposal would be expected to last 12 months, with the wind farm then to operate for a 25 year period before being decommissioned.

17. The sites of the proposed highway works in Appeals B and C are shown as Detail 3 and 4, and Detail 29, respectively, on the Delivery Analysis, which is Figure 3.1 of the SEI. This also indicates the proposed route for abnormal indivisible loads (AIL). Grid connection works were considered in the ES, but are not part of the appeal scheme and would need to be the subject of separate consideration by the distribution network operator.[42]

18. Based on a wind turbine with a nominal capacity of 1.8 MW, the proposed wind farm would have an estimated installed capacity of 12.6 MW. The proposed wind farm would be capable of producing the equivalent amount of electricity per

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[38] Shown on ES Figure 5.6.
[39] ES paragraphs 5.5.37-42.
[40] SoCG.
[41] An aerial photograph showing the siting of the proposed turbines and mast is at ID10. Turbine layout with micro-siting is shown on Drawing No.02340D2107-05 and infrastructure layout on Drawing No.02340D1001-14.
[42] ES Section 13 and ID37.

annum that is required for the annual domestic needs of approximately 7,585 households based on the UK averaged domestic electricity consumption of 4,700 kilowatt hours per annum, so offsetting approximately 15,300 tonnes of carbon dioxide per annum.[43]

Statement of Common Ground

19. A Statement of Common Ground (SoCG) between the Council and the appellant dated 26 March 2013 sets out, amongst other things, documentation for the applications. However, the application drawings in the SoCG were revised at the Inquiry to the List of Plans attached to this decision.[44] This clarified that other drawings submitted are indicative and do not form part of the applications. A drafting error for proposed highway works (Detail 9) was corrected at the Inquiry.[45]

20. The Council has no objections to the proposal on a number of grounds, subject to the imposition of appropriate planning conditions. These are ecology, tourism, archaeology, shadow flicker, public safety, ice-throw or driver distraction, loss of agricultural land, human rights, hydrology, contamination, aviation, health effects of infrasound or low frequency noise, and electro-magnetic interference. The SoCG states that commercial viability, including available wind speed, is not a land use consideration.

21. The Council's concerns about the effects of the proposed wind turbines on the residential amenity of nearby occupiers relate solely to the properties at Turncole Farm and Broadward Farm.

22. With respect to landscape character effects, the SoCG states that the proposal would not give rise to any significant direct effects on the physical fabric of the landscape in the longer term. The Council and the appellant agree that the effects of Bradwell and Middlewick wind farms would be such that the host landscapes Area D7 and Area D8 would have wind turbines as a key characteristic across portions of the two areas. It is further agreed that the additional effects of Turncole wind farm would be to extend the influence that would already arise from Middlewick wind farm and Bradwell wind farm across character Area D8, such that wind farms would become a key characteristic of the entire character area.

23. The Council and the appellant agree that the operation of the wind farm would affect the setting of heritage assets in the vicinity of the development, but any such effects would be reversed when the wind farm was decommissioned. The Council's concern relates to a number of specified listed buildings.[46] The issue between the Council and the appellant is the balance of the benefits of the proposal against any harm to the significance of listed buildings in the vicinity due to change in their setting, by Turncole wind farm alone and in combination with Middlewick and Bradwell wind farms.

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[43] SoCG Section 20 notes that these offset figures would change during the lifetime of the proposed wind farm as the national mix of generation sources changes.
[44] ID13.
[45] ID15.1 and ID15.2.
[46] These are Old Montsale, Newman's Farmhouse, Dammer Wick Farmhouse, Bridgewick Cottages, Court Farmhouse, together with the nearby Bake/Brewhouse and Barn, and the Church of St James. Relevant extracts from the Statutory List are at PoE3 Appendix B.

24. Appendix 2 of the SoCG sets out an agreed statement about energy policy, and there is agreement about the public benefits that would result from the generation of renewable energy (RE) and reduction of greenhouse gases (GHG) in terms of offsetting carbon dioxide, based on certain assumptions.

25. LP Policy PU6 is the most relevant policy as it deals with wind energy development. Other policies which may be relevant are set out in the SoCG, with the weight to be given to them a matter to be determined. A summary of these policies is included as Annex 1 to this report.

26. A noise common ground statement includes an agreed set of tables documenting representative average typical background noise levels, and noise levels with the appropriately derived noise limits for various lower absolute noise limits for Turncole wind farm alone, and cumulatively with Middlewick wind farm operating at its consented noise limits.[47] The Council and the appellant agree about a night-time fixed limit, but there is a dispute about what would be the appropriate day-time fixed limit.

27. The landscape experts at the Inquiry set out matters in dispute concerning the removal of trees and vegetation along the route proposed for construction vehicles.[48] There is disagreement about the acceptability of the visual and character effects at several locations, whether Tree 10 should be Grade A or B, and the effects of the proposal on its health and longevity. Similar concerns exist for Tree 11. Other issues concern the implications for a roadside pond, along with the effects of the removal of roadside vegetation on the residential amenity of some dwellings.[49]

The case for SIEGE

The main points are as follows.[50]

28. National planning policy provides strong support for the development of RE, and the central message contained within paragraph 17 of the *Framework* is that planning should "encourage...the development of renewable energy." But there are other material considerations, which must be taken into account. It is self-evident that wind turbines can have dramatic adverse effects on landscape and on amenity. Therefore, a balancing exercise must be carried out. The benefits of the scheme, both in terms of its actual output of electricity, the resultant benefit to overall climate change objectives, along with other benefits, including socio-economic benefits, are to be weighed against the disbenefits. SIEGE adopts and supports the Council's case, but focuses on cumulative impacts, particularly in relation to residential amenity and construction traffic.

29. There is no presumption in favour of RE development. The presumption contained in the *Framework* is only in favour of sustainable development. The reference to "impacts" in paragraph 98 makes it plain that this guidance is not the engagement of a balancing exercise that balances impacts against the overall need for RE, but an evaluation of whether the landscape, visual and other

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[47] ID7.
[48] ID22.
[49] Photographs are included in PoE11 Appendices 5 and 6 with locations at ID 21. Appendix 10 of PoE2 shows the delivery analysis drawings with aerial photograph overlays.
[50] Based on closing submissions at ID38.

impacts are, of themselves, acceptable. EN-1 makes plain that the landscape and visual effect of wind turbines is directly relevant to the issue of whether or not they can be permitted. The decision maker "should judge whether any adverse impact on the landscape would be so damaging that it is not offset by the benefits (including need) of the project." [51] Paragraph 98 of the *Framework* does not preclude weighing in the balance the actual energy benefits which flow from a scheme against its adverse impacts. Nor does it prevent consideration of the suitability, overall, of a particular location for a proposed scheme.

30. The language within the *Framework* indicates a weakening of the support for renewables from the policy provisions of the former PPS22, a key principle of which suggested that the benefits of renewable development must always be afforded "significant weight". A blanket approach of simply assuming that there is a significant substantial weight to be attached to the appellant's need case should not be adopted. This is not a major RE scheme, and EN-1 paragraph 3.2.3 provides that substantial weight should be given to considerations of need, with the weight so attributed in any given case being proportionate to the anticipated extent of a project's actual contribution to satisfying a need for a particular type of infrastructure.

31. The benefits of the scheme should be considered in terms of targets for installed renewables capacity, energy output and socio-economic benefits. Regional and sub-regional targets are only a mechanism by which it is sought to ensure that national targets are met. The UK's international obligations are imposed in national terms. When assessing planning weight it is necessary to make that assessment within the context of an understanding of performance against national targets. An understanding of the amount of energy which would actually be produced is the first step to understanding how much displacement there would be of energy produced from fossil fuel sources. The scheme if allowed to run at full capacity would produce 12.6 MW, compared to 20 MW at each of the Bradwell and Middlewick wind farms. It would not be a major wind farm development, nor would it make a large contribution to national RE targets. There would be benefits in electricity generation, and reduction of GHG, but their significance in a national context is less clear, and the appellant has probably overstated these benefits. There would also be some socio-economic benefits, primarily from the construction of the wind farm, but the amount of money generated which would remain in the local economy would be limited, and few permanent jobs would result once the scheme was operational.

32. Against this must be balanced the very real harm which the appeal proposals would do. In relation to landscape and visual matters, the starting position is the view of the Dengie as an unspoilt, rural location of peace, tranquillity and vast skies. The introduction of more turbines into this highly sensitive landscape would have a variety of negative landscape effects. The sheer size of the industrial structures would impose on an area where very few features protrude above the natural landscape. They would stand clear of any woodland or other landscape features, and in any near or medium distance views would dominate and dwarf any existing structures and dwellings. In terms of materials, form and functionality the turbines would be alien to the local landscape, with blade

[51] EN-1 paragraph 5.9.15. A similar statement is made in respect of visual impact at paragraph 5.9.18.

rotation drawing attention. The blades would have a swept area 7% greater than that of the turbines at Middlewick wind farm, and 28% greater than those at Bradwell wind farm, which would increase the visual distraction.[52] In combination with the Middlewick turbines the appeal scheme would induce an increasing sensation of creeping industrialisation into a rural area, which with the visual and noise effects, would significantly reduce the remaining sense of remoteness and tranquillity. This would harm the recreational amenity of the area for walkers, cyclists and equestrians.[53]

33. The Council and the appellant have not given full consideration to the significant damage this development, alone and cumulatively, would cause to the residential amenity of a number of properties.[54] There has been no assessment of cumulative impact on the residential amenities of properties other than Turncole Farm and Broadward Farm. The appellant's methodology is not transparent. This is important because intimidating cumulative effects on residential amenity have been found at a distance of 2 km in the *Sillfield* appeal.[55] The ES in relation to West Wycke Farm states that there " are likely to be uninterrupted views of the proposed wind farm from first floor rear windows", and in relation to West Wycke Bungalow that there " are likely to be more open views of the turbines from the rear gardens".[56] More crucially, in relation to Great West Wycke Farmhouse the ES states that the nearest turbine would be 0.83 km to the north, and that "The principal focus and direction of views from both the house and garden is to the north and northwest... On the basis that views from the main living areas and garden towards the proposed turbines are unobstructed and likely to be dominated by the proposed wind farm development the effects on visual amenity are deemed to be considerable." [57] The appellant's witness found that the scheme would not be overbearing or oppressive, and so was forced into the unenviable position that the ES was inconsistent and wrong.

34. The public interest is engaged when damage to residential amenity is such that the property would become an unattractive place to live.[58] In addition, wide-ranging damage to residential amenity that does not make any single property unattractive, but harms the general attractiveness of the outlook of the local area as a place to live, is also a public issue, which must engage the public interest. Local residents chose to live in the Dengie because of its peace, quietness, unspoilt landscape and tranquillity.[59] The test applied in the *Carland Cross* appeal is for determining whether or not a scheme should be refused on residential amenity grounds alone – it does not follow that if this test is not met that these effects should simply be disregarded.[60]

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[52] PoE8 paragraph 2.1.
[53] PoE7 paragraph 17.
[54] WR4
[55] CD69 paragraph 47.
[56] ES paragraphs 5.11.8 and 5.11.10.
[57] ES paragraph 5.11.12. In WR2 the occupiers refer to this property as Great West Wycke Farmhouse, but it is referred to in the ES as Great West Wick R3 and Great West Wycke Farm in the suggested noise conditions.
[58] WR2.
[59] PoE6, PoE7, WR2 and WR3.
[60] CD62.

35. There is no policy or precedent which supports the appellant's position that the financial interests of the occupiers of Turncole Farm and Broadward Farm renders harm to the residential amenity of these properties acceptable. The accepted test is whether residential amenity would be damaged in the opinion of the public at large, as potential purchasers of the property.

36. The appellant's study of Inspectors' decisions in relation to residential amenity should be given very little weight because there is no analysis of how many decisions related to cumulative effects, spread or number of turbines involved.[61] These are factors that would affect the field of view. The cumulative impact in relation to 70 properties, with clear or peripheral line of sight, especially at times when deciduous trees have lost their leaves, weighs in the planning balance against the scheme.[62] Unacceptable effects on residential amenity were found in the *Enifer Downs* decision, which concerned five turbines spread out at 800 m, with little or no screening.[63] Support derives from the *Poplar Lane* decision where seven turbines at 750 m were found unacceptable on the grounds that they would be overwhelming, obstructive and unavoidable to residents on the basis of a single field of view from main rooms and gardens.[64] In the *Brightenber* decision it was found that potential views for those working the land were oppressive and overbearing as the farmer would be unable to escape them.[65] This would apply to farmland at Northwycke Farm, which would be 300 m from the nearest Middlewick turbine and 1,450 m from the nearest Turncole turbine.

37. The Council's case on noise is largely supported, but noise levels should never have been set above 35 dB, and the Middlewick Inspector was wrong to determine a lower noise limit of 38 dB. If WHO revised guidelines had been considered, ETSU noise limits should be 30 dB during the day-time. Concerns exist about the methodology used in the noise assessment, particularly calibration uncertainty, induced noise from windshields, exclusion of rain affected results, and monitoring undertaken in moderately exposed positions. ETSU-R-97 day-time limits are intended to apply in sheltered positions such as gardens and patios, not in more windy positions. Given the difficulty in assessing noise, perhaps an uncertainty of +/- 3 dB should be added to the predicted noise levels from the turbines. There is also concern about noise health effects. Noise can be a problem for people, which can be particularly acute for those not kindly disposed to them and/or those who can see them.[66]

38. ETSU-R-97 is inadequate in protecting residents from harmful noise impacts when used in very low background noise areas. Wind farms are industrial development to which BS4142 *Method for rating industrial noise affecting mixed residential and industrial areas* should apply. Dwellings situated between the Middlewick and Turncole wind farms would be subject to the combined noise generated, which would be incessant and overwhelming. It would be impossible to apportion the contribution that each of the two wind farms had made in the

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[61] Appellant's PoE10 Appendix I.
[62] Table 1 PoE8. SIEGE highlights concern about overwhelming panoramas of rotating turbines in views from Great West Wycke Farmhouse, Wraywick Farm, Wraywick Cottages, Montsale Bungalow and Middlewick Cottages.
[63] CD68.
[64] Appeal Reference:APP/L3245/A/08/2088742 and 2088745.
[65] CD61.
[66] PoE5 sections 3, 4, 5 and 8. Health issues are also raised in WR4.

event that noise limits imposed were exceeded.[67] Reference should also be made to the *Noise Policy Statement for England* (NPSE), which aims, within the context of Government policy on sustainable development, to avoid significant adverse impacts on health and quality of life, to mitigate and minimise such impacts, and where possible contribute to the improvement of health and quality of life.[68] This approach should be preferred because it is a more recent statement of Government policy, and because it seeks to clarify the underlying principles and aims of existing policy documents, legislation and guidance related to noise.

39. A condition dealing with amplitude modulation is necessary to protect local residents from a phenomenon that they think would be a significant issue, which the appellant denies would occur. The suggested condition would control the period during which greater than expected amplitude modulation (which is referred to in this report as Other Amplitude Modulation (OAM)) could occur, where this is defined as a change in the measured $L_{Aeq,\ 125\ milliseconds}$ of more than 3 dB occurring within a 2 second period.[69] There would be no harm to the appellant in accepting such a condition if the appellant is sure that OAM would not arise. If there is difficulty in enforcing an OAM condition, or noise limits because of cumulative effects, then the appeal scheme should not be built.

40. There is concern about construction traffic and highway safety from the appeal scheme and cumulative effects with construction traffic from other wind farms.[70] The difficulties of manoeuvring large vehicles through local roads would result in real danger to other road users. The junction of Church Road/Southminster Road and Burnham Marsh Road, and the proximity to St Mary's Church, Ormiston Academy and St Mary's Primary School, are of particular concern.[71] Middlewick wind farm is required to commence construction by May 2014, but there is no time limit for its completion.[72] There is a possibility that construction traffic from Middlewick and Turncole wind farms could use the same local roads at the same time. The appellant's evidence is not based on a worst case scenario, and there are no grounds to find that there would not be significant adverse impacts from construction traffic. Even if construction of the two wind farms was consecutive rather than contemporaneous, the extended duration of disruption would be more significant for the residents affected.

41. SIEGE adopts the Council's case concerning a marine transport route, but raises two points concerning the appellant's reasons why a route via Burnham Wick Farm was not possible; severe impact on breeding lapwing, and conflict of interest with a tenant leasing an airstrip. The latter has been overcome by the relocation of fixed wing aircraft.[73] Burnham Wick Farm is just over 2 km from Turncole Farm and its use as a lapwing breeding ground has not been considered.

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[67] PoE7 paragraphs 19 and 22.
[68] CD103.
[69] ID19.
[70] PoE8 and PoE7.
[71] ID26 and WR1.
[72] CD58.
[73] ID36.

42. There is also concern that the turbines would affect foraging and roosting birds which come in from the SPA at times of high tides.[74]

43. There has been no assessment of the size or condition of the hedgerows proposed to be removed by road widening, notwithstanding that were planning permission to be granted no separate application under the Hedgerow Regulations 1997 would be needed. Such a basic assessment is required by BS5837.[75] In the absence of such information the evidence provided is deficient.

44. The PPG confirms what SIEGE understood to be the Government's view of onshore wind development.[76] Its advice about location and output is relevant as the same installation could produce 25% more power on coastal sites facing the predominant south-westerly winds. Wind is unreliable and not effective.[77] ETSU-R-97 makes no allowance for infrasound. Paragraph 31 of the PPG refers to the strategic road network, but with only two B class roads to the peninsula the road network is not suitable for construction traffic. The advice about cumulative impacts in the PPG supports SIEGE's view that the proposal would result in a wind farm dominated landscape.

45. The scheme would bring some benefits and Government policy supports RE development generally, where possible. However, the considerable harm here demonstrably outweighs those benefits for what is unsustainable development. Moreover, the lack of proper consideration of a number of material matters leaves room for significant uncertainty as to the impact of the proposal, and the appeals should be dismissed.

The case for Maldon Council

The Council's case refers to noise, landscape and visual impact, residential amenity, cultural heritage, marine delivery route, and the planning balance. The main points are as follows.[78]

Noise

46. The cumulative impact of Turncole wind farm in combination with Middlewick wind farm would result in significant and demonstrable noise implications upon Broadward Farm, Wraywick Cottage, Wraywick Farmhouse, and Montsale Bungalow resulting in a harmful loss of amenity to the detriment of the occupiers of these residential properties, making them unacceptable places to live, contrary to LP Policies CON5 and PU6.

47. ETSU-R-97 is a convenient tool, but falls well short in taking into account what existing background levels are for the purposes of deciding whether increases in noise levels could be kept to an acceptable level. ETSU-R-97 is only part of the enquiry and it is not proper to assume that increasing the noise level from a low background level to a level of 35 dB would not have an adverse impact. There is nothing to rule out the use of other tools or methodologies being used in addition

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[74] PoE8 paragraph 6.6. WR4.
[75] British Standard 5837:2012 *Trees in relation to design, demolition and construction* at CD97.
[76] ID43.2.
[77] WR4.
[78] Based on closing submissions at ID39.

to ETSU-R-97 as part of an overall assessment, which would result in noise impact being better understood. Applying the approach set out in BS4142 there would be a major loss of amenity at eight dwellings in the vicinity of the proposed turbines, with the main loss of amenity at night when background levels are lower than during the day. The significant adverse impacts would be in breach of NPSE.[79]

48. There is considerable agreement by the noise experts about the objective noise data, and how the consented wind farm at Middlewick should not, in accordance with ETSU-R-97, be considered as part of the prevailing background noise. However, the experts disagree about the determination of the lower cumulative noise limit when applying the factors set out in ETSU-R-97. This provides that the actual value within the range 35-40 dB should depend upon (1) the number of dwellings in the neighbourhood, (2) the effect of noise limits on the number of kWh generated, and (3) the duration and level of exposure. In this case the number of dwellings impacted by the Middlewick and Turncole wind farms would be about twice the number of dwellings impacted by Middlewick wind farm alone. With both schemes in place there would be roughly twice the number of turbines compared with just Middlewick wind farm. Accordingly, whilst the increase in the number of dwellings affected might suggest decreasing the lower absolute cumulative limit, that would effectively be cancelled out by the fact that it would reduce the generating capacity of roughly twice as many turbines. So there is no persuasive case, by reference to these three factors, for setting the absolute lower cumulative limit for Middlewick and Turncole wind farms any higher than the lower limit for the Middlewick scheme alone.

49. The appellant favours the highest possible cumulative limit of 40 dB. The Council is not prepared to go any higher than 38 dB. This would require all the turbines to be switched off if the wind direction was between 60 and 150 degrees. This is a strong indication that it is simply not possible satisfactorily to accommodate a second wind farm on the scale proposed that would be acceptable in noise terms. The appellant argues for an increased absolute lower limit to 40 dB not because of any sound justification by reference to the ETSU-R-97 criteria, but because it would be necessary to do so to make the two wind farms ETSU-compliant. With or without reference to ETSU-R-97 the proposal would result in an unacceptable level of noise, harming residential amenity.

Landscape and visual impact

50. As a result of the scale of the proposed turbines and their visual intrusion in combination with Middlewick and Bradwell wind farms the proposal would have a detrimental impact upon this unique countryside and coastal landscape, which is recognised for its natural beauty and tranquillity as a SLA. The proposed development would be contrary to LP Policies CC6, CC7, BE1 and PU6.

51. It is necessary in assessing LVIA of the Turncole proposal to consider the landscape that existed before any wind turbines were there at all, not just the additional effects of Turncole wind farm against a baseline of the other wind turbines, as existing and including Middlewick wind farm.[80] This is the only way to come to a proper judgement about the capacity of the landscape to

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[79] PoE1 section 9 and 13.
[80] PoE2 section 3 deals with landscape character, and section 4 with visual amenity.

accommodate wind farm development. Otherwise an assessment which only extended to considering the quantum of additional development each time could go on indefinitely, becoming easier each time to justify a further quantum of additional development. It is not simply that Turncole wind farm would reinforce this key characteristic. It is more complex, with the addition of another wind farm raising important questions about the compositional relationship between Middlewick and Turncole wind farms in visual terms. There is a lack of coherence in how the turbines in the two wind farms would be distributed relative to each other.[81] This is contrary to the Scottish National Heritage guidance which states that a key factor determining the cumulative impact of wind farms is the distinct identity of each group, typically related to their degree of separation and similarity of design, and that it is critical to achieve a balance between wind farms and the undeveloped open landscape retained between them. It adds that adequate separation would help to maintain wind farms as distinct entities, but that the separation distance required would vary according to the landscape characteristics.[82]

52. There is more to landscape character than simply the underlying physical quality of the land, and central to this is how it would be perceived. The presence of further wind turbines in this area would lead to a further substantial change in how this open and flat landscape would be perceived. Turncole wind farm would extend the area experiencing at least a medium magnitude of change to virtually the whole of landscape character Area D8.[83] Furthermore, this analysis refers to only two categories of magnitude of effect, medium and high, and Middlewick wind farm alone would result in an area of high magnitude effects. The effects would be intensified still further in the area of overlap were both Middlewick and Turncole wind farms to be built; but such an effect would not be captured by the categories used in the appellant's assessment.

53. This raises issues about landscape capacity. The only capacity study prepared for the area assumes a separation distance of 10 km between wind farms, and on this basis estimates that Character Area 81 (Greater Thames Estuary) as a whole could accommodate 18 turbines.[84] Adding Turncole wind farm to Bradwell and Middlewick wind farms would result in 27 turbines in the Dengie peninsula alone.

54. The SLA is likely to have been designated as a result of a subjective assessment that considered that there was something special about it, not just on the assumption that the most interesting aspects of rural landscape are good amplitude of relief, vegetation cover and the presence of water as a landscape element, as set out in the Countryside Conservation Plan in 1986.[85] The SLA designation underlines how important it is, when carrying out a landscape character assessment, not just to consider whether the development would make physical changes to the land, but also whether it would lead to changes in how the landscape was perceived.

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[81] Illustrated in ES Figure 5.16D and 5.18D, and PI4 and PI7 supplementary viewpoints in Additional Visualisations.
[82] CD83.
[83] SEI Figure 5.2 and update at ID24.
[84] CD87 and PoE2 Appendix 8.
[85] CD90.

55. Main viewpoints of concern to the Council are as follows.[86] Cumulative VP1 should be considered with caution given that dwellinghouses conceal the turbines, which would be more visible back and further along Marsh Road from this viewpoint.[87] For Cumulative VP2 the magnitude of change should be medium-high or high given the proximity of the proposed turbines.[88] From Cumulative VP4 Turncole wind farm would result in the entirety of the framed scene from this vantage point being consumed by turbines. The in-combination cumulative visual effect at this location would be of high magnitude.[89] The appellant's assessment for Cumulative VP9 fails to take account of the degree of change to the overall composition of the scene, which would be substantially more cluttered with turbines than would be the case if only the Middlewick turbines were developed.[90] Supplementary VP PI3 should be assessed as high-medium because very similar effects were so graded for PI2. Supplementary VPs PI4 and PI7 highlight concerns about the harmful compositional relationship between the proposed Turncole turbines and those already consented. The three wind farms would present as a cluttered mass of turbines, poorly related to each other in scale and distribution. This demonstrates how the Turncole proposal would tip the balance, forcing a quantum of wind farm development on this landscape that is beyond its capacity to accommodate satisfactorily.

Residential amenity

56. In combination with Middlewick wind farm the proposal would result in extreme cumulative effects on the outlook of Turncole Farm and Broadward Farm that would make them unpleasant places to live, contrary to LP Policies BE1 and PU6. This is illustrated in Supplementary Viewpoints PI 8-11. There would be no proper respite from an outlook consumed by turbines from any of the main residential areas in either property.[91] This would result in an unpleasant feeling of being entirely surrounded by wind turbines and the experience would be akin to living, sleeping and relaxing within a wind farm, which would not be consistent with the proper planning of the area. No test is prescribed by law or policy to determine whether the effects on residential amenity would be acceptable. It is ultimately a matter for the decision maker, who has a very broad discretion, having regard to the advice in *The Planning System: General Principles* ODPM 2005. However, in deciding whether residential amenity would be compromised to such an extent by visual effects that it would be in the public interest to refuse permission, it is not necessary to go so far as to show that the properties would be uninhabitable for the threshold to be met.

Cultural heritage

57. Scattered historic farmsteads are intrinsic to the historic character of the area. The proposed development and its cumulative impact with Middlewick and Bradwell wind farms would have a detrimental impact on this historic landscape and the wider setting of listed buildings in the area, contrary to LP Policies CC6

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[86] A comparative table by the landscape experts of their assessment of effects on viewpoints is at ID17.
[87] ES Figure 5.15D.
[88] ES Figure 5.16D.
[89] ES Figure 5.18D.
[90] ES Figure 5.23D.
[91] PoE2 section 5.

and BE1.

58. Heritage impact was not thoroughly tested at the Middlewick Inquiry; the Council did not put forward a heritage witness, the Inspector did not identify the impact on heritage assets as a main issue, and the decision predated English Heritage's (EH) advice on the setting of heritage assets.[92]

59. The Council's assessment methodology appropriately builds in consideration of significance into the assessment of magnitude of change, and does not overstate the relevance of visual change, which is a vital consideration in relation to setting.[93] The appellant's analysis is flawed because it does not, as a cultural heritage matter, deal with the detrimental impact of the proposal on the historic landscape. EH's *The Setting of Heritage Assets* sets out that setting embraces all the surroundings (land, sea, structures, features and skyline) from which the heritage asset can be experienced or that can be experienced from within the asset.[94] The wider landscape is not something that stands separately from setting, but can potentially be a fundamental part of the setting of a listed building.

60. The marshland on which the listed buildings in question were erected was reclaimed for agricultural purposes in the 18th century, and all, except for the Church of St James, were built shortly after the land was reclaimed to facilitate the agricultural use. These buildings are generally isolated and free-standing. A key part of the heritage significance of these buildings is their intimate connection with the reclaimed marshland. Their heritage significance does not lie primarily in their historic fabric. For example, if the buildings were to be dismantled and re-erected in the middle of Maldon, they would lose much of their heritage significance because of the loss of their intimate association with the marshland.

61. It is not sufficient to argue that the proposal would retain the working agricultural setting with fields and farms that contribute positively to the significance of the listed buildings, as this does not deal with how the Turncole proposal would impact visually on those settings. For example, it is plain that the aspect from Old Montsale could hardly be more open.[95] The suggestion that erecting wind turbines on this land would not have any impact on the setting of Old Montsale could not reasonably be made. In terms of the *Framework*, this would result in substantial harm to the setting from Turncole wind farm alone. Substantial harm would similarly result to Newman's Farmhouse. For Dammer Wick Farmhouse, Bridgewick Cottages, Court Farmhouse together with bake/brewhouse and barn, and Church of St James, Turncole wind farm alone would result in less than substantial harm to setting. With respect to the Church of St James the Council is concerned about views from the church.[96] Cumulatively with Middlewick wind farm substantial harm to setting would result to all the listed properties cited above, except for Dammer Wick Farmhouse.[97]

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[92] CD58 paragraphs 5 and 63-65. CD107.
[93] CD108 paragraph 119.
[94] CD107.
[95] PoE3 plate 3.
[96] Shown on ES Figure 5.18D.
[97] PoE3 section 5.

62. The judgment in *East Northamptonshire DC v SoS for CLG* [98] is a reminder of what must be done to ensure compliance with the statutory duty in section 66(1) of the Planning (Listed Buildings and Conservation Areas) Act 1990, which requires special regard to be given to the desirability of preserving the setting of a listed building. Paragraphs 133-134 of the *Framework* require a balancing exercise between harm and benefits, and should be approached with caution in the light of this judgment. The Council does not consider the approach in the *Framework* to be necessarily deficient, but for the purpose of the section 66(1) duty it will be necessary, when weighing the harm, whether substantial or not, to make clear that special regard has been paid in that exercise to the desirability of preserving the setting of listed buildings. This may lead to more weight being attached to the harm side of the balance than might have previously been considered appropriate.

Construction traffic and marine delivery route

63. The proposal would lead to noise and disruption from AIL and other construction traffic, particularly using Old Heath Road and the residential section of Marsh Road. Significant levels of tree and hedgerow removal would be needed along Old Heath Road, which would have a detrimental impact on the character and appearance of this narrow tranquil rural road.[99]

64. Insufficient justification has been provided to demonstrate why a marine delivery route for AIL, which is to be used in constructing Middlewick wind farm, cannot be accommodated as an alternative for AIL to Turncole wind farm. The local road network would be subject to an excessive increase in vehicle movements, which would have a detrimental impact upon the residential amenities of properties along the construction routes, contrary to LP Policies CC10, BE1, T2 and PU6.

65. In Appeal B (Fambridge) removal of trees and hedgerows and intensification of road usage and noise on Lower Burnham Road would harm the character and appearance of this rural road and the SLA. The proposal would also result in potential noise and vibration affecting the amenity of residential properties. The appeal scheme would be contrary to LP Policies CC6, CC7, CC10 and CON5.

66. In Appeal C (Twizzlefoot) construction traffic would lead to a significant increase in noise and disruption along the residential section of Marsh Road, to the extent that it would harm the residential amenities of occupiers of these properties, contrary to LP Policies BE1 and PU6.

67. The failure to adequately investigate the use of a marine delivery route is contrary to relevant policy.[100] Emails submitted during the Inquiry are the extent of evidence about the appellant's investigation.[101] These do no more than ask the relevant landowner to confirm the appellant's understanding that the owners were not willing to grant a right of marine access over their land. No investigation was undertaken to see if commitments made to other operators could be overcome. There is nothing before the Inquiry of any approach to the Middlewick wind farm developer directly to facilitate both developers having

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[98] ID12.
[99] PoE2 section 6 and ID22.
[100] As set out in section 4 of PoE4.
[101] ID35.1 and ID35.2.

marine access. This is a serious failure to comply with EN-3, which provides that it may be appropriate for developers to work together to ensure that AILs are managed to ensure that disruption to local residents and other highway users is reasonably minimised.[102] There is no evidence that the appellant investigated this option with anything like the degree of proactivity that it was reasonable to expect in the circumstances. The need for the extensive tree and vegetation removal adjacent to local roads has not been demonstrated.

Planning balance and policy

68. The proposal would be in breach of the development plan policies cited, and the *Framework* is a material consideration in deciding whether other material considerations are sufficient here to warrant granting planning permission notwithstanding the conflict with the development plan. Paragraph 14 of the *Framework* is triggered in this case because LP Policy PU6 is out of date. However, other LP Policies such as Policy CC6 and CC10 are of a general nature in relation to certain matters. There is nothing inherently in these generic policies that is considered out of date. But as paragraph 14 of the *Framework* applies planning permission should be granted unless (1) the adverse effects of doing so would significantly and demonstrably outweigh the benefits, or (2) specific policies in the *Framework* indicate that development should be restricted. Permission should be refused on both limbs.

69. Substantial weight should be given to the high level of support for RE projects, but paragraph 98 of the *Framework* provides that permission should only be granted if the impacts are (or can be made) acceptable. The totality of adverse impacts in terms of noise, landscape and visual harm, residential amenity, cultural heritage and transport implications, when assessed in the round, significantly and demonstrably outweigh the benefits, when assessed against the *Framework* as a whole.

70. Even if the test in the first limb is not met, permission should still be refused because on its own Turncole wind farm would result in substantial harm to the setting of two heritage assets, and in combination with the Middlewick wind farm substantial harm would be caused to the setting of three other Grade II listed buildings. Paragraph 133 of the *Framework* provides that permission should be refused unless it can be demonstrated that the substantial harm or loss is necessary to achieve substantial public benefits that outweigh that harm or loss. The proposal would make a contribution to the wider benefits of generating RE, but in isolation, the extent of that contribution would not result in 'substantial public benefits'.

71. In any event, it is not accepted that any substantial benefits would outweigh the harm caused. Two features of this case distinguish it from a typical wind farm assessment pursuant to paragraph 14 of the *Framework*; the public interest in avoiding the very substantial harm to the residential amenity of the occupiers of Turncole Farm and Broadward Farm, and the startling inadequacy of efforts to mitigate the transport impacts of the scheme.

72. The PPG cancels PPS22CG, but EN-1 and EN-3 still apply, and the June 2013 Ministerial written statements have not been superseded or withdrawn. The PPG

[102] EN-3 paragraph 2.7.82.

can be treated as an annex to paragraph 98 of the *Framework*, which provides that applicants are not required to demonstrate the need for RE development. But the PPG indicates that when a decision is finely-balanced consideration may now be given to the energy contribution that would be made by the proposal. This concerns the relative efficiency of the installation. The Inquiry heard little evidence about this, other than in reference to reduced capacity were a noise constraint to apply, which was not fully tested at the Inquiry. The PPG gives added weight to the Council's case concerning impact in an extremely flat landscape, and in recognising that turbines within the setting of a heritage asset may cause substantial harm to the significance of the asset.[103]

73. Appeal A should be dismissed because of conflicts with the development plan and, having considered the *Framework* in particular, there are no material considerations that would warrant a different outcome. Appeals B and C should be dismissed as their primary purpose is to facilitate Appeal A.

The case for the appellant

The appellant considers the main issues here concern noise, cultural heritage, residential amenity, and landscape and visual effects. The main points are as follows.[104]

Noise

74. Issues raised by SIEGE concerning background noise measurements, noise predictions and sleep disturbance have been appropriately addressed.[105]

75. The Council relies on paragraph 123 of the *Framework* and section 5.11 of EN-1, along with the aims of the NPSE, in its approach to the need to avoid significant negative impacts on amenity from operational noise. But the advice about wind farm noise is crystal clear. ETSU-R-97 should be used to assess and rate noise from wind farms.[106] EN-3 advises that where the correct methodology has been followed and compliance with ETSU-R-97 demonstrated, it may be concluded that little or no weight should be given to adverse noise impacts.[107] This is particularly important because it acknowledges that there may be adverse noise impacts which in policy terms will nonetheless be acceptable.

76. On the basis that ETSU-R-97 alone should be used, the only dispute between the noise experts is whether the day-time fixed noise limit should be 36 dB or 38 dB for Turncole wind farm alone, and therefore whether the allowable cumulative noise level for Turncole wind farm with Middlewick wind farm should be 38 dB or 40 dB. The latter is to be preferred having regard to the three factors advised in ETSU-R-97 for determining the appropriate fixed noise level.[108] Firstly, there are comparatively few houses which would receive noise levels in excess of 35 dB.[109] The second factor concerns the effect of noise limits on electricity generation, and there is uncontested evidence that a 1 dB reduction in the noise limit here would

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[103] ID44.2.
[104] Based on closing submissions at ID40.
[105] PoE9 and ID41.2.
[106] EN-3 paragraph 2.7.56.
[107] EN-3 paragraph 2.7.58.
[108] PoE9 paragraphs 5.29-5.33.
[109] SEI Figure 1.2.

result in a 12% loss of annual energy generation.[110] This is an imbalance that points to allowing a 40 dB cumulative level. Finally, with respect to the duration and level of exposure, there is a very strong WSW to SSW prevailing wind. Only three of the 10 properties considered lie downwind of the prevailing wind direction for the proposed Turncole turbines.[111] Of these Turncole Farm and Broadward Farm are financially involved with the scheme, the other, Montsale Bungalow, would receive wind farm noise immission levels of less than 33 dB at all relevant wind speeds, even in the prevailing wind direction when downwind of Turncole wind farm. No property could be downwind of Middlewick wind farm and Turncole wind farm at the same time, such that the cumulative effect would be significant. The duration and level of exposure to noise from Turncole wind farm of any property, save for those financially involved, above 35 dB, would be very limited. There is strong evidence that a day-time fixed noise limit of 38 dB for Turncole wind farm would be appropriate.[112]

77. SIEGE requested a condition to regulate OAM, but the Council makes no such request and does not engage on this topic. There is no evidence to warrant the imposition of an OAM condition. In the two appeals where such conditions have been imposed, *Denbrook* and *Swinford*, the conditions either do not work, or are imprecise and unenforceable.[113]

Cultural heritage

78. The planning officer did not recommend an objection based on cultural heritage, and the Council's reason for refusal of the Turncole wind farm was not specific about the particular listed buildings which the Council Members had in mind.[114] The Council's Statement of Case did not identify the listed buildings of concern, and this was not clarified until publication of the SoCG. Insofar as the Council's evidence to the Inquiry represents the position of the Members, it should be treated with caution because it emerged after the Members' decision and was not referred back to them. No case was made at the Inquiry of a detrimental impact on the historic landscape, and no evidence has been adduced about any cumulative impact of Turncole wind farm with Bradwell wind farm.

79. There was no reason for refusal on cultural heritage grounds in the Middlewick wind farm application, and the Inspector found no harm would be occasioned to heritage assets by that development, notwithstanding that the Middlewick ES did find significant impacts on some listed buildings.[115] The Council's case in the Turncole wind farm Inquiry raises concern about the in-combination effect of Turncole wind farm and Middlewick wind farm, but does so without any assessment of harm to the significance of cultural heritage assets from the impact of Middlewick wind farm alone. This is a major omission. Court Farm, Bridgewick Cottages and the Church of St James Dengie are much closer to the site of Middlewick wind farm than to that of the proposed Turncole wind farm,

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[110] Based on the analysis for Wraywick Farm ID18.
[111] The 10 properties are included in Table 8 of Appendix C PoE9, which assumes downwind propagation at all times. The location of the dwellings is shown on ES Appendices Figure 3.2.
[112] This would result in the noise limits set out in the appellant's proposed noise limits for Table 1 Condition 24 at ID4.7.
[113] CD39 and CD65.
[114] CD14, CD17 and CD20.
[115] CD58 and CD115.

and if these properties would not be harmed from Middlewick wind farm then that is good evidence that they would not receive harm from Turncole wind farm.

80. There are very clear differences between the appellant's and the Council's method of assessment for cultural heritage impacts.[116] The appellant's should be preferred because the Council's approach; (1) relies on an assessment of sensitivity in which an essential link between the level of change and the contribution of setting to significance is lost, (2) assesses levels of change (magnitude) on a visual basis without reference to the contribution that setting makes to significance [117], (3) deals only with visual amenity as opposed to the significance of the cultural heritage asset [118], and (4) does not reflect revised guidance [119].

81. A wider setting does exist for the post-reclamation Grade II listed farmhouses seen in a farming environment, but overall the contribution of setting to significance is very local given the type of listed buildings. The landscape has evolved and contains modern agricultural buildings, modern fencing, and evidence of modern cultivation methods. Newman's Farmhouse and Dammer Wick Farmhouse do not lie in the same open marshland as the other properties and are located close to the boundary of the D8 landscape character area. Overall, considering Turncole wind farm alone, or cumulatively with Middlewick wind farm, either additionally or in-combination, there would be no harm to the significance of listed buildings. In the absence of harm no balancing exercise applies under the *Framework*.

82. There is a tension between section 66 of the Planning (Listed Buildings and Conservation Areas) Act 1990, as applied in the *Barnwell* judgment, and the advice in the *Framework*.[120] The statutory requirements refer to a listed building or its setting, while the *Framework* refers to harm to significance. However, nothing in the *Barnwell* judgment imports a substantive test into section 66. It remains a requirement to pay particular attention to the desire expressed in the section. The substance of the tests relating to harm and substantial harm in the *Framework* are matters of policy, and are quite separate from the statutory requirements. Nonetheless, if harm arose to the significance of a listed building, which resided in any impact on setting, planning permission might still be granted based on the need for, and benefits of, the proposed wind farm. The *Framework* presumes in favour of granting permission for RE development. In this case there is nothing within the evidence or the law which should lead to a refusal of permission on the basis of harm to the significance of any cultural heritage asset.

Residential amenity

83. The visual component of residential amenity has been debated at many wind farm inquiries and the issue has reached maturity.[121] The test is whether or not

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[116] PoE12 Appendix 2 and PoE3 Appendix 1.
[117] PoE3 paragraph 4.16.
[118] PoE3 Appendix A.
[119] CD107 and CD108.
[120] *Barnwell Manor* wind farm appeal decision at CD60 and High Court judgment at ID12, which is now a matter for the Court of Appeal.
[121] PoE10 Appendix 1 and the *Burnthouse Farm* decision at CD47 paragraph 10.

the proposed development would affect the outlook of residents to such an extent i.e. be so unpleasant, overwhelming and oppressive, that the residence would become an unattractive place to live. There is no specific development plan policy in this case which sets out a test in different terms. Furthermore, the test is not whether a house would become less attractive to inhabit, but unattractive. That is not to say that significant visual effects on residents are not a material consideration if they fall short of converting a property into being 'an unattractive place to live'. It might be that in a particular case significant visual effects on a number of houses falling short of an impact on residential amenity would carry sufficient weight to warrant at least a careful approach to the planning balance. But that would be a very different issue from residential amenity.

84. The issue here is the impact on the visual component of the residential amenity of Turncole Farm and Broadward Farm, where the occupiers have a financial interest in the appeal scheme. In other appeal decisions judgements about residential amenity have been influenced by the financial involvement of the occupiers.[122] There is nothing wrong in law with this approach, and ETSU-R-97 takes a similar approach with respect to noise.

85. It is common ground between the Council and the appellant that Middlewick wind farm alone has been found to be acceptable, and that Turncole wind farm alone would also be acceptable. The only issue relates to their cumulative impact. There are only 13 properties within 1 km of the proposed turbines. None of the dwellings in relative proximity to the site would be affected by views of the turbines, including in combination with Middlewick wind farm, to the extent that there would be unacceptable harm to residential amenity from a visual perspective.[123] If, on the contrary, it was necessary to do so, taking into account the financially involved status of Turncole Farm or Broadward Farm, neither would become an unattractive place to live.

86. A shadow flicker assessment predicts that only Turncole Farm could experience such an effect; from T4 for up to 16 minutes per day during the afternoon from mid to late December.[124] However, the actual amount would be likely to be much less because of times of cloud cover and variation in the orientation of blades. Shadow flicker could be addressed by a condition which required the avoidance of such effects.[125]

Landscape and visual effects

87. The third edition of GLVIA does not engage with landscape capacity, and is solely concerned with the landscape and visual impact of projects.[126] The East of England Regional Assembly publication *Placing Renewables in the East of England* is therefore of limited assistance.[127] It is clear that there is some capacity for wind energy development in the area.[128]

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[122] *Middlewick* CD58 paragraph 31 and *Gayton-Le-Marsh* ID16 paragraph 49.
[123] PoE10 section 6.
[124] ES section 12.7.
[125] ID4.7 Condition 18.
[126] ID14.
[127] CD87.
[128] Natural England's consultation response at CD94.

88. GLVIA provides that cumulative impacts may be assessed either incrementally or in combination, but an incremental effects assessment is crucial in assessing the impacts of Turncole wind farm on the relevant baseline. A pure in-combination effects assessment can easily stray into issues of capacity. The emphasis must always remain on the main project being assessed, and whether it would add to or combine with others to create a significant cumulative effect.[129] The Council does not assess the incremental landscape effects of Turncole wind farm, but assesses landscape effects purely on an in-combination basis. This contrasts with the Council's approach to visual effects, which assessed impacts on an additional or incremental basis.

89. Furthermore, the Council's assessment makes no attempt to evaluate the proposed development against the key characteristics of the landscape character area, which are a sense of huge sky, sound of birds, tranquillity and panoramic views across the marshland and out to sea. However, with respect to tranquillity, the Inspector in the Bradwell wind farm appeal found that the area was one which most people would recognise as being tranquil in a general sense.[130] This degree of tranquillity applies to the site of the proposed Turncole wind farm.

90. The Council's landscape assessment finds that in combination Turncole wind farm would breach a critical threshold of acceptability.[131] But this does not take into account Middlewick and Bradwell wind farms in development baseline information, and is a capacity finding without a capacity study. It is not possible from the Council's visual impact assessment to determine the additional effects of Turncole wind farm on a baseline of Middlewick wind farm and perhaps Bradwell wind farm. Impacts on receptors such as individual residents and settlements from viewpoints should be determined, and the Council's broad conclusions, such as a finding of major significance from cumulative visual effects for residents within the Marshes, are unhelpful.[132] This is important because it means that the evidence of the landscape experts cannot be compared on a like-for-like basis.

91. Landscape and visual effects are summarised as follows.[133] Effects on landscape elements would be negligible with only limited removal of some roadside vegetation. Turncole wind farm would mainly affect an area of landscape already significantly affected by Middlewick wind farm. Changes would be of low magnitude and of moderate-slight significance to the edges of character Area D8 to the east of Burnham-on-Crouch and Southminster. The host landscapes Areas D7 and D8 will have turbines as a key characteristic across the two areas as a result of the permitted wind farms. Adjacent landscapes to the east and west would already have views of turbines from most of the areas that would also be affected Turncole wind farm. Cumulatively there would be a slightly intensified effect at the southern end of character Area D8.

92. Turning to visual effects there would be localised significant effects on views from local receptors, including PROW and residents up to 3-4 km from the proposed turbines. However, in such a flat landscape the visibility of turbines disappears more quickly than in other landscapes due to the layering effect of hedgerows

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[129] GLVIA Paragraph 7.28 at CD14.
[130] CD57 paragraph 18.
[131] PoE2 paragraph 3.57.
[132] PoE2 paragraph 4.67.
[133] PoE 10 section 6.

and trees intercepting sightlines. Most of the receptors in the area would be affected by the significant visual effects of Middlewick wind farm.[134] Significant visual effects from Turncole wind farm would be limited in their extent, magnitude and number of receptors affected.[135] However, in a few locations the turbines would give rise to effects of major-moderate significance.[136]

93. The impacts of Turncole wind farm would be acceptable, and nothing has been demonstrated to indicate that the development would give rise to landscape character and visual impacts above and beyond those of the many wind farms which have secured permission.

94. With respect to the local environmental impact of highway works, contested evidence concerning trees is limited to the likely effects on Trees 10 and 11, and Tree Group 32 and 33.[137] There is evidence from a qualified and experienced arboriculturist that Trees 10 and 11 could be safeguarded by condition.[138] Trees within Group 32 would be very likely to be lost, but there are no specimen trees and some of the trees are already damaged by passing vehicles. The proposed highway works in Appeal B would result in the loss of a semi-mature ash tree and up to 60 m of hedgerow, but this is described as a 2 m wide mature species-poor hedgerow, which is dominated by diseased elm with blackthorn, hawthorn and field maple.[139] This and other losses of roadside vegetation would not be unacceptable given the impacts of Dutch Elm Disease, along with the obligation of the highway authority to maintain a cleared height along public roads. There is also potential for replanting at the Fambridge South bend;[140] and to some extent along the remainder of the Appeal A access route. The impacts of Appeals B and C, and the highway improvements in connection with Appeal A would cause no landscape character effect of any significance and would be acceptable in terms of local environmental effects.

Other considerations

95. The Council contends that the appeal scheme should use the same route, or another marine delivery option, as that to be used by Middlewick wind farm, involving landing AIL on the south coast of the Dengie peninsula on land managed by Strutt and Parker Farms. The Council's case that there is insufficient justification for not pursuing a marine delivery route for AIL is not a main issue because approaches to the only landowners who could provide such a route, given the extensive mud flats on the east coast of the peninsula, were rebuffed.[141] The appellant had to commit to a scheme at the appeal stage, and use of a marine landing site would have required an additional planning permission. The Council's reliance on national planning advice about developers working together to manage AILs does not take into account that the promoters

134 Viewpoints 2 and 6.
135 Viewpoints 1, 3 and 5.
136 Viewpoint 4.
137 SEI Figure 3.2 Detail 8, Detail 9 and Detail 13. PoE11 Appendix 6 Photographs 3 and 4 show Groups 32 and 33, Tree 10 is included in Appendix 5. Tree 11 is shown on ID15.1.
138 PoE11 and ID4.7 Condition 6.
139 SEI Volume 1 Text Table 1 page 43.
140 ID34.
141 ID35.1 and ID35.2.

of Development Consent Orders have compulsory purchase powers.[142] This is not an option for the appellant, who cannot compel an owner to cooperate.

96. The transport assessment in the SEI found that construction traffic would not result in a significant increase in traffic volumes on local roads. AIL would be escorted and the Highway Authority does not consider that it would result in an unacceptable risk to highway safety. Local fears about traffic chaos and danger at school arrival and leaving times at the junction of Southminster Road and Marsh Road do not take into account that not all construction traffic would arrive by this route. There would only be 49 one-way movements of AIL, involving activity over a total of 1-2 weeks using the proposed widening in front of the entrance to St Mary's Church. Undue disruption could be avoided by conditions limiting the use of this widened junction to AIL and controlling movements at school arrival and leaving times.[143] No evidence was brought by the Council about construction traffic noise in support of its reasons for refusal, and the appellant's technical evidence on this is uncontested.[144]

97. Ecological issues raised by SIEGE and the RSPB have been addressed and there are no residual concerns.[145] The implementation of habitat management within the site under a scheme to be approved would result in a net ecological benefit for the site, and post construction monitoring of birds would be required by the suggested condition.[146]

98. An initial objection from Southend Airport concerning possible radar interference was withdrawn, and there is evidence of a reasonable prospect of mitigation being installed.[147] This is a matter that can be addressed by condition.[148] The objection from the operator of the grass airstrip at Burnham Wick Farm has also been withdrawn on the basis that fixed wing operations would be relocated to an alternative site.[149]

Planning balance and policy

99. Pursuant to the Renewable Energy Directive of 2009, the UK Renewable Energy Strategy 2009 and the Renewable Energy Roadmap 2011/2012, there is the clearest expectation that at least 30% of all electricity consumed in the UK must come from renewable sources by 2020.[150]

100. Section 38(6) of the 1990 Act applies, but other material considerations in the form of national policies are far more important than those of the LP in this case. LP Policy PU6 is in effect an embargo on wind farm development because of the requirement that there should be no significant visual impact.[151] Policy PU6 is not consistent with the *Framework,* and very little weight (in terms of the impact on the character and appearance of the area) should therefore be given to it.

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[142] EN-1 paragraph 5.13.10 and EN-3 paragraph 2.7.82.
[143] ID4.7 Conditions 6 and 7(h).
[144] PoE9.
[145] WR5.
[146] ID4.7 Conditions 17 and 21.
[147] ID33.
[148] ID4.7 Condition 22.
[149] ID11 and ID36.
[150] PoE13 Section 3 and Appendix 1.
[151] CD57 paragraph 31.

Emerging Policy D4 has a similar limitation in that it requires 'no adverse impacts on locally designated sites', but in any event this can be given little weight at present.[152] Policy PU6 requires no unacceptable effects in terms of noise and traffic, but is deficient in terms of the tests applied to cultural heritage and residential amenity. Policy PU6 refers to acceptability and ultimately defers to EN-3, since this can only be assessed by reference to specific guidance on operational wind farm noise.

101. Policy CC6 concerning landscape protection should be given little or no weight because it is irrelevant to the reasons for refusal and contains a 'no harm' test contrary to the *Framework*. Similarly, LP Policy CC7 concerning the SLA should be given very little weight as the 'conserve and enhance' development control test, if it means no harm should be occasioned, compares unfavourably with paragraph 2.7.48 of EN-3. SLAs were abandoned for the structure plan in 2001, and the designation is not carried forward in the emerging plan. There is no clarity about the reasons why the designation was made. Amplitude of relief, vegetation and presence of water were valued in the 1985 designation, but these features are notably absent in the area of the Dengie Marsh.[153]

102. Policy BE1 deserves no weight as the policy and supporting text only refers to new buildings, and it was never intended to apply to plant or machinery. Policy CON5 is concerned only with pollution unrelated to noise and so is not relevant. Policy T2 is of marginal help, notwithstanding that it deals with off-site highway improvements, because there is no development control test within it. Adequate highway information has been submitted. Policy CC10 concerns historic landscape features, but the Council makes no case on this issue. No weight should be given to Policy CC11, dealing with the coastal zone in purely locational terms, on the grounds that it is not consistent with the *Framework*.

103. The proposed development would breach several provisions of the development plan, but the appeals should be determined by reference to national guidance; the *Framework*, and via it to EN-1 and EN-3, along with the recent PPG. Likely impact here does not go beyond what is expected for any wind energy development with associated highway access works.[154] The balancing exercise for cultural heritage in paragraphs 133 or 134 of the *Framework* is not required. Proposed conditions would require the decommissioning of development, and paragraph 2.7.43 of EN-3 recognises the materiality of reversibility. Operational noise could comply with appropriate rating levels under ETSU-R-97.

104. The paragraph 14 *Framework* presumption in favour of sustainable development applies to wind energy development, so planning permission should be granted unless adverse impacts would significantly and demonstrably outweigh the benefits when assessed against the policies in the *Framework* taken as a whole. In doing so close regard should be given to paragraph 93, which provides that the delivery of RE is essential to the economic, social and environmental dimensions of sustainable development, and to paragraph 98, which favours proposals where impacts are, or can be made, acceptable. The presumption in the *Framework* is more powerful than previous advice in PPS22

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[152] CD23b and ID32.
[153] CD90.
[154] EN-1 paragraphs 5.9.8 and 5.9.14-5.9.18.

that significant weight should be given to the need for and benefits of RE development.

105. Nothing in the PPG creates a different approach in planning policy terms to the determination of proposals for wind farms.[155] The Council did not challenge the material on capacity factors submitted to the Inquiry, in which it was calculated that the power output would be 46.5 GWh/yr if Vestas V90 1.8 MW candidate turbines were used.[156] SIEGE did not raise issues concerning the merits of alternative wind farm sites or infrasound at the Inquiry. Consultation and engagement was undertaken with the local community before the wind farm application was submitted.[157]

106. This is not a case where there is overwhelming local objection to the proposal. There was support at the Inquiry.[158] At the application stage there were 270 expressions of support, set against the 470 expressions of opposition. There is a compelling case for allowing the appeals on the basis of the policy in the *Framework*, along with EN-1 and EN-3.

Written representations

Application stage

107. The Council received about 470 letters objecting to, and about 270 letters supporting, the proposed development in Appeal A.[159] The application was opposed by 18 Parish and Town Councils, but supported by one Parish Council.[160] In Appeal B five written submissions against the proposal were submitted to the Council at the application stage, along with objections from North Fambridge Parish Council and Cold Norton Parish Council.[161] In Appeal C there were five written submissions opposing the development and objections from Southminster Parish Council and Burnham-on-Crouch Town Council.[162]

Appeal stage

108. There were 71 written submissions at the appeal stage about Appeal A. These raise concerns similar to those expressed by the Council and SIEGE, but also refer to the impact of construction vehicles on the wider road network, health issues and shadow flicker from turbines, along with concerns about wildlife and nature conservation. At the appeal stage 28 written representations were submitted about the SEI in respect of Appeals B and C. In summary these

[155] ID44.1 and ID44.4.
[156] ID18.
[157] ES sections 3.7 and 3.8.
[158] ID27.
[159] These are summarised on pages 46-48 and pages 53-54 of CD14.
[160] Objections were submitted by Southminster Parish Council, Burnham-on-Crouch Town Council, Tillingham Parish Council, Asheldham/Dengie Parish Council, Bradwell-on-Sea Parish Council, Maryland Parish Council, Latchingdon Parish Council, Althorne Parish Council, Purleigh Parish Council, Cold Norton Parish Council, Stow Maries Parish Council, Woodham Walter Parish Council, Maldon Town Council, Langford & Ulting Parish Council, Little Braxted Parish Council, Goldhanger Parish Council, Tolleshunt Major Parish Council, Tolleshunt Knights Parish Council. St Lawrence Parish Council supported the proposal. A summary of these submissions is set out in pages 8-17 of the Council's Committee report at CD14.
[161] CD15 and CD18.
[162] CD16 and CD19.

concerned road safety, noise, vibration and disturbance, along with loss of roadside vegetation.

Consultees [163]

109. Natural England (NE) withdrew its initial objection subject to conditions on biodiversity enhancement, mitigation measures and monitoring. Furthermore, NE does not consider that there would be any likely significant effects on designated European sites or protected species. NE considers that the openness and tranquillity of the landscape contribute to its high sensitivity to change, and that in such a flat landscape any vertical structure would be highly prominent. However, NE acknowledges that the turbines would not break or interrupt any significant feature of the skyline, and that very open landscapes have a greater capacity for wind turbine developments. On balance, NE found that the Dengie peninsula has a greater capacity to accommodate wind farm energy, and raised no objection to the appeal proposal on landscape grounds.[164]

110. The Royal Society for the Protection of Birds (RSPB) withdrew it previous objection subject to the imposition of appropriate planning conditions, but sought agreement on post-construction monitoring by means of a section 106 agreement.

111. The Environment Agency (EA) has no objection subject to an approved Working Method Statement.

112. The Highway Authority initially objected, but the details in the SEI addressed its concerns, and there is no objection to the proposal subject to conditions dealing with, amongst other things, a construction/decommissioning traffic management plan, site access details, and before and after survey. There is no objection regarding Public Rights of Way.

113. English Heritage (EH) advised that the proposal has been considered by its specialist staff and that it did not wish to offer any comments, other than that the proposal should be determined in accordance with national and local policy guidance, and on the basis of the Council's specialist conservation advice. The latter provides that the seven wind turbines and associated infrastructure within the historic, natural landscape, would have a significant impact on the setting of a number of listed buildings, given that the historic buildings on the Dengie were mostly associated with agricultural use of the reclaimed marshes.

114. The Civil Aviation Authority advised on procedural matters, but left it for others to comment on the proposal. The Ministry of Defence (MoD) has no objection, but requested notification if planning permission was granted so that information could be plotted on flying charts. National Air Traffic Services (NATS) advised that the proposal would not conflict with NATS safeguarding criteria and, therefore, no objection was raised. London Southend Airport initially objected to the proposal, but indicated that this could be withdrawn if appropriate mitigation measures were identified. The wording of a suitable condition was subsequently agreed. There is no objection from London Stansted Airport.

[163] Responses are included in the Questionnaire.
[164] CD94.

115. The Joint Radio Company (on behalf of UK Power Networks and National Grid Gas Networks) does not foresee any potential problems concerning interference.

Conditions and obligations

116. The Council and the appellants in earlier versions of the SoCG agreed suggested conditions in the event that the appeals were to succeed and planning permission to be granted. SIEGE participated in the without-prejudice round table discussion at the Inquiry about suggested conditions. I also questioned the wording of some conditions. The discussion had regard to Circular 11/95 *The Use of Conditions in Planning Permissions*. The outcome of the discussion was a revised list of suggested conditions.[165] These are dealt with in more detail in the Conclusions section of this report.

117. No planning obligation pursuant to section 106 of the 1990 Act has been submitted. No submissions were made at the Inquiry that an obligation would be necessary in this case. I asked at the Inquiry whether an obligation would be required to regulate traffic routing, but there was no dispute that this could be addressed by a condition requiring a scheme of traffic movement. The RSPB submission refers to an obligation for monitoring, but this is also a matter that could be the subject of a condition.

My Conclusions begin on page 33 of this report.

[165] A final version setting out matters in dispute is at ID4.7.

Conclusions

Preliminary matters

118. The following conclusions are based on the evidence given at the Inquiry, the written representations and my inspection of the site and its surroundings. In this section the figures in parenthesis [ ] at the end of paragraphs indicate source paragraphs from this report.

Environmental Impact Assessment

119. The ES and SEI reasonably comply with the relevant provisions of the EIA Regulations. Given that the appeals are linked, they should be either all allowed or all dismissed. [1,2,73]

Main considerations

120. The three appeal schemes relate to a single proposal. The linked development means that the main considerations apply to the totality of the proposal. In the absence of any matters set out, about which the Secretary of State particularly wishes to be informed for the purposes of considering these appeals, the evidence indicates that the main considerations here are as follows. [1,16]

(1) The effects of the proposed development on its own, and in combination with other existing and permitted wind turbines in the locality, on

- a) The character and appearance of the area, having regard to policies for countryside protection.
- b) The living conditions of nearby residents, with particular reference to;
  - (i) outlook;
  - (ii) noise and disturbance;
  - (iii) other living conditions considerations.
- c) Heritage assets.
- d) Air safety.
- e) Nature conservation and biodiversity.
- f) Highway safety.
- g) Other considerations.

(2) Whether sufficient justification has been provided to demonstrate why a marine delivery route for abnormal loads cannot be accommodated as an alternative.

(3) The compatibility of the proposed development with national and local policy in respect of the generation of energy from renewable sources.

(4) Whether any benefits of the scheme would be sufficient to outweigh any harm that might be caused.

(5) The extent to which the proposed development would be in accordance with the development plan for the area.

(6) The extent to which the proposed development would be in accordance with the *National Planning Policy Framework* (the *Framework)*.

(7) Whether any permission should be subject to any conditions or obligations and, if so, the form that these should take.

(8) Overall conclusions.

The remainder of this report addresses the matters outlined above, and my recommendations are based on these findings.

(1a) Character and appearance

Landscape and visual impact assessments

121. The methodologies used in compiling the expert landscape and visual impact assessments (LVIA) submitted by the Council and the appellant do not provide for a direct like-for-like comparison of sensitivity, magnitude, and significance of effects. Furthermore, these pre-date the Landscape Institute's third edition of the *Guidelines for Landscape and Visual Impact Assessment* (GLVIA). [4,51,90]

122. EN-1 acknowledges that it will not be possible to develop necessary large-scale energy infrastructure without some significant residual adverse impacts.[166] The relative scale of wind farms might be open to some interpretation, but what is relevant here is that the appeal scheme comprises seven very tall structures. The PPG advises that cumulative impacts require particular attention. It adds that cumulative landscape impacts are the effects on the fabric, character and quality of the landscape, and is concerned with the degree to which proposed development would become a significant or defining characteristic of the landscape. Cumulative visual impacts concern the degree to which development would become a feature in particular views or sequence of views, and the impact upon people experiencing those views.[167] GLVIA Chapter 7 deals with cumulative effects, and refers to definitions used in *Assessing the Cumulative Effect of Onshore Wind Energy Developments.*[168]

123. There was some debate at the Inquiry about what should be the baseline here for any assessment. GLVIA provides that the baseline for LVIA of a project comprises existing schemes and those which are under construction. In this case the LVIA baseline includes the turbine at Southminster and those erected or under construction at Bradwell. The baseline for assessing cumulative landscape and visual effects (CLVIA) according to GLVIA should include those schemes considered in the LVIA baseline and, in addition, potential schemes that are not yet present in the landscape, but for which planning permission has either been applied for, or been granted. This would include the permitted Middlewick wind farm. GLVIA recognises that CLVIA could focus on either additional effects of the appeal scheme on top of the cumulative baseline, or the combined effects of all the past, current and future proposals together with the appeal scheme.[169] Both should be assessed in this case because the Dengie peninsula is recognised as a distinct part of the coastal landscape, where incremental and combined effects would need to be considered. This section of the report is therefore structured as follows. In dealing with landscape character the solus effects of the appeal scheme are considered first, followed by an assessment of cumulative effects,

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[166] EN-1 paragraph 3.2.3.
[167] PPG paragraphs 39 and 40.
[168] Published by Scottish Natural Heritage in 2012 at CD80.
[169] ID14 paragraph 7.18.

with the latter having regard to both additional and combined effects. The same approach is then undertaken for visual effects. [12,51,52,88,90]

124. GLVIA notes that people living in an area might be affected by changes in views and visual amenity, and that the visual receptors most susceptible to change are likely to include residents at home or engaged in outdoor recreation.[170] It adds that effects on private property are frequently dealt with through 'residential amenity assessments', which are separate from LVIA. GLVIA provides that visual effects assessment may sometimes be carried out as part of a residential amenity assessment, in which case it would supplement and form part of the normal LVIA for a project.[171] This distinction is recognised by dealing in this section with the visual amenity of residents as a character and appearance issue, and dealing separately with deprivation of outlook from specific dwellings as a living conditions issue later in this report.

125. The GLVIA defines landscape receptors as aspects of the landscape resource with potential to be affected by the proposal. Visual receptors are individuals or groups of people with potential to be affected by the proposal. For both landscape and visual effects the GLVIA methodology combines sensitivity of receptors (value of receptor/particular view and their susceptibility to the change proposed) with magnitude of effects (size/scale, geographical extent, duration and reversibility of effects) to indicate the significance of effects.[172]

126. The 2008 ARUP study for the East of England Regional Assembly considered that Area 81 Greater Thames Estuary, given the large scale, relatively simple nature of this landscape, but with a degree of remoteness, had a medium sensitivity to commercial scale turbine development.[173] This study is useful as background information for considering LVIA sensitivity, but as the GLVIA emphasises, it is not a substitute for the individual assessment of the susceptibility of the receptors in relation to change arising from a specific development proposal.[174] Therefore, little weight should be given to ARUP's capacity estimate of a maximum of 18 turbines for Area 81, which is based on examination of a separation distance of 10 km between wind farms for sparsely populated, less sensitive landscapes. [53,87]

127. EN-3 advises that the length of time the development would be operational is a material consideration. The appeal scheme would have a limited duration of 25 years, and conditions could ensure that decommissioning reversed significant harmful effects. However, this would be a substantial period for those who would have to endure any adverse effects from the proposed wind farm. Turncole wind farm would be a long-term development and the reversibility of the scheme should not be an influential factor in determining these appeals. [103]

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[170] ID14 paragraphs 6.13 and 6.33.
[171] ID14 paragraphs 6.17 and 6.36.
[172] The ES uses a four point scale for significance of major, moderate, slight and minimal; but the terminology suggested in the GLVIA (paragraph 3.34) should be preferred, which is major/moderate/minor/negligible. The ES categorises sensitivity as high, medium or low; and magnitude as high, medium, low or negligible and these terms are used in this report (ES Appendices paragraph 5.1.23).
[173] PoE2 Appendix 8 page D7.
[174] CD14 paragraph 5.41.

Landscape character

128. The area is valued for its perceptual qualities and for some recreational activities like walking and cycling, where experience of the landscape is important.[175] This is reflected in its SLA and Coastal Zone designation, the latter with strongly protective policy seeking to maintain the open and rural character of the coastline. The basis for the SLA designation is not fully transparent, but it is likely to have been influence by the perceptual qualities of the area, and so it is a consideration which should be given weight.[176] The *Essex Historic Environment Characterisation Project* defines character areas with a particular focus on the historical integrity present in the landscape. However, it is not very helpful in assessing the landscape effects from the proposed wind farm in its agricultural context.[177] [13,14,54,101]

129. The baseline for assessing the solus effects of the appeal scheme on the local landscape includes the turbines already erected and those under construction. Relevant landscape receptors for landscape character Area D8 Dengie Drained Estuarine Marsh include its large scale and lack of complexity, along with a sense of openness and huge sky. National Character Area 81: Greater Thames Estuary is described as having a strong feeling of remoteness and wilderness on the open beaches and salt marshes, on the reclaimed farmed marshland and also on the mudflats, but the Dengie peninsula is mostly a settled agricultural area. Its restricted access gives it a feeling of remoteness, but not of wilderness, because it is largely drained arable farmland with some large agricultural buildings. The openness of the area contributes to its tranquillity, but agricultural activity and vehicles are intrusive at times. The proposed turbines would have little effect on the fabric of the landscape, but would add tall structures that would introduce movement and noise. There would be some adverse effects on tranquillity. However, the size of the turbines, given their simple and slender form, would not be out of scale with the vast skies and openness of the area. In my view landscape character Area D8 has medium sensitivity to the proposed development. The SEI states that if Turncole wind farm was to be considered alone it would result in a high magnitude of landscape effects and major/moderate significance within an area about 1 km from the turbines (with medium-low sensitivity). It also found that medium magnitude and moderate significance would extend some 2.3 km to 3 km from the turbines.[178] My site visits indicated that the solus effects of the appeal scheme would be of moderate significance to landscape character Area D8 as a whole. [13,14,18,52,89]

130. Landscape character Area C3 Dengie Flats Estuarine Marsh/Mudflats is an inter-tidal landscape and its character is influenced by the changing colours of the sea and sky. The proposal would only affect the southern part of this area, and with medium sensitivity and a low magnitude of effect, the appeal scheme would be of moderate/minor significance. There is a marked transition in topography between landscape character Area D8 and Area E2, with the latter characterised by gently undulating farmland, locally quite steep, located behind the coastal marshland. Only the south-eastern part of this area would be

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[175] Taking into account all the factors set out in Box 5.1 page 84 of GLVIA CD14.
[176] CD90.
[177] PoE2 Appendix 5.
[178] SEI paragraphs 5.3.15 and 5.3.16.

affected by the appeal scheme because of the topography and intervening vegetation and buildings within settlements. With medium sensitivity and a low magnitude of effect, the appeal scheme would be of moderate/minor significance. Landscape character Area D7 Bradwell Drained Estuarine Marsh shares some of the characteristics of Area D8, but it also contains Bradwell Power Station and Bradwell wind farm, and is about 6 km north of the proposed Turncole wind farm. The effects of the appeal scheme would have negligible significance on landscape character Area D7. This would also apply to other landscape character areas in the wider locality. [14]

131. Taking all these findings into account I find that the overall solus effects of the appeal scheme on the landscape resource of the area would be of moderate significance. I turn next to the different approaches put to the Inquiry about cumulative effects.

132. The appellant's analysis emphasises additional effects of the appeal scheme on top of the cumulative baseline. Middlewick wind farm by itself would leave only small parts of the south-western corner and the south-eastern tip of landscape character Area D8 outside the area that would experience a medium magnitude of effect.[179] Turncole wind farm would extend the influence that would arise from Middlewick wind farm across relatively small areas in the overall context of Area D8 adjacent to Burnham-on-Crouch and the River Crouch. In terms of size/scale this would not be a substantial change to the landscape resource, but it would result in wind farms becoming a key characteristic of the entire character area. A small area between the Middlewick and Turncole wind farms would have high magnitude of effect from both schemes, but this would have a limited geographical extent, and the intensified effect would not significantly affect Area D8 as a whole. Overall effects on the cumulative baseline would be of low magnitude, and with medium sensitivity, of moderate/minor significance. The presence of Middlewick wind farm would therefore mean that the change to landscape character as a result of the appeal scheme would not be as substantial as would the effects of Turncole wind farm alone on the existing baseline. Given this finding it is necessary to also consider the combined cumulative effect. [88,91]

133. The Council favours an assessment of the combined effects of all the past and current proposals together with the appeal scheme. The combined effects of Bradwell, Middlewick and Turncole wind farms would alter the overall perception of the eastern part of the Dengie peninsula as a remote and tranquil area. However, high magnitude landscape effects would largely be contained within parts of Area D7 and Area D8, with only limited effects on Area C3 and Area E2. The dominant characteristics of this part of the Dengie peninsula would remain its huge skies, wide horizon and openness of this flat landscape. The combined effects of the existing and proposed turbines would not result in more than moderate significance for the landscape resource. No cumulative threshold of acceptability for wind turbine development on the Dengie peninsula would be breached as a result of the appeal scheme. [51,52]

134. In terms of landscape character, I consider that the solus effects of Turncole wind farm would be adverse and of moderate significance, but cumulatively with

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[179] ID24.

Middlewick wind farm this significance would be reduced to moderate/minor. Furthermore, given the scale of this landscape, the combined effects of Bradwell, Middlewick and Turncole wind farms on this part of the Dengie peninsula would not result in effects of more than moderate significance for the overall landscape resource. I turn next to visual effects.

Visual effects

135. The assessment of visual effects concerns the effects of the proposed wind farm on the views available to people and their visual amenity. The zone of theoretical visibility (ZTV) for such large and moving structures in this landscape is extensive, but there is a measure of agreement between the experts about an appropriate study area and representative viewpoints.[180] Visual receptors here include people living and working in the area, along with visitors and those engaged in recreational activities. These people are likely to be particularly susceptible to the change in views that would result from the proposed turbines, and there is evidence that the visual amenity of the area is valued. GLVIA notes that residents at home, especially using rooms normally occupied in waking and daylight hours, are likely to experience views for longer than those briefly passing through an area.[181] I consider that visual receptors here would have high sensitivity to the change in views that would result from the appeal scheme. [11,18,32]

136. In assessing the size/scale of visual effects this section considers the solus effects, and the additional and combined cumulative effects, for various vantage points/locations, so as to come to a judgement about the overall significance of visual effects. This is based on the expert evidence, wireframes and photomontages, along with my observations on site visits.[182] The following considers likely visual effects on five broad areas, (1) the area in the vicinity of the proposed Turncole wind farm and extending south-west to Burnham-on-Crouch (2) the area to the south and along the river (3) the eastern part of the Dengie peninsula (4) the area to the immediate and more distant north, and (5) the immediate area extending north-west to Southminster. [51,55,92]

137. The area in the vicinity of the proposed Turncole wind farm and extending to the south-west includes dwellings R1-6.[183] The wireframe at ResVP3 is indicative of views from these properties and the local road.[184] It shows how the proposed turbines would be distributed along part of this long horizon. Such large structures in open view would adversely affect the rural scene. Dwellings R16 and R17 are closer to Burnham-on-Crouch and would be less affected. The proposed wind farm would be exposed in views from VP2.[185] VP1 is further to the west and intervening trees, buildings and telegraph poles would soften the

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[180] ES Figure 5.13.
[181] ID14 paragraph 6.36.
[182] ID17 is a useful summary of the experts' assessment of effects on viewpoints, but Mr Goodrum's evidence concerns the effects of adding Turncole wind farm to the baseline of Middlewick and Bradwell wind farms, while Mr Cowlin's evidence focuses entirely on in-combination cumulative effects. These are not, therefore, directly comparable. This report follows the guidance in GLVIA.
[183] Residential dwellings are numbered R1-R25 on Figure 5.14 of the ES.
[184] ES Figure 5.30.
[185] ES Figure 5.16A and 5.16B.

visual effects of the proposed wind farm.[186] The alignment of the proposed turbines from VP1 and VP2 is shown on ID25. The Bradwell turbines at about 9 km distance have little impact. The Turncole turbines would have limited effects on views from the outskirts of Burnham-on-Crouch. I find that the proposal by itself would have medium magnitude of effect on views from the part of the road east of Twizzlefoot bridge and in the vicinity of the associated dwellings, reducing to low to the west of VP1. Solus visual effects would be of major/moderate significance, reducing to moderate in the western part of this area, and minor or negligible from Burnham-on-Crouch. Cumulatively, with Middlewick wind farm seen in the background, or set to one side and set back from Turncole wind farm, the two wind farms would be seen as separate features.[187] This would limit any visual confusion. Additional or in-combination cumulative visual effects would not raise the significance above that found for the solus effects.

138. The view from the south and along the river is shown in VP9.[188] In this wide view the turbines would have a low magnitude of effect. VP8 is more distant and shows that the turbines would have a limited visual effect in this panoramic view.[189] From parts of the footpaths in this area nearest to the proposed turbines there would be a medium magnitude of effect. Sequential views, when the observer needs to travel to another view point to see other turbines, such as along a road or footpath, apply to the sea wall path.[190] However, with such extensive ZVTs for the wind farms sequential views would be more influenced by the changing visual relationships between wind farms, based on separation distances and spatial distribution. This is apparent in the views from VPI4 and VPI5, with perspective creating a clear distinction between the wind farms. However, the additional visual effect of the Turncole turbines with a cumulative baseline that included Middlewick wind farm would result in some overlapping and resultant visual clutter (VPI4) and an extension of wind farms along more of the horizon (VPI5). By itself the appeal scheme would generally have moderate significance of visual effects, but for some parts of the footpaths it would have major/moderate significance. Additional and in-combination cumulative effects would be of major/moderate significance.

139. Views from the eastern part of the Dengie peninsula are depicted in VPI3 and VP6, and from the sea wall path in VPI6 and VPI7. From the vantage points closer to the proposed turbines the significance of solus visual effects would be major/moderate, but from the sea wall this would reduce to moderate or moderate/minor, and to negligible at the Chapel of St Peter on the Wall (VP7). This area includes the line of dwellings R18-25, along with R7 and R8 at East Wick. ResVP24 and ResVP8 indicate typical views.[191] Solus visual effects would be of significance ranging from major/moderate to negligible in the north-eastern part of this area. The additional cumulative effect with Middlewick wind farm would be significant and is shown on VPI3. However, the wide separation between the wind farms would be apparent. The combined cumulative visual effect would not substantially diminish the expansive views of open sky and long

[186] ES Figure 5.15A and 5.15B.
[187] ES Figures 5.16C and 5.16D, Figures 5.15C and 5.15D.
[188] ES Figures 5.23A and 5.23B.
[189] ES Figures 5.22A and 5.22B.
[190] CD14 Table 7.1 page 131.
[191] ES Figure 5.34 and Figure 5.31.

horizon in this eastern part of the Dengie peninsula. Cumulative visual effects would be of moderate/minor significance.

140. VP4 and VP5 are to the north of both the proposed Turncole wind farm and the permitted Middlewick wind farm. Views from the front of the Church of St James of Turncole wind farm by itself would be of moderate significance, with the nearest turbine 3.8 km away.[192] VP10, VP11, VP12, VP13, VP14 and VP15 are much further to the north and the visual effects of the Turncole wind farm would be negligible from vantage points in these areas. The additional effect of Turncole wind farm on a baseline which included Middlewick would alter the view from the Church significantly. This would spread turbines across a large proportion of the view to the south, over lower lying parts of the Dengie Marsh, and so increase significance of visual cumulative effects to major/moderate.[193] Views towards Bradwell wind farm would be largely screened by buildings and vegetation and the significance would not be enhanced by any in-combination cumulative effects.

141. The immediate area extending north-west to Southminster includes dwellings R9-12 and further to the west R13-15, along with the road that provides access.[194] From VPI2 and this part of the road the Turncole turbines would be prominent features at a distance of about 1 km. This effect would diminish with distance to the west and the effect at VPI1 and VP3, the latter on the outskirts of Southminster, would be much less.[195] From the nearer parts of this area the solus visual effects would be of major/moderate significance, reducing to moderate towards Southminster. Cumulatively, with Middlewick wind farm in the baseline, the main additional effect would be the presence of wind farms on both sides of this road. It would be possible to see the two wind farms from some vantage points together within the same wide arc of view, or in the vicinity of Broadward and Turncole Farms in succession with a turn of the head so as to see the other wind farm. But from the western approaches within this area VP3, VPI1 and VPI2 indicate the substantial visual separation that would exist between the wind farms, and in which other features such as the open sky, the long horizon or nearer vegetation would soften the visual effects of the turbines. Closer to Broadward and Turncole Farms views to the north would be towards Middlewick wind farm and in the distance Bradwell wind farm, and to the south towards Turncole wind farm.[196] However, views from within this area would take in the wide gap between the wind farms. This visual perception of separation distance between Middlewick and Turncole wind farms would limit any additional or in-combination cumulative visual effects. I do not consider that cumulative effects in this area would increase the overall the significance of visual effects above major/moderate.

LVIA conclusions

142. The PPG sets out landscape issues which might need to be documented in an assessment of cumulative impacts, including scale of development, sense of

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[192] ES Figures 5.18A and 5.18B.
[193] ES Figures 5.18C and 5.18D.
[194] VPI10 and VPI8 along with ResVP10 at ES Figure 5.32 and ResVP14 at ES Figure 5.33 indicate likely typical views from this area.
[195] ES Figures 5.17A and 5.17B.
[196] VPI8/9 and VPI10/11.

distance, focal points, skylining and sense of remoteness or wildness.[197] The proposed turbines would be large structures, but would be set within a landscape that is characterised by features of substantial scale, such as the vast skies and wide, flat expanse of the land. The proposed turbines would not, given the separation distance from both Middlewick and Bradwell wind farms, erode a sense of perspective and distance in views across the Dengie pensinsula. There are no significant focal points in the local landscape which would be affected by the proposed development. The addition of Turncole wind farm would not result in development along the skyline appearing disproportionately dominant, or significantly detract from any sense of wildness. The limited removal of roadside vegetation would not unduly affect the character or appearance of the area. Trees 10 and 11 contribute to the visual amenity of the area, but measures could be taken to safeguard these trees during road improvements. Some of the work to roadside vegetation, including within Tree Groups 32 and 33, would need to be carried out in any event as routine maintenance, and so the proposed alterations would not unduly affect the rural scene. The proposal would not conflict with LP Policy CC10 concerning any materially adverse impact upon protected lanes and hedgerows. [13,19,27,32,44,63,65,66,67,72,91,94]

143. The proposal would have a limited effect on the character of the undeveloped coast and so would not conflict with advice in the *Framework* that such areas should be maintained, and their distinctive landscapes protected and enhanced.[198] The PPG also advises that schemes may have visual impacts on the marine and coastal environment and that it may be appropriate to assess potential impacts on seascape character.[199] However, the area in which the appeal site lies is defined by land and sky, and the flatness of the terrain, rather than the sea itself. The wide expanse of mudflats at low tide visually separates the sea from the land. The proposed Turncole turbines would be prominent features in views from the sea towards the peninsula, but they would not, either by themselves or cumulatively with other onshore and offshore turbines, have a significant effect on its seascape character. [12,15]

144. Natural England (NE) considers that the openness and tranquillity of the landscape contribute to its high sensitivity to change, and that in such a flat landscape any vertical structure would be highly prominent. However, NE acknowledges that the turbines would not break or interrupt any significant feature of the skyline, and that very open landscapes have a greater capacity for wind turbine developments. NE found on balance that the Dengie peninsula has a greater capacity to accommodate wind farm energy. On this basis, NE raises no objection to the proposal. [109]

145. The proposed development would have an adverse effect on landscape character of moderate significance, which would cumulatively with Middlewick wind farm reduce to moderate/minor significance. It would have an adverse effect on visual amenity, both by itself and cumulatively, of major/moderate significance from some vantage points, but more generally of moderate significance, reducing to minor or negligible with distance. I find that the overall adverse effect on the landscape character and visual amenity of the area would be of moderate significance. This is a consideration which weighs against the

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[197] Last bullet point of Figure 1 on page 13.
[198] *Framework* paragraphs 109 and 114.
[199] PPG paragraph 9.

proposal and brings it into conflict with the aims of LP Policies PU6, CC6, CC7, CC11, S2 and BE1, which are considered in more detail later.

(1bi) Living conditions - outlook

146. The Council's second reason for refusal in Appeal A concerns cumulative effects on the outlook of Turncole Farm and Broadward Farm, but many local residents, in written representations to the Council and at the appeal stage, expressed concerns about the effects of the proposed turbines on their residential amenity. There is no test prescribed by law or policy to assess deprivation of outlook. *The Planning System: General Principles* ODPM 2005 states that the planning system does not exist to protect the private interests of one person against the activities of another, although private interests may coincide with the public interest in some cases. It adds that it may be necessary to distinguish between public and private interests and that the question is whether the proposal would unacceptably affect the amenities and the existing use of land and buildings which ought to be protected in the public interest.[200] The Secretary of State in the *Burnthouse Farm* appeal considered that in assessing the effect on visual outlook it is helpful to pose the question; "would the proposal affect the outlook of these residents to such an extent, i.e. be so unpleasant, overwhelming and oppressive that this would become an unattractive place to live? "[201] [21,33,34,56,83]

147. However, it was acknowledged at the Inquiry that the Secretary of State's view in the *Burnthouse Farm* appeal is not to say that significant visual effects on residents are not a material consideration if they fall short of converting a property into being 'an unattractive place to live'. The appellant believes that it might be, in a particular case, that significant visual effects on a number of houses falling short of an impact on residential amenity would carry sufficient weight to warrant at least a careful approach to the planning balance.[202] It seems to me that any such impact should properly be categorised as an effect on the visual amenity of the area, which would fall to be considered as a separate component of visual effects in a LVIA. This would, therefore, be a character and appearance issue to be weighed accordingly in the planning balance. This approach is recommended, and would be consistent with the latest edition of GLVIA. [83,84]

148. The appellant's primary submission is that there would be no harm to the visual component of residential amenity at either Turncole Farm or Broadward Farm, but that if it was necessary, account should be taken of the financially involved status of these properties. Neither resident has objected to the proposed development. In the *Middlewick* appeal the Inspector, in identifying properties that would have principal aspects and/or gardens that would look towards the appeal site, set aside cottages with a financial interest in the proposal.[203] In the *Gayton* appeal the Inspector noted that the nearest dwelling to a turbine was the home of the landowner who could be expected to have made his own assessment of the likely visual impact of the development on his living

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[200] *The Planning System: General Principles,* Office of the Deputy Prime Minister 2005, paragraph 29.
[201] CD47.
[202] ID40 paragraph 64.
[203] CD58 paragraph 31.

conditions.[204] The Council argues that judgements about residential amenity should not be affected by financial involvement, and that there is no policy support for such an approach. It may well be that no policy is necessarily required to underpin the approach taken by the Inspectors in the *Middlewick* and *Gayton* appeals, and nothing wrong in law in doing so. However, in the absence of a specific policy provision, such as exists in ETSU-R-97 for noise[205], it seems to me that if a private interest was required to be protected in the public interest, then the requisite protection would be justified irrespective of who occupied the dwelling. It would not be in the public interest to create dwellings with unsatisfactory living conditions. If the public interest was so engaged the personal preferences of the current occupier would not be decisive. Therefore, it seems to me that a different threshold of impact on outlook should not apply for Turncole Farm and Broadward Farm on account of the current occupiers' financial interest in the proposed wind farm. [35,84,85]

149. The judgment in the *Spring Farm Ridge* case does not provide much help concerning a test to assess deprivation of outlook to be applied in the current appeal.[206] In that case a local plan policy required development to not unacceptably harm the amenities of any neighbouring properties, and it was held that the Inspector did not apply a higher threshold of acceptability than that set out in the local plan. However, there is no comparable development plan policy in the current case. It seems to me that where decision makers have asked whether the impact would make a property an 'unattractive' or 'unsatisfactory' or 'unsuitable' place to live, they were articulating effects on outlook in this way as an aid to making a judgement about whether a private interest was, in the particular circumstances, required to be protected in the public interest.

150. In considering deprivation of outlook in relation to a wind farm scheme, it is useful to ask whether the presence of turbines, by reason of their number, size, layout, proximity and movement, would have such an overwhelming and oppressive impact on the outlook from a dwelling and its amenity space that they would result in unsatisfactory living conditions, and so would unacceptably affect amenities and the use of land and buildings which ought to be protected in the public interest. This public interest threshold is a matter to be determined in the particular circumstances which apply. However, the level of impact or threshold at which the public interest would be so engaged should be no different for wind turbines than would be the threshold applicable to other types of development.[207]

151. Where the impairment of outlook for any dwelling was so deleterious that this threshold was breached then the resultant harm to living conditions would be a weighty consideration against allowing the development proposal to proceed. If this applied to more than one dwelling in the locality then the greater would be the harm. Conversely, if the effects of development fell below this threshold the protection afforded to the public interest by the planning system would not be engaged. As a result, any such adverse effect on outlook would not feature in

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[204] ID16 paragraph 49.
[205] Notwithstanding some similarities in principle, an important difference between the effects of noise and outlook on involved occupiers is that ETSU-R-97 quantifies a level of difference for noise which is acceptable, whereas it would be difficult to identify such a threshold for deprivation of outlook.
[206] *South Northamptonshire Council and SoS CLG* at ID30.
[207] Inspector's question to Mr Stewart.

the planning balance, irrespective of how many dwellings were so affected. But to reiterate, this would not preclude weighing in the balance, as a component of the character and appearance issue, the effects on the locality generally that would derive from visual effects on resident receptors, which nonetheless fall short of impacting adversely on living conditions by deprivation of outlook. [34]

152. The assessment in the ES identified 13 dwellings within about 1 km of the proposed turbines, and an additional 14 dwellings within 2 km.[208] I was able to make a reasonable assessment of the likely relationship between these properties and the proposed turbines on the basis of the submitted documentation, along with my accompanied and unaccompanied site visits to the area. It is clear from the wireframes, photomontages and my site visits that the outlook from some dwellings and their amenity space would be significantly altered by the siting and height of the proposed turbines. References to other decisions and separation distances are not of much assistance, as so much depends on local circumstances, such as the specific configuration of the turbines, orientation and layout of dwellings, topography and vegetation. [36,83,85]

153. T3 would be about 830 m from Great West Wyke Farmhouse. The principal focus and direction of views from both the house and garden is to the north and north-west across an extensive and open landscape. The turbines would be prominent in views from the garden and from those windows which afford views to the north-west, north and north-east. The wind farm would occupy an arc of view of 96 degrees.[209] But within this T1, T2, T6 and T7 would be 1 km or more from Great West Wyke Farmhouse. At this distance I do not consider that these turbines would have an overbearing or dominating effect. Neither would T3, T4 and T5 be so close or so high as to create an oppressive feel to living and amenity spaces within the property. The rotation of turbine blades would be eye-catching and at times distracting, but turbines are structures which lack solidity and the proposed layout would mean that they were spaced so that the vast open sky would remain the most significant feature in the outlook from this dwelling. The existing turbine at Southminster would be visible just to the west of T1, but given its height and separation distance it would not cumulatively with Turncole wind farm add significantly to the overall impact on the outlook from Great West Wyke Farmhouse. The permitted Middlewick wind farm at a distance of about 3 km would appear in views from this property between T4 and T5 of the Turncole wind farm. Bradwell wind farm would be apparent beyond this at a distance of about 9 km. These other turbines would add to visual clutter and movement along this part of the wide flat horizon. However, at the distances involved the effect, whilst a relevant LVIA consideration, would not cumulatively with the appeal scheme add significantly to the sense that this property was overwhelmed by wind farm development. The offshore turbines are too distant to have any significant impact. In my judgement, the overall effect of Turncole wind farm, both by itself and cumulatively with other existing or proposed turbines in the area, would not have an overwhelming and oppressive impact on the outlook from Great West Wyke Farmhouse. The outlook from Redward Cottages, which lies further to the south, would be even less affected. [33]

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[208] Appendix 4 of the SoCG provides agreed distances and directions of residential dwellings within about 1 km of the proposed turbines.
[209] ES Figure 5.30. EXPLAIN MORE

154. Similar considerations apply to the likely effect on the outlook from West Wyke Farm and West Wyke Bungalow, which would be about 800 m from the nearest proposed turbine. However, T4, T5, T6 and T7 would be between 1 km to 1.5 km from these properties. Notwithstanding that there would be some uninterrupted and open views of the proposed turbines from these properties, given the separation distance and layout, I do not consider that the appeal scheme would, by itself or cumulatively, have an impact on outlook that would engage the planning regime as a matter of public interest.

155. Further to the east of Great West Wyke Farmhouse there are two bungalows sited within the curtilage of a large poultry farm, which would be about 800 m south of the nearest turbine.[210] The outlook from these properties is influenced by large low rise poultry sheds with feed silos. In this context the turbines, although much higher than any other structures in view, would not have an oppressive impact on the outlook from these bungalows. East Wick Cottages, which comprises four dwellings, lie about 1 km to 1.1 km south-east of the site of the nearest proposed turbine. T1 would be about 2.5 km away. Turncole wind farm would occupy a small arc of view of 28 degrees and would appear as a compact, albeit significant, feature in views across the intervening open and flat farmland.[211] Some of the views in this direction would also encompass some nearby agricultural outbuildings, and garden trees, which would provide a degree of local screening from some vantage points within these properties. The separation distance and layout of the proposed wind farm would not result in any overwhelming effect on East Wick Cottages. In the outlook from these properties Turncole, Middlewick and Bradwell wind farms would appear as separate and distinct features, diminishing in relative scale with distance, on this broad horizon. They would not, cumulatively, unduly impact on the living conditions of occupiers by virtue of any oppressive impact on outlook.

156. Montsale Bungalow, Old Montsale and New Montsale lie to the east of the proposed wind farm. The view from these properties across open farmland is typified by Residential Building VP24 from Montsale Bungalow.[212] This has an arc of view of 35 degrees. Other dwellings to the south-east of Montsale Bungalow would be more aligned with the proposed wind farm along its length from T6/T7 to T1. These dwellings are some 1.16 km to 1.25 km from the site of the nearest proposed turbine, and at this distance and configuration I do not consider that the scheme would have an adverse impact on outlook insofar as this would affect living conditions. Middlewick wind farm would be seen as a separate development to the north-west of Turncole wind farm and no significant cumulative impact on outlook would result. Other dwellings to the east are more distant from the proposed wind farm, which would further diminish any adverse effects on the outlook from these properties.

157. Turncole Farm is about 750 m north of proposed T4 and T7, and about 1.3 km north-east of T1.[213] The dwelling has an east-west orientation with principal garden areas located to the south and west of the house. There are large

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[210] New Bungalow and Poultry farm in ES paragraphs 5.11.15-5.11.18.
[211] ES Figure 5.31.
[212] ES Figure 5.34.
[213] Rear and front views are at VPI10 and VPI11 of the Additional Visualisations, the angle of view towards Turncole and Middlewick wind farms is shown on SEI Figure 5.4.

agricultural buildings located close to the eastern and southern curtilage of the dwelling, which would largely screen T7, T6 and T5. There are also some garden trees which would soften the visual impact of T1, T2 and T3. T4 would be prominent in views from habitable rooms facing south, and from parts of the rear garden. However, with perspective its hub height would be comparable to that of the roof ridge of the nearest part of the nearby large agricultural building. The scale of T4 would not dominate the outlook from this property. By turning around it would be possible to see turbines from both the Turncole and Middlewick wind farms from parts of the garden and tennis court. But given the orientation of the building, views from windows would be largely towards Turncole wind farm to the rear and towards Middlewick wind farm to the front. It was apparent from my site visit that the outlook from the front and rear of the premises are quite distinct aspects of the property. The front overlooks a small grassed area, parking and turning area, and the road. The outlook to the rear takes in the private amenity space, along with the agricultural buildings. I do not consider that the introduction of wind turbines into both of these aspects would cumulatively create a feeling that the premises was enclosed or surround by wind farms.

158. Broadward Farm lies some 750 m north of proposed T2.[214] It has a similar orientation to Turncole Farm, but has a more open aspect to the south and east. My site visit confirmed comment in the ES that there would be uninterrupted views towards the proposed wind farm from south facing windows, and from the rear garden area resulting in a considerable change in the nature of the existing views. The proposed turbines would have an arc of view of 81 degrees. T7, T6 and T5 would be furthest from the property and would appear at an oblique angle, and at a height comparable, with perspective, to the nearest of the line of telegraph poles that runs into the distance to the east of T7. However, T4, T3, T2 and T1 would be more prominent. Nonetheless, these would be widely spaced with scope for the open sky to retain its dominance in the overall outlook. Given the separation distance and configuration of the proposed wind farm, I do not consider that it would have an overwhelming or oppressive effect on the outlook to the rear of Broadward Farm. Cumulative issues similar to Turncole Farm arise with respect to Middlewick wind farm. However, Middlewick wind farm would be further away and at a more oblique angle to the frontage of Broadward Farm, and for the reasons set out above, any cumulative impact on outlook would not weigh significantly against the proposal.

159. I also visited Wraywick Cottage and Wraywick Farmhouse as part of my accompanied site inspection. These lie to the north and north-west of the proposed Turncole wind farm, and to the west and south-west of Middlewick wind farm. T2 would lie about 1 km to the south of Wraywick Cottage. VPI2 assists in assessing the likely relationship between these properties and the proposed wind farms, although the view point is not within the curtilage of either property.[215] The principal focus of views from the front of Wraywick Cottage is to the south-west and not towards Turncole wind farm. In addition, there is extensive planting and vegetation to the side and rear of the property, including tall conifer trees, which would provide a degree of screening in this direction. Given the

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[214] ES Figure 5.32, rear and front views are at VPI8 and VPI9 of the Additional Visualisations, the angle of view towards Turncole and Middlewick wind farms is shown on SEI Figure 5.3.
[215] VPI2 of the Additional Visualisations.

separation distance, orientation and local screening, Turncole wind farm would not adversely impact on the outlook from this property. The extensive planting to the rear would also mean that no cumulative effects on outlook would arise with Middlewick wind farm. Wraywick Farmhouse would be about 1.3 km from the nearest turbine proposed at Turncole and about 870 m from the nearest with permission at Middlewick. It has an extensive garden and a large conservatory, which along with other windows in the house, would afford views towards the proposed wind farms. However, Turncole wind farm would be a sufficient distance away so as not to have an overbearing effect on the outlook from this property, either by itself or cumulatively with Middlewick wind farm.

160. The wireframe from Rumbolds is indicative of the likely effects of Turncole wind farm on the outlook from properties to the west and in the vicinity of Southminster.[216] It would occupy a small sector of the wider panoramic view across the Dengie marshes. This indicates that the proposal would not have a dominating or overbearing effect on the outlook of dwellings in this area. I have had regard to all the representations, but it was clear from my site visits that the outlook from other dwellings in the wider area, not specifically addressed in this section of the report, would not be materially affected by the proposal. [36]

161. The *Enifer Downs* appeal is not comparable to the circumstances which apply here because three dwellings in that case were located less than 500 m from the proposed 120 m high turbines.[217] In my view, the proposed Turncole turbines, either by themselves or cumulatively with other existing or proposed turbines, would not result in an overwhelming and oppressive impact on the outlook from nearby dwellings or their associated amenity space that would result in unsatisfactory living conditions. The limited removal of roadside vegetation along the route proposed for AIL would not harm the residential amenity of nearby occupiers. [27,36,64]

162. In my judgement, the proposal would not unacceptably affect amenities and the use of land and buildings which ought to be protected in the public interest. If the Secretary of State were to come to a different conclusion about the effects of the proposal, either by itself or cumulatively, concerning deprivation of outlook from any nearby dwelling, the resultant harm and policy conflict would weigh heavily against allowing the appeals.

(1bii) Living conditions - noise and disturbance

163. The PPG states that ETSU-R-97 should be used when assessing and rating noise from wind energy developments, and refers to the endorsement of the GPG as a supplement to ETSU-R-97.[218] The *Noise Policy Statement for England* (NPSE) is also relevant.[219] This aims through the effective management and control of noise within the context of Government policy on sustainable

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[216] At a separation distance of 1.61 km and arc of view of 11 degrees. ES Figure 5.33.
[217] CD68 paragraph 42.
[218] PPG paragraph 30. *The Assessment and Rating of Noise from Wind Farms*, ETSU-R-97 at CD102. This was drafted by the Noise Working Group for ETSU, which is an abbreviation for Energy Technology Support Unit. EN-3 states at paragraph 2.7.56 that ETSU-R-97 should be used in the assessment of noise from the operation of wind turbines, and footnote 32 to paragraph 2.7.55 provides that ETSU-R-97 includes any supplementary guidance to it endorsed by the Government.
[219] ID103.

development to avoid significant adverse impacts on health and quality of life, mitigate and minimise adverse impacts on health and quality of life, and where possible, contribute to the improvement of health and quality of life. BS4142 *Method for rating industrial noise affecting mixed residential and industrial areas* and the WHO revised guidelines can help inform an overall judgement about the likely effects of noise. However, ETSU-R-97 found a literal interpretation of BS4142 difficult to apply to an assessment of wind farm noise and that it might not be appropriate. Given the policy support for ETSU-R-97 the WHO revised guidelines should not be determinative. There was some criticism of specific details concerning the manner in which the appellant's noise assessment was carried out. However, I am satisfied that the methodology and its implementation reasonably accords with relevant guidance about good practice. There are no substantive grounds to find the assessment wanting by reason of any calibration uncertainty, induced noise from windshields, exclusion of rain affected results, or monitoring undertaken in exposed positions. [37,38,47,74,75]

164. Turncole wind farm on its own would comply with ETSU-R-97. The noise experts disagree about whether the day-time fixed noise limit should be 36 dB or 38 dB for Turncole wind farm alone, and therefore whether the allowable cumulative noise level for Turncole wind farm with Middlewick wind farm should be 38 dB or 40 dB. There are no reasons to find against the agreed limit for the night-time fixed noise limit. [12,26,48,76]

165. ETSU-R-97 is not to be interpreted as statute or applied inflexibly, especially as the document describes a framework for the measurement of wind farm noise and gives indicative noise levels thought to offer a reasonable degree of protection to wind farm neighbours, without placing unreasonable restrictions on wind farm development or adding unduly to the costs and administrative burdens of developers or local authorities. The noise limits set out in ETSU-R-97 are fixed limits within the range of 35-40 dB during the day and 43 dB during the night (with higher limits for dwellings with a financial interest in the scheme), or 5 dB above the prevailing background level, whichever is the greater. The actual value chosen within the 35-40 dB range depends upon three factors: the number of dwellings in the neighbourhood of the wind farm, the effect of noise limits on the number of kWh generated, and the duration and level of exposure.[220]

166. ETSU-R-97 states with regard to the first of these factors that the more dwellings that are in the vicinity of a wind farm the tighter the limits should be as the total environmental impact would be greater, and conversely if only a few dwellings would be affected then noise limits towards the upper end of the range may be appropriate. The GPG states that the number of neighbouring properties will depend on the nature of the area (rural, semi-rural, urban), and that the predicted 35 dB contour can provide a guide to the dwellings to be considered in this respect. This is a rural area and Figure 1.1 of the SEI indicates that only eight dwellings would fall within the predicted 35 dB contour. Two of these are dwellings where the occupiers have a financial interest in the appeal scheme. Considerations here would, therefore, indicate a noise limit towards the upper end of the range. [48,76]

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[220] CD102 pages viii and 65. This is also addressed in Section 3.2 of the GPG at ID41.

167. The second factor concerns the potential impact on the power output of the wind farm. The GPG provides that this is mainly based on the relative generating capacity of the development. It adds that where the amenity fixed limit has little or no impact on the generating capacity then a reduced noise limit may be applied. But that it is not the case here, where cumulative noise is a significant design constraint. There is undisputed evidence that the imposition of the noise limits suggested by the Council would result in a significant reduction in energy yield.[221] This would indicate that a reduced noise limit would not be appropriate in this case. [48,49,76]

168. The GPG states that the third factor, duration and level of exposure, is more difficult to formulate. ETSU-R-97 states that the proportion of the time at which background noise levels are low, and how low the background noise level gets, are both recognised as factors which could affect the setting of an appropriate lower limit. The GPG notes that in rural areas this will often be determined by the sheltering of the property relative to the wind farm site. However, this would not be a consideration here in this open and flat landscape. In accordance with the GPG, account can also be taken of the effects of wind directions and likely directional effects, and that for cumulative developments, the effective duration of exposure may increase because of cumulative effects. With the prevailing WSW to SSW wind there would be limited periods where any dwellings would be significantly affected by downwind noise from both Turncole and Middlewick wind farms. [48,49,76]

169. ETSU-R-97 provides that in low noise environments, such as applies in this case, a day-time level within a range of 35-40 dB would offer a reasonable degree of protection to wind farm neighbours without placing unreasonable restriction on wind farm development. It adds that these levels are low compared to some advisory documents reviewed by the Noise Working Group and that this was because of its concerns to properly protect the external environment. In this case I consider, based on the three factors above, that a lower fixed day-time cumulative limit of 40 dB would properly accord with the provisions set out in ETSU-R-97. Furthermore, there are no particular circumstances or factors which apply here to justify a departure from applying ETSU-R-97 for operational noise. A condition could provide for a methodology to be approved for detecting a breach of these limits where both Middlewick and Turncole wind farms were operating. [38,39,75]

170. EN-3 provides that where the correct methodology has been followed and a wind farm shown to comply with ETSU-R-97 recommended noise limits, the decision maker may conclude that it will give little or no weight to adverse noise impacts from the operation of the wind turbines.[222] Subject to setting a lower fixed day-time cumulative limit of 40 dB, that is the situation which would apply here. On this basis, the scheme could be operated in accordance with the provisions and limits set out in ETSU-R-97, and it would not be necessary to impose the limits suggested by the Council. If, on the contrary, the Secretary of State were to find that a lower limit was required to accord with ETSU-R-97, the limits suggested by the Council for Table 1 of the noise condition would significantly affect the electricity output from the proposed development. This

[221] ID18.
[222] EN-3 paragraph 2.7.58.

would be a consideration to weigh in the planning balance. [49,76]

171. ETSU-R-97 incorporates some consideration of blade swish, but there is local concern that wind turbine noise might be more intrusive due to amplitude modulation that would be in excess of that acknowledged by the Noise Working Group. This was referred to as Other Amplitude Modulation (OAM) at the Inquiry. However, there is currently no technical evidence to justify the specific parameters proposed in the condition suggested by SIEGE concerning amplitude modulation. Furthermore, the GPG states that the evidence in relation to OAM is still developing, and that current practice is not to assign a planning condition to deal with amplitude modulation.[223] ETSU-R-97 states that developers have to consider the interests of individuals as protected under the Environment Protection Act 1990. Current practice as set out in the GPG and endorsed as a supplement to ETSU-R-97 therefore means that any unacceptable noise impact resulting from OAM would have to be addressed under the provisions for statutory nuisance. The Council took no issue with OAM and did not suggest a condition. No compelling evidence has been adduced at this Inquiry to indicate that it would be necessary and reasonable to impose a condition to deal with OAM. [39,77]

172. There is considerable concern about noise, vibration and disruption from construction traffic using the local road network having a detrimental impact upon the residential amenities of properties along the route, particularly AIL passing along Old Heath Road and the residential section of Marsh Road. However, the Council did not present any technical evidence at the Inquiry to dispute the appellant's assessment. This concluded that noise levels at the nearest properties to the construction traffic route were predicted to equate to a moderate noise impact, that construction and decommissioning would have a minor noise effect, and that such noise could be dealt with by way of planning conditions restricting the hours when noisy activities could take place. Furthermore, no convincing evidence was adduced to contradict the appellant's findings that the potential impact of vibration would be negligible, provided that any defective surfaces likely to be of significance for ground-borne vibration were treated in accordance with an appropriate planning condition. [40,63,65,66,96]

173. Wind turbine noise and some disturbance during construction and decommissioning would, to some extent, detract from the tranquillity of the area. However, the suggested conditions would minimise such impacts. The expert evidence indicates that the scheme could operate within acceptable ETSU-R-97 limits. Furthermore, the NPSE aims are to be applied in the context of Government policy on sustainable development. I find no conflict with LP Policies CON5 and PU6 insofar as noise and disturbance is concerned.

(1biii) Living conditions – other considerations

174. There is local concern about possible shadow flicker from moving turbine blades. However, given the separation distance from dwellings, this is a matter

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[223] The GPG represents good practice as at May 2013 and it does not exempt further advances from being used. A regular review will be undertaken with a new version produced when significant changes have occurred (GPG paragraph 1.2.3). If such advances or changes were to arise before the issue of the Secretary of State's decision this might be a matter that would need to be referred back to the parties.

that could be adequately addressed by the imposition of an appropriate planning condition. Flashes of reflected light from blades could be minimised by approving the surface treatment. The imposition of such conditions would accord with the advice in the PPG.[224] There is no convincing evidence before the Inquiry that the proposed wind farm would give rise to unacceptable infrasound or adversely affect the health of local residents. Any fears about such possible adverse effects cannot be given significant weight. [44,86,105]

175. The last bullet point in PPG paragraph 15 states that protecting local amenity is an important consideration which should be given proper weight in planning decisions. The PPG does not define the term 'local amenity' or refer to it in the questions to be considered in paragraphs 29-45, but it seems to me that it includes more than 'visual amenity', which is specifically cited in paragraph 41. Local amenity should, therefore, be given its ordinary meaning. As such the PPG seeks to safeguard the pleasantness of a place or locality. However, reference to a particular place would not preclude this being a specific dwelling. Local amenity could therefore include an element that derives from residential amenity. In the absence of any definition of 'local amenity' it is reasonable to apply the last bullet point of paragraph 15 to both the locality and to residential amenity, having regard to the distinction drawn in this report between the effects of the proposal on the character and appearance of the area, and the effects on living conditions of nearby residents attributable to noise, disturbance and any deprivation of outlook. Protecting local amenity should be given significant weight. I have found that the proposal would have an adverse impact on the character and appearance of the locality, but that any adverse effects on living conditions, having regard to relevant national policy for wind farms, would not weigh heavily against the proposal.

176. The evidence indicates that the combined effects of the proposed turbines on the outlook of nearby occupiers, along with operational noise in compliance with ETSU-R-97 limits, likely shadow flicker, health fears, and any disturbance or disruption during construction, operation or decommissioning, would not have a significant adverse effect on the living conditions of local residents. As a result, there would be no conflict with those parts of LP Policies PU6, CON5 and BE1 that aim to protect the amenity of neighbouring properties and their occupiers.

(1c) Heritage assets

177. The Council's fifth reason for refusal in Appeal A states that the proposed development and its cumulative impact with the consented Middlewick and Bradwell wind farms would have a detrimental impact on the historic landscape and the wider setting of Grade II listed buildings in the area. The circumstances which applied in the Middlewick wind farm appeal are not directly comparable with those that now apply, in terms of both evidence adduced about cultural heritage and relevant policy, and so drawing on that case is not helpful in determining these appeals. The main parties agree that the operation of the proposed wind farm would affect the setting of heritage assets in the vicinity of the development, and that any such effects would be reversed when the wind farm was decommissioned. However, what is disputed is whether this would

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[224] PPG paragraphs 36 and 37.

amount to substantial harm, or less than substantial harm. [10,23,57,58,59,78,79]

178. Section 66(1) of the Planning (Listed Buildings and Conservation Areas) Act 1990 requires special regard to be given to the desirability of preserving the setting of a listed building. Recent judgments set out how this applies.[225] The *Framework* provides that development resulting in substantial harm to the significance of heritage assets should not be permitted unless it would be necessary to achieve substantial public benefits that would outweigh the harm. Where less than substantial harm would result, this should be weighed against the public benefits of the proposal. The PPG states that the significance of heritage assets derives not only from their physical presence, but also from their setting, and that depending on their scale, design and prominence a wind turbine within the setting of a heritage asset may cause substantial harm to the significance of the asset.[226] [62,80,82]

179. The *Maldon District Historic Environment Characterisation Project* refers to reclamation of the Dengie Marshes in the 17th century and that the row of farms from Bridgewick to Holliwell are located on or close to the chenier or sand and shell island in the centre of the marsh.[227] This is the historical context for the Grade II listed buildings at Bridgewick Cottages, Court Farmhouse and the Bake/Brewhouse to its north and the barn on the opposite side of the road, and Old Montsale. The agricultural land surrounding these properties does make a contribution to the significance of these heritage assets. However, the proposed wind turbines would, apart from their visual impact, have a limited effect on the appreciation of the agricultural surroundings that comprise the setting to these properties. The predominance of historic farmed land around the listed buildings would remain, albeit with some modern agricultural buildings and practices evident. The turbines would be tall vertical structures occupying a relatively small part of the wider agricultural setting. Their visual impact would have a minor effect on the significance of these heritage assets. This would be so even with a cumulative baseline that included Middlewick and Bradwell wind farms. [60,61,81]

180. Newman's Farmhouse and Dammer Wick Farmhouse lie towards the edge of the marsh and closer to Burnham-on-Crouch. Their historic association with the draining of the marsh is not as apparent as it is for the farmhouses located along the chenier in the centre of the marsh. The cluster of farm buildings around each listed building provides their more immediate setting. Although the proposed Turncole turbines would be seen in the wider setting of these buildings, both by themselves and cumulatively with Middlewick and Bradwell wind farms, they would have a negligible effect on the setting and the significance of these heritage assets. [61,81]

181. The Church of St James Dengie is located on the edge of a small settlement. It is sited within a walled graveyard and enclosed by trees and vegetation in Dengie Manor to the north and west. It is a modest building, and in this context it is not a visual focal point. Long range views towards the Church do not contribute much to its significance. However, it is sited on a low ridge and has

225 ID12 and ID42.
226 PPG paragraph 34.
227 CD92.

an outlook to the south over the marsh, which would be towards the proposed Turncole and Middlewick wind farms. The nearest Turncole turbine would be some 3.8 km distant, with the closest Middlewick turbine about 1.7 km from the Church. Views of both the Church and the proposed turbines in combination would be limited to some parts of the graveyard close to the Church. These would not detract from the historic significance of the Church. The outlook from the Church towards the proposed wind farms would have a negligible effect on the setting and significance of this heritage asset. [61]

182. There is nothing to indicate that any adverse effects on archaeological features within the appeal site in Appeal A could not be mitigated by the imposition of a condition that required the implementation of a programme of archaeological works approved by the Council.[228]

183. The evidence indicates that the proposed turbines would not significantly affect views that are important to the setting of heritage assets. English Heritage does not object to the proposed development. Having special regard to the desirability of preserving the setting of listed buildings, I find that the proposed development would have a minor or negligible effect. This would not be sufficient to bring the proposal into conflict with LP Policy CC10 concerning landscape features of historic importance. Similarly, any adverse effects on heritage assets would be so slight as to not result in any material conflict with those parts of LP Policies BE1 and PU6 concerning historic buildings and areas of historical importance. The less than substantial harm to heritage assets that would result from the solus and cumulative effects of the proposed development would be a matter to be weighed against the benefits of the scheme in accordance with the provisions of the *Framework*. [62,82,113]

(1d) Air safety

184. There is no objection to the proposal from either the MoD or NATS on air safety grounds. There is local concern about air safety given the proximity of Southend-on-Sea airport. However, any radar interference from the proposed turbines is a matter that could be dealt with by means of an appropriate planning condition. There is evidence to indicate a reasonable prospect of any necessary mitigation being installed within the lifetime of any grant of planning permission. [98,114]

185. There is a grassed airstrip located to the south of the proposed wind farm. The operator of this airstrip initially objected to the proposed wind farm, but subsequently agreed with the appellant for fixed wing air craft to fly from another site, with only helicopters using the existing airstrip. The General Aviation Awareness Council raised a similar objection to that of the local operator. However, there is no reason to find that the proposed turbines, with the revised arrangement for the local operator, would compromise air safety. [98,108]

186. Subject to the imposition of appropriate planning conditions, there is no basis to find against the proposal on air safety grounds. This would accord with the advice in the PPG that risks to air safety can often be mitigated through consultation.[229]

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[228] SoCG paragraph 19.4.
[229] PPG paragraph 31.

(1e) Nature conservation and biodiversity

187. There is concern about the adequacy of the information available to assess the likely effects of removing some roadside vegetation, and that no assessment has been made to assess if the hedgerows were classified as important under the Hedgerow Regulations. However, any such assessment should be proportionate, and in Appeal B the SEI refers to the loss of up to 60 m of mature species-poor hedgerow, which is dominated by diseased elm with blackthorn, hawthorn and field maple. There is sufficient information available to come to a decision about the likely effects of removing roadside vegetation to provide for AIL. The evidence indicates that the limited removal of roadside vegetation envisaged would not have a significant effect on nature conservation. Measures could also be taken to safeguard the roadside pond. [27,43,94]

188. Foraging and roosting birds may come inland from the SPA and Wallasea Island in periods of high tides, but there is no evidence that the proposed turbines would significantly affect these movements. One of the reasons cited by the landowner against a marine delivery route across Burnham Wick Farm was that it would severely impact on breeding lapwing. This is an area close to the River Crouch and about 2 km from the proposed turbines. However, I do not consider at such a distance that this reference is sufficient to outweigh the findings of the assessment in the ES and SEI, which concluded that the appeal scheme would be unlikely, by itself or in combination with other turbines, to adversely affect the favourable conservation status of lapwings.[230] The proposal, either by itself or in combination with other development, would not significantly affect the Crouch and Roach Estuaries SSSI and Special Protection Area, Special Area of Conservation and Ramsar site to the south of the appeal site. [10,41,42]

189. The SEI provided adequate information for Natural England to remove its objection to the scheme. The RSPB also withdrew its objection subject to suitable conditions being imposed concerning mitigation, biodiversity enhancement and post-construction monitoring. With the imposition of appropriate planning conditions, the proposal would not have a significant adverse impact on nature conservation or biodiversity. This is not a consideration which materially weighs against allowing the appeals. Subject to the imposition of appropriate planning conditions the scheme would accord with LP Policies CC1, CC2 and CC3 which concern development affecting internationally, nationally and locally designated nature conservation sites. It would also comply with LP Policy CC5, which aims to safeguard protected species and features of nature conservation interest, and with LP Policy CON5, which expects all development to minimise the impact on the environment by adopting environmental best practice and implementing the necessary pollution prevention measures. [97,109,110,117]

(1f) Highway safety

190. There is local concern about highway safety on the road network due to construction vehicles. However, there is no objection from the Highway Authority, and no substantive challenge to the findings of the traffic assessment in the SEI that likely traffic increases would not be significant. The junction of

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[230] ES Volume 2 Text paragraphs 6.8.67, 6.8.76, 6.8.87 and 6.8.94. SEI Volume 1a paragraph 1.6.9.

Church Road/Southminster Road and Burnham Marsh Road, and the proximity to St Mary's Church, Ormiston Academy and St Mary's Primary School, are of particular concern to local residents. The management of construction traffic could be controlled, and this could be coordinated if necessary with vehicular movements associated with the construction of Middlewick wind farm. The effects on the local road network could be minimised by enforcement of an approved construction traffic management scheme. I am satisfied that those constructing the wind farm would have sufficient control over construction traffic for this to be a matter that was adequately controlled by a condition, and that it would not be necessary to deal with this by means of an obligation. Subject to the imposition of such conditions, I find no conflict with the relevant provision of LP Policy T2 concerning highway safety. [40,44,96,112,117]

(1g) Other considerations

191. It was confirmed at the Inquiry that the preferred grid connection location would be a substation on the south-eastern side of Burnham-on-Crouch and that power lines would be routed to the substation via underground cabling. Notwithstanding several recorded archaeological sites between the appeal site and the south-eastern side of Burnham-on-Crouch, there is nothing to indicate that a satisfactory route could not be designed for such an underground connection.[231] The SoCG records that likely potential environmental effects of this grid connection were considered in the ES and considered not to be significant.[232] Grid connection would be a matter for the relevant regional Distribution Network Operator (DNO). There are no obvious reasons why such a connection would not be possible, or that the necessary approvals would be refused, but this remains a matter for the DNO, and a commercial risk for the appellant.[233] Proximity of a likely grid connection is not a consideration which would weigh against the proposal.

192. There is no evidence that the proposed turbines would result in any interference with electro-magnetic transmissions in the locality. This is a matter that in accordance with the PPG could be addressed by condition. [20,115]

193. The proposal would result in some socio-economic benefits, primarily from the construction of the wind farm, but the impact on the local economy would be limited. [31]

(2) Alternative marine delivery route for abnormal loads

194. The Council's fourth reason for refusal in Appeal A considers that insufficient justification has been provided to demonstrate why a marine delivery route for abnormal loads cannot be accommodated as an alternative. It adds that such an approach is to be used with the Middlewick wind farm, and would be the preferred AIL delivery route.[234] EN-1 advises that the relevance or otherwise of alternatives is in the first instance a matter of law, and that from a policy perspective there is no general requirement to consider alternatives or to

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[231] ES Figures 7.1 and 7.2.
[232] SoCG paragraph 8.2.
[233] CD26 section 4.9.
[234] The Inquiry heard that this would involve landing AIL on the south coast of the Dengie peninsula on land managed by Strutt and Parker Farms.

establish whether the proposed project represents the best option.[235] The appeals should accordingly be dealt with on their merit. However, with respect to road traffic noise from construction vehicles for residents along the proposed route, it is relevant to note that the NPSE aims to mitigate and minimise adverse impacts on the quality of life. The *Framework* advises that the planning system should contribute to and enhance the natural and local environment by, amongst other things, minimising impacts on biodiversity. Furthermore, EN-3 encourages applicants to work together so as to minimise cumulative effects on highway users.[236] Given that the proposed route for AIL in the appeal scheme would result in the loss of some roadside vegetation, along with the aims of the NPSE, the availability of alternative access for AIL is a relevant consideration to be weighed in the balance in this case. [64,67,95]

195. However, the issue is not whether an alternative might be more appropriate than that proposed, but whether an available alternative access for AIL might meet the need in a way which could be less objectionable than the appeal scheme. If so, this would add weight to arguments in favour of dismissing the appeals. If not, this would add weight to the case that the appeals should succeed. There would be biodiversity and amenity advantages in AIL avoiding local roads by using a marine delivery route. But the evidence before the Inquiry is that such an option is currently unavailable to the appellant.[237] The Council believes that the appellant could have pursued this more rigorously with the landowners involved. However, the landowners' responses do not provide any reasonable basis for doing so. Strutt and Parker Farms confirmed that it was not able to grant rights of access due to commitments made to other operators. SIEGE argues that the alternative arrangement for fixed wing aircraft using the grassed strip, which only emerged at the Inquiry, is a relevant consideration given that the owner of the only other land which could facilitate marine delivery cited the creation of a conflict of interest with a tenant leasing an airstrip as one reason for having no interest in developing an access route across his land. Nonetheless, EN-1 paragraph 4.4.3 last bullet point supports the case that there should be some onus on those advocating an alternative approach to provide evidence about its suitability. It seems to me that this might include evidence showing that a preferable alternative was available, or at least had reasonable prospects. No such evidence was adduced at this Inquiry. The likelihood of an alternative marine delivery route for AIL does not, therefore, add weight to arguments in favour of dismissing the appeals. [41,67]

(3) Renewable energy (RE)

196. There is a wide measure of agreement about relevant policy for RE, which is helpfully set out in Appendix 2 to the SoCG, along with common ground in Appendix 3 about constructed, under construction and consented capacity in the region. In summary, the European Union Renewable Energy Directive has a commitment to a binding target of 20% of its energy coming from renewable sources by 2020. The UK Renewable Energy Strategy confirms the 15%

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[235] EN-1 paragraph 4.4.1.
[236].EN-3 paragraph 2.7.82. However, it should be noted that those promoting Nationally Significant Infrastructure Projects would have compulsory purchase powers, which is not so for the appellant.
[237] Emails from landowners dated August 2012. ID35.1 Strutt and Parker Farms and ID35.2 Burnham Wick Farm.

contribution which the UK is expected to make to the EU's 2020 target, and in order to be achievable, it will require more than 30% of the UK's electricity generation to come from renewable sources. The Government has since confirmed in the UK Renewable Energy Roadmap 2011 the scale of the development of RE that will be required to meet the 2020 targets. [24,69,99]

197. The *Written Ministerial Statement by Edward Davey: Onshore Wind* provides that appropriately sited onshore wind, as one of the most cost effective and proven RE technologies, has an important part to play in a responsible and balanced UK energy policy as it reduces reliance on imported fossil-fuels and helps keep the lights on and our energy bills down. The statement adds that the UK has some of the best wind resources in Europe, and that the Government is determined that the UK will retain its reputation as one of the best places to invest in wind energy.[238] [72]

198. The proposed wind farm would be capable of producing the equivalent amount of electricity per annum that is required for the annual domestic needs of approximately 7,585 households based on the UK averaged domestic electricity consumption of 4,700 kilowatt hours per annum, so offsetting approximately 15,300 tonnes of carbon dioxide per annum.[239] The PPG refers to capacity factor as the simplest way of expressing the energy capture at a site, and notes that this can be useful information in considering the energy contribution to be made by a proposal, particularly when a decision is finely balanced.[240] However, in this case an estimate of actual electricity generation has been submitted, which was not disputed at the Inquiry. This takes into account local wind conditions and the candidate turbine. The generation of 46.5 GWh/yr of RE would make a significant contribution to meeting national targets and reducing GHG emissions. This is a consideration which weighs heavily in favour of the proposal. [18,28,31,44,72,105]

(4) Planning balance

199. The planning balance is a matter of judgement. The proposed wind farm would have an adverse effect on landscape character and visual amenity of overall moderate significance. However, its likely effects on the living conditions of those residing in the area would not be significant having regard to relevant policy. There would be some harm to local amenity, but this would largely be attributable to the effects on the local landscape and visual amenity of the area, which should not be double counted in the balancing exercise. The proposal would have a minor effect on cultural heritage. Subject to the imposition of appropriate conditions the wind farm would not unduly affect air safety, biodiversity or highway safety. Some minor benefits would accrue to the local economy. The main consideration here is the effect on the character and appearance of the area, against which must be weighed the benefits of the RE that would be generated during the lifetime of the proposed wind farm. EN-3 recognises that the landscape and visual effects will only be one consideration to be taken into account and that these must be considered alongside the wider

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238 ID43b.
239 SoCG section 20 notes that these offset figures would change during the lifetime of the proposed wind farm as the national mix of generation sources changes.
240 PPG paragraph 38.

environmental, economic and social benefits that arise from RE projects. The balancing exercise should be made within the context of Government policy on sustainable development.

200. The proposed development would make a significant contribution to RE targets and towards the reduction of GHG. This should be given significant weight. The proposal would not generate an unacceptable level of noise or traffic, and having regard to Government policy on sustainable development would accord with the aims of the NPSE. The harm to the character and appearance of the area, and any disruption and inconvenience for those using the local road network during construction and decommissioning, along with any slight effect on heritage assets, would be outweighed by the public benefits of generating electricity from a renewable source. I am satisfied that the circumstances here would justify the removal of part of the hedgerow in Appeal B.[241] In my judgement, the planning balance falls in favour of the proposed development. [30,31,32,44,45]

(5) Development plan

201. Section 38(6) of the Planning and Compulsory Purchase Act 2004 requires these appeals to be decided having regard to the development plan, and to be determined in accordance with it, unless material considerations indicate otherwise. The proposal would conflict with LP Policy PU6, which permits renewable energy facilities provided that they would not have a significant visual impact on the appearance of the surrounding area, the countryside or local landscape. But there would be no conflict with the provisions of Policy PU6 concerning an unacceptable effect on noise and traffic. The proposal would conflict with LP Policy CC6, which permits development in the countryside only where no harm would be caused to the landscape character of the locality. The proposed wind farm would also be contrary to LP Policy CC7 concerning the SLA because it would not conserve the character of the area. Furthermore, the scheme would not meet the requirements in LP Policy CC11 that development permitted in the Coastal Zone would require a coastal location and have minimal impact on views into and out of the area. Nor would it accord with a requirement that development outside development boundaries should make a positive contribution to the landscape and open countryside pursuant to LP Policy BE1. A similar conflict arises with Policy S2, which provides that outside the boundaries for settlements the coast and countryside would be protected for their own sake, particularly for their landscape. However, the proposal would not offend Policy CC10 concerning the historic landscape, or the other LP Policies set out in Annex 1 to this report. But overall, the proposal conflicts with the development plan when read as a whole. However, the *Framework* provides that due weight should be given to relevant policies in existing plans according to their degree of consistency with the *Framework*. [7,68,100-103]

(6) National Planning Policy Framework

202. The economic, social and environmental roles for the planning system, which derive from the three dimensions to sustainable development in the *Framework,* require in this case that a balancing exercise be performed to weigh the benefits

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[241] Regulation 6(e) of The Hedgerow Regulations 1997 provides that the removal of any hedgerow to which the Regulations apply is permitted if it is required for carrying out development for which planning permission has been granted.

of the proposed wind farm against its disadvantages. Core planning principles in the *Framework* support the transition to a low carbon future in a changing climate, and encourage the use of renewable resources, for example by the development of RE. Supporting the delivery of RE is central to the economic, social and environmental dimensions of sustainable development. Other core principles recognise the intrinsic character and beauty of the countryside, along with conserving and enhancing the natural environment, and conserving heritage assets in a manner appropriate to their significance. It also provides that a proposal for RE should be approved if its impacts are, or could be made, acceptable. SIEGE submits that this reference to "impacts" means that this is not the engagement of a balancing exercise between impacts and the need for RE, but an evaluation of whether the landscape, visual and other impacts are, of themselves, acceptable. However, whether 'acceptable' here means worthy or deserving of being accepted, or satisfactory/tolerable, this is a matter to be judged, not in some absolute sense, but in the context of the *Framework's* overall objectives for sustainable development. [29,69,70,103,104]

203. The LP does not include criteria-based policies to enable the assessment of RE schemes. Furthermore, whilst the SLA designation is indicative of a valued landscape, the LP does not set criteria based policies against which proposals for any development on or affecting such landscape areas would be judged. The provisions in the LP are not consistent with the *Framework*. This is not disputed by the Council. On matters about which the development plan is silent, the *Framework* advises that permission should be granted unless any adverse impacts of doing so would significantly and demonstrably outweigh the benefits, when assessed against the policies in the *Framework* taken as a whole; or specific policies in the *Framework* indicate development should be restricted. With respect to the latter, the minor effect on designated heritage assets in this case would not be sufficient to justify such a restriction. [68]

204. I have found that the planning balance here falls in favour of the proposal. This is not a case where the adverse impacts I have identified would significantly and demonstrably outweigh the benefits of the scheme. The proposal would not accord with the development plan, but I consider that it would be acceptable having regard to the *Framework's* objectives for sustainable development. The encouragement given in the *Framework* for RE is sufficient here to outweigh any harm to the intrinsic character and beauty of this part of the countryside. The suggested conditions would make this scheme acceptable, and in accordance with the *Framework* this would indicate that the RE proposal should be approved. The proposed development gains considerable support from the *Framework*, when read as a whole. There are grounds here to find that the proposal would be sustainable development, to which the presumption in favour set out in the *Framework* would apply.

(7) Conditions and obligations

205. The need for conditions and their wording should properly be considered in the light of the advice contained in Circular 11/95 *The Use of Conditions in Planning Permissions*. The parties reached a measure of agreement at the Inquiry about possible conditions in the event that planning permission was granted for the proposal. [116]

206. The conditions agreed at the Inquiry, with some minor alterations in the interests of precision and enforceability would be necessary to minimise the

impact of the proposed development. The conditions set out in the Schedule of Conditions attached to this report would reasonably relate to the proposed development and would appropriately address some of the issues raised at the Inquiry. The reason for each condition is set out in more detail below. No planning obligation has been submitted and none is necessary. [117]

Appeal A

207. A five year commencement period would be appropriate given the requirement for off-site highway works (Condition 1). This was not disputed at the Inquiry. This would be a temporary permission and a condition would need to specify that it would expire 25 years from the date that electricity was first exported to the grid (Condition 2). Otherwise than as set out in any decision and conditions, or approval pursuant to a condition, it would be necessary that the development be carried out in accordance with the approved plans, including micro-siting, for the avoidance of doubt and in the interests of proper planning (Condition 3). Provision for the removal of structures and restoration, including any turbines which ceased to operate for a continuous period of 12 months, would be necessary in the interests of the appearance of the area, and to accord with paragraph 45 of the PPG (Conditions 4 and 5). A construction method statement would need to be approved and implemented to safeguard the amenities of the area (Condition 6). For similar reasons, it would be necessary to implement approved works in the public highway, subject to an arboricultural method statement, to accommodate abnormal indivisible loads (AIL) (Condition 7).

208. A traffic management plan for all construction vehicles would be necessary in the interests of highway safety (Condition 8), as would a restriction on AIL movements prior to the completion of the proposed highway works at Fambridge and Twizzlefoot (Condition 9). Hours of operation of the construction phase would need to be restricted, whilst making provision for emergency works and AIL (Conditions 10 and 11). On-site cabling would need to be underground in the interests of the appearance of the area (Condition 12). For similar reasons, the finish of the turbines and other details of the transformer units and masts would need to be approved, and no name, sign, symbol or logo should be displayed on any of these structures (Condition 13). The height and location of the proposed turbines, subject to appropriate micro-siting, would need to be specified so as to accord with the assessment of their likely effects (Condition 14). Turbine blades should rotate in the same direction for visual amenity reasons (Condition 15). Similarly, external lighting would need to be controlled (Condition 16). So too would details about the substation and compound (Condition 17).

209. A scheme for ecological mitigation and enhancement would need to be approved and implemented in the interests of biodiversity (Condition 18), as would ornithological monitoring (Condition 22). It would be necessary to secure the implementation of a programme of archaeological work in accordance with an approved scheme of investigation (Condition 19). Conditions would be required to deal with any electro-magnetic interference to TV and radio reception, and any shadow flicker (Conditions 20 and 21). Details of a scheme to mitigate any adverse effects of the development on the Primary Surveillance Radar at Southend Airport would need to be approved and implemented (Condition 23).

210. A noise condition would be necessary to accord with the provisions of ETSU-R-97. The suggested form of the condition and associated Guidance Notes would accord with the Institute of Acoustics' Good Practice Guide. In Guidance

Note 4, given the possibility of other wind turbines in the area not under the control of the appellant, it would be necessary for a methodology to be approved for the measurement of the influence of residual noise. There is a dispute between the appellant and the Council, in the event that it was necessary to constrain the normal running of turbines so as to comply with the noise condition, about the need to impose a condition requiring a scheme to be submitted showing the meteorological conditions under which each turbine was to be constrained and the nature of the constrained mode. The appellant considers that this should be a matter for the operator, as it might vary depending on circumstances. This argument has some force. In ensuring compliance with the condition it would not be necessary for the Council to be advised of any scheme of constraint, only that it was effective.

Appeals B and C

211. A five year commencement period for the schemes in Appeals B and C would be necessary to accord with any planning permission granted in Appeal A (Condition 1). Otherwise than as set out in any decision and conditions, it would be necessary that the development be carried out in accordance with the approved plans, for the avoidance of doubt and in the interests of proper planning (Condition 2). However, in Appeal B the detail on Sheet 2 is noted as indicative only, and so would need to be approved as part of a scheme of works. This would also need to include a timetable for implementation. Similarly for Appeal C works would need to be approved because the drawing states that details of the bridge are indicative only and subject to detailed design. For both, details would need to be approved of implementation works, restoration and maintenance of land outside the highway carriageway, along with in Appeal B a method statement to safeguard trees (Condition 3). The link between Appeals B and C with Appeal A should not just be to the grant of planning permission for Turncole wind farm, but to the implementation of that permission, as the proposal has been assessed as an integrated scheme (Condition 4).

(8) Overall conclusions

212. The *Written statement to Parliament Local planning and onshore wind* proposes amended secondary legislation to make pre-application consultation with local communities compulsory for the more significant onshore wind applications, to ensure that community engagement takes place at an earlier stage in more cases.[242] In this case consultation and engagement with the local community was undertaken before the application was submitted. Furthermore, there has been extensive community involvement in the processing of the applications and appeals. There is considerable local opposition to the proposed development, which is evident from the written representations and the submissions made at the Inquiry, but also some support. One of the aims of national planning policy is to strengthen local decision making.[243] However, it remains a general principle of the planning system that local opposition or support for a proposal is not in itself a ground for refusing or granting planning permission, unless it is founded upon valid planning reasons.[244] The proposal falls to be determined on its planning merits. [72,105]

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[242] ID43a.
[243] *National Planning Policy Framework* Annex 1: Implementation.
[244] *The Planning System: General Principles* ODPM 2005.

213. The proposed development would result in some harm. EN-1 states that without significant amounts of new large-scale energy infrastructure, the objectives of the Government's energy and climate change policy cannot be fulfilled, but it will not be possible to develop the necessary amounts of such infrastructure without some significant residual adverse impacts.[245] The relative scale of wind farms might be open to some interpretation, but for such tall structures this advice would be relevant here, particularly as cumulatively the appeal scheme would contribute to the Government's objectives. In my judgement, the likely harm from Turncole wind farm, both by itself and cumulatively with other existing or proposed turbines in the locality, would be outweighed by the RE benefits of the proposal. The scheme would conflict with the development plan, but the Council accepts that relevant policy is out-of-date. The support the proposal gains from the *Framework* carries the greater weight. National policy and guidance is a consideration in this case which indicates that the appeals should be determined other than in accordance with the development plan. Taking all these considerations into account, I consider that the proposed wind farm would be acceptable in this location.

214. All other matters raised in evidence have been taken into account, but there is nothing to outweigh the main considerations that lead to my conclusions.

Recommendations

215. It is recommended that the appeals be allowed and that planning permission be granted, subject to the conditions set out in the attached Schedule of Conditions.

John Woolcock
Inspector

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[245] EN-1 paragraph 3.2.3.

ANNEX 1 Summary of Local Plan policies cited in the SoCG

Policy PU6 states that proposals for the development of RE facilities will be permitted provided they would not: (a) have a significant visual impact on the appearance of the surrounding area, the countryside or local landscape: and (b)(i) generate an unacceptable level of noise or traffic; or (ii) have an adverse impact upon areas of ecological, architectural, landscape, historical or conservation importance; or have a detrimental impact upon adjoining properties and landholdings.

Policy S1 concerns development boundaries for settlements, and S2 provides that outside these boundaries, the coast and countryside would be protected for their own sake, particularly for their landscape, natural resources and areas of ecological, historical, archaeological, agricultural and recreational value.

Policy BE1 sets out criteria for the design of new development and landscaping. These include compatibility with their surrounding in terms of matters such as scale, visual impact, effect on amenity, relationship with mature trees, and traffic impact and access arrangements.

Policies CC1, CC2 and CC3 concern development affecting internationally, nationally and locally designated nature conservation sites, respectively.

Policy CC5 aims to safeguard protected species and features of nature conservation interest, and includes provision for mitigation measures and habitat enhancement where wildlife gains can be achieved.

Policy CC6 aims to protect, conserve and enhance the natural beauty, tranquillity, amenity and traditional quality of the landscape. It permits development in the countryside only where no harm would be caused to the landscape character of the locality, the location, siting, design and materials would be appropriate, and landscaping would protect and enhance the local distinctiveness and diversity of the area.

Policy CC7 provides that within SLAs permission would not be given for development unless its location, siting, design, materials and landscaping would conserve or restore the character of the area.

Policy CC10 provides that development would not be permitted which would have a materially adverse impact upon landscape features of historic importance such as ancient woodland, registered parks and gardens, registered battlefields protected lanes and hedgerows.

Policy CC11 states that within the defined Coastal Zone development would only be permitted if it, amongst other things, required a coastal location, would not adversely affect the open and rural character of the area, its historic features and its wildlife, and had minimal impact on views into and out of the area.

Policy CON5 provides that development having an adverse impact on the environment by pollution of land, air, water etc would be refused, and expects all development to minimise its impact on the environment by adopting best practice and implementing necessary pollution prevention measures.

Policy T2 provides that new development should, where appropriate, provide for safe access, off-site highway improvements, and road layouts appropriate for the location. It adds that larger scale development requires a Green Travel Plan.

SCHEDULE OF CONDITIONS

Appeal A: APP/X1545/A/12/2174982

1) The development hereby permitted shall begin not later than five years from the date of this decision.

2) This permission shall expire 25 years from the date when electrical power is first exported from any of the wind turbines hereby permitted to the electricity grid network, excluding electricity exported during initial testing and commissioning ("First Export Date"). Written confirmation of the First Export Date shall be provided to the local planning authority no later than one calendar month after the event.

3) The development hereby permitted shall be carried out in accordance with the following approved plans: Planning Application Boundary (Site Location Plan) Drawing No.02340D2908-05, Turbine Layout with Micro-siting Drawing No.02340D2107-05 and Infrastructure Layout Drawing No.02340D1001-14.

4) If any wind turbine fails for a continuous period of 12 months to supply electricity to the local electricity grid network, then, unless otherwise approved in writing by the local planning authority that wind turbine and ancillary development solely related to it shall be taken down and removed from the site and the land shall be reinstated in accordance with a reinstatement scheme approved in writing by the local planning authority (which shall include a timetable for the removal of the turbine(s) and the reinstatement of the land). The developer shall submit the reinstatement scheme to the local planning authority not later than 28 days after the expiry of the twelve month period provided for in this condition, and the scheme shall be implemented as approved.

5) No later than twelve months before the expiry of this permission a scheme for the decommissioning and the restoration of the site shall be submitted to the local planning authority for approval in writing. The scheme shall make provision for the removal of the wind turbines and their associated ancillary equipment to a depth up to one metre below ground and the reinstatement of the site. The scheme shall include proposals for the management and timing of the works, measures to be taken to safeguard and where possible enhance wildlife habitats and a traffic management plan and shall be implemented as approved.

6) No development shall commence until a Construction Method Statement has been submitted to and approved in writing by the local planning authority. The construction of the development shall only be carried out in accordance with the approved Construction Method Statement, unless otherwise approved in writing by the local planning authority. The Construction Method Statement shall address the following matters:
(a) A Site Environmental Management Plan to include details of measures to be taken during the construction period to protect wildlife, habitats and hydrology; an ecological survey; an investigation and monitoring scheme to oversee and direct construction works; and details of soil handling, storage and restoration.
(b) Details of the timing of works and methods of working for cable trenches and foundation works.

(c) Details of the timing of works and construction of the substation/control buildings and anemometry masts.
(d) Dust management.
(e) Pollution control: protection of water courses and ground water and soils, bunding of fuel storage areas, sewage disposal.
(f) Disposal of surplus materials.
(g) Construction noise management plan including identification of access routes, locations of materials lay-down areas, details of equipment to be employed, operations to be carried out, mitigation measures and a scheme for the monitoring of noise.
(h) Details of a site evacuation/flood management plan.
(i) Temporary site illumination.
(j) The construction of the access into the site and the creation and maintenance of visibility splays.
(k) Wheel cleaning facilities.
(l) Arrangements for keeping the site entrance and adjacent public road clean.
(m) Post-construction restoration and reinstatement of the working areas.

The approved Construction Method Statement shall be implemented and maintained for the duration of the construction works.

7) No development shall commence until a scheme providing for works in the public highway (reflecting the works shown on Figures 3.1 and 3.2 of submitted Supplementary Environmental Information) to enable abnormal indivisible loads (AIL) to access the site has been submitted to and approved in writing by the local planning authority. The scheme shall be implemented as approved and shall:
(a) Make provision to ensure that the use of the improvement works at the junction of Marsh Road with Church Road/Southminster Road Burnham-on-Crouch is restricted to these AIL only.
(b) Include an arboricultural method statement which shall address management and safeguarding of all trees along the AIL route.

8) No development shall commence until a Construction Traffic Management Plan has been submitted to and approved in writing by the local planning authority. The plan, which shall be implemented as approved, shall apply to all construction traffic and shall include, but shall not be limited to:
(a) A pre and post construction road survey, and a programme and methodology for any repairs as a consequence of any damage caused by construction traffic following the completion of construction.
(b) Provisions for the routeing of traffic to and from the site.
(c) Proposal for the timing of traffic movements.
(d) Proposal for the management of traffic movements at junctions with, and pedestrian crossings of, the public highway.
(e) Provisions of signs warning of construction traffic.
(f) The removal and replacement of street furniture, road verges, or other items within the public.
(g) Arrangements to ensure that construction traffic does not use the junction of Marsh Road with Church/Southminster Road Burnham on Crouch when children are scheduled to arrive at or leave Ormiston Academy or St.Mary's Primary school.

9) No AIL movements shall take place until all works have been completed in accordance with the permissions granted pursuant to Appeal References APP/X1545/A/12/2179484 and APP/X1545/A/12/2179225.

10) The hours of operation of the construction phase of the development and any traffic movements to or from the site associated with the construction of the development hereby permitted shall be limited to 0700 hours to 1900 hours on Mondays to Saturdays. No work shall take place on Sundays or Bank Holidays, except for any works previously approved in writing by the local planning authority. Construction works so approved shall not be audible from the boundary of any dwelling. Any emergency works carried out outside the hours provided for in this condition shall be notified in writing to the local planning authority within seven working days of occurrence.

11) Notwithstanding the provisions of Condition 10, delivery of abnormal indivisible loads may take place outside the hours specified subject to not less than 24 hours prior notice of such traffic movements being given to the local planning authority.

12) All cabling on the site between the wind turbines and the site sub-station shall be installed underground.

13) The turbines shall have a semi matt finish and a pale grey colour. Prior to the erection of any turbine its exact finish and colour along with details of the dimensions, finish and colour of any external transformer units and the proposed meteorological and communications masts shall be submitted to and approved in writing by the local planning authority. No name, sign, symbol or logo shall be displayed on any external surfaces of the turbines or any external transformer units or the masts other than those required to meet statutory requirements. The development shall be carried out as approved and thereafter be retained in accordance with the approved details.

14) The height of each of the wind turbines shall not exceed 126.5 metres to the tip of the blades when the turbine is in the vertical position. The hub height of the wind turbines shall be between 77 metres and 87 metres. In each case the height shall be as measured from natural ground conditions immediately adjacent to the turbine base.

The wind turbines shall be erected at the following coordinates:

Turbine ID	X	Y
T1	597864	197734
T2	598203	197889
T3	598408	197589
T4	598756	197686
T5	599047	197452
T6	599442	197280
T7	599420	197663

Notwithstanding the locations of the turbines and other infrastructure shown on Figure 4.2 of the Environmental Statement the turbines may be located within the micro-siting areas shown on Figure 4.1 of the Environmental Statement. The consequential realignment of the associated infrastructure shall also be permitted.

15) All wind turbine blades shall rotate in the same direction.

16) No wind turbine or anemometry mast shall be externally lit except for a PIR activated light above the door to turbines and substation to aid engineers accessing the site during dusk or darkness, temporary lighting required during the construction period or during maintenance, unless otherwise previously approved in writing by the local planning authority.

17) No development of the substation shall commence until details of the appearance, surface materials and dimensions of the proposed substation have been submitted to and approved in writing by the local planning authority. The details of the compound and substation shall reflect what is shown in Figures 4.7 and 4.8 of the Environmental Statement and shall not exceed the total area shown in those figures unless otherwise approved in writing by the local planning authority. The development shall be carried out as approved.

18) No development shall commence until a scheme reflecting the Ecological Mitigation and Enhancement Strategy contained in Chapters 6 and 14 of the Environmental Statement has been submitted to and approved in writing by the local planning authority. The scheme shall be implemented as approved.

19) No development shall take place until the applicant has secured the implementation of a programme of archaeological work in accordance with a written scheme of investigation which has been submitted to and approved in writing by the local planning authority.

20) No development shall take place on site until a scheme to secure the investigation and alleviation of any electro-magnetic interference to TV and radio reception caused by the operation of the turbines has been submitted to and approved by the local planning authority. The scheme shall provide for the investigation by a qualified independent television engineer of any complaint of interference with television reception at a dwelling (defined for the purposes of this condition as a building within use Class C3 of the Use Classes Order) which lawfully exists or had planning permission at the date of this permission where such a complaint is notified to the developer by the local planning authority within 12 months of the First Export Date. Where impairment is determined by the qualified independent television engineer to be attributable to the wind farm, details of the mitigation works which have been approved in writing by the local planning authority shall be implemented in accordance with the approved scheme.

21) Prior to the erection of any wind turbine a scheme providing for the avoidance of shadow flicker at any dwelling lawfully existing or with planning permission at the date of this permission shall be submitted to and approved in writing by the local planning authority. The approved scheme shall be implemented and thereafter retained.

22) Prior to the commencement of the development an ornithological post construction monitoring scheme (to include but not be limited to corpse searching) for a period of five years to commence when all of the wind turbines have been erected shall be submitted to and approved in writing by the local planning authority. The scheme shall include a methodology for the carrying out of the monitoring and shall make provision for annual reports of that monitoring to be submitted to the local planning authority. The monitoring scheme shall be implemented as approved.

23) No development shall take place until details of a scheme to mitigate any adverse effects of the development on the Primary Surveillance Radar at

Southend Airport which shall include the arrangements for the implementation of the scheme, have been submitted to and approved in writing by the local planning authority. No turbine shall be erected until the scheme has been implemented in accordance with the approved details.

24) The level of noise immissions from the combined effects of the wind turbines within this development (including the application of any tonal penalty) when calculated in accordance with the attached Guidance Notes, shall not exceed the values for the relevant integer wind speed set out in the attached Table 1. Noise limits for dwellings which lawfully exist or have planning permission for construction at the date of this consent but are not listed in the Tables attached shall be those of the physically closest location listed in the Tables unless otherwise approved in writing by the local planning authority. The coordinate locations to be used in determining the location of each of the dwellings listed in Table 1 shall be those listed in Table 2.

The wind farm operator shall continuously log power production, wind speed and wind direction, all in accordance with Guidance Note 1(d). These data shall be retained for a period of not less than 12 months. The wind farm operator shall provide this information to the local planning authority on its request within 28 days of receipt in writing of such a request. The data shall be supplied in comma separated values in electronic format unless otherwise approved in writing by the local planning authority.

Within 28 days from receipt of a written request from the local planning authority following a complaint to the local planning authority from an occupant of a dwelling which lawfully exists or has planning permission at the date of this permission, the wind farm operator shall, at the wind farm operator's expense, employ an independent consultant approved in writing by the local planning authority to assess the level of noise immissions from the wind farm at the complainant's property in accordance with the procedures described in the attached Guidance Notes. The written request from the local planning authority shall set out at least the date, time and location that the complaint relates to and any identified atmospheric conditions, including wind direction.

The wind farm operator shall provide to the local planning authority the independent consultant's assessment of the said complaint in accordance with the attached Guidance Notes within the later of two months of the date of the written request of the local planning authority above or two months following the approval of the local planning authority of the independent consultant and the approval of rain gauge location(s) under Guidance Note 1e, unless the time limit is extended in writing by the local planning authority. All data collected for the purposes of undertaking the compliance measurements shall be made available to the local planning authority on its request within 28 days of receipt in writing of such a request.

Table 1

Noise limits expressed in dB $L_{A90,10\text{-}minute}$ as a function of the standardised wind speed (m/s) at 10 metre height as determined within the site averaged over 10 minute periods

Location	Standardised wind speed at 10 m height in m/s								
	4	5	6	7	8	9	10	11	12
West Wycke Farm	38.0	38.0	38.0	38.0	38.0	40.3	45.2	50.7	50.7
Great West Wycke Farmhouse	38.0	38.0	38.0	38.0	39.7	44.3	49.1	53.3	53.3
1 Redward Cottages	38.0	38.0	38.0	38.0	39.7	44.3	49.1	53.3	53.3
New Bungalow	38.0	38.0	38.0	38.0	39.7	44.3	49.1	53.3	53.3
Turncole Farm	44.8	44.6	44.3	44.1	44.0	44.0	48.6	54.3	54.3
Broadward Farm	44.9	44.7	44.6	44.4	44.4	44.3	45.5	50.8	50.8
Poultry Farm	38.0	38.0	38.0	38.0	39.7	44.3	49.1	53.3	53.3
3 East Wick Cottages	38.0	38.0	38.0	38.0	38.0	41.6	45.7	48.5	48.5
Montsale Bungalow	38.0	38.0	37.9	37.2	36.7	43.4	48.8	53.5	53.5
West Wycke Bungalow	38.0	38.0	38.0	38.0	38.0	40.3	45.2	50.7	50.7
Old Montsale Farm	38.0	38.0	38.0	38.0	38.9	44.0	49.0	53.6	53.6
Wraywick Farm	38.0	38.0	37.4	36.4	35.7	39.2	45.3	50.7	50.7
Deal Hall	38.0	38.0	38.0	38.0	39.5	44.2	49.1	53.6	53.6
New Montsale	38.0	38.0	38.0	38.0	39.2	44.1	49.0	53.6	53.6
Middlewick Cottage	38.0	38.0	38.0	38.0	39.7	43.3	48.5	53.4	53.4
Middle wick	38.0	38.0	38.0	37.6	37.2	43.5	48.8	53.5	53.5
Court Farm	38.0	38.0	38.0	37.4	36.9	43.4	48.8	53.5	53.5
Wraywick Cottage	38.0	38.0	38.0	38.0	38.0	40.6	45.7	50.9	50.9
Dammerwick Farmhouse	38.0	38.0	38.0	38.0	38.0	40.5	45.3	50.7	50.7
Newmans Farm	38.0	38.0	38.0	38.0	38.0	40.4	45.3	50.7	50.7
8 Dammerwick Cottages	38.0	38.0	38.0	38.0	38.0	40.5	45.3	50.7	50.7
Brook Farmhouse	38.0	38.0	38.0	38.0	38.0	40.5	45.3	50.7	50.7
1 East Wick Cottages	38.0	38.0	38.0	38.0	38.0	41.6	45.7	48.5	48.5
2 Coney Hall Cottages	38.0	38.0	38.0	38.0	38.0	41.6	45.7	48.5	48.5
Coney Hall	38.0	38.0	38.0	38.0	38.0	41.6	45.7	48.5	48.5

Table 2

Coordinate locations of the properties listed in Table 1.

House Name	British National Grid Coordinates	
	Easting	Northing
West Wycke Farm	597924	196919
Great West Wycke Farmhouse	598490	196714
1 Redward Cottages	598532	196564
New Bungalow	598818	196666
Turncole Farm	599105	198347
Broadward Farm	598483	198639
Poultry Farm	598944	196651
3 East WickCottages	600254	196617
Montsale Bungalow	600456	198210
West Wycke Bungalow	597954	196928
Old Montsale Farm	600729	197742
Wraywick Farm	598431	199214
Deal Hall	601025	197108
New Montsale	600712	197419
Middlewick Cottage	600712	198664
Middle wick	601275	198759
Court Farm	601408	199092
Wraywick Cottage	598135	198948
Dammerwick Farmhouse	596297	196913
Newmans Farm	596221	197420
8 Dammerwick Cottages	596029	196953
Brook Farmhouse	595815	197145
1 East WickCottages	600105	196506
2 Coney HallCottages	600877	196576
Coney Hall	600901	196689

Note to Table 2: The geographical coordinate references are provided for the purpose of identifying the general location of dwellings to which a given set of noise limits applies.

Guidance Notes for Noise Conditions

These notes are to be read with and form part of Condition 24. They further explain the noise conditions and specify the methods to be employed in the assessment of complaints about noise immissions from the wind farm. Reference to ETSU-R-97 refers to the publication entitled *The Assessment and Rating of Noise from Wind Farms* (1997) published by the Energy Technology Support unit (ETSU) for the Department of Trade and Industry (DTI).

Guidance Note 1

(a) Values of the $L_{A90,10\text{-minute}}$ noise statistic should be measured at the complainant's property, using a sound level meter of EN 60651/BS EN 60804 Type 1, or BS EN 61672 Class 1 quality (or the equivalent UK adopted standard in force at the time of the measurements) set to measure using the fast time weighted response as specified in BS EN 60651/BS EN 60804 or BS EN 61672-1 (or the equivalent UK adopted standard in force at the time of the measurements). This should be calibrated in accordance with the procedure specified in BS 4142: 1997 (or the equivalent UK adopted standard in force at the time of the measurements). Measurements shall be undertaken in such a manner to enable a tonal penalty to be applied in accordance with Guidance Note 3.

(b) The microphone should be mounted at 1.2-1.5 metres above ground level, fitted with a two-layer windshield or suitable equivalent approved in writing by the local planning authority, and placed outside the complainant's dwelling. Measurements should be made in "free field" conditions. To achieve this, the microphone should be placed at least 3.5 metres away from the building facade or any reflecting surface except the ground at the approved measurement location. In the event that the consent of the complainant for access to his or her property to undertake compliance measurements is withheld, the wind farm operator shall submit for the written approval of the local planning authority details of the proposed alternative representative measurement location prior to the commencement of measurements and the measurements shall be undertaken at the approved alternative representative measurement location.

(c) The $L_{A90,10\text{-minute}}$ measurements should be synchronised with measurements of the 10-minute arithmetic mean wind speed and operational data logged in accordance with Guidance Note 1(d), including the power generation data from the turbine control systems of the wind farm.

(d) To enable compliance with the conditions to be evaluated, the wind farm operator shall continuously log arithmetic mean wind speed in metres per second and wind direction in degrees from north at hub height for each turbine and arithmetic mean power generated by each turbine, all in successive 10-minute periods. Unless an alternative procedure is previously approved in writing by the local planning authority, this hub height wind speed, averaged across all operating wind turbines, shall be used as the basis for the analysis. Each 10 minute arithmetic average mean wind speed data measured at hub height shall be 'standardised' to a reference height of 10 metres as described in ETSU-R-97 at page 120 using a reference roughness length of 0.05 metres. It is this standardised 10 metre height wind speed data which is correlated with the noise measurements and referred to in Table 1. All 10-minute periods shall commence on the hour and in 10- minute increments thereafter synchronised with Greenwich Mean Time and adjusted to British Summer Time where necessary.

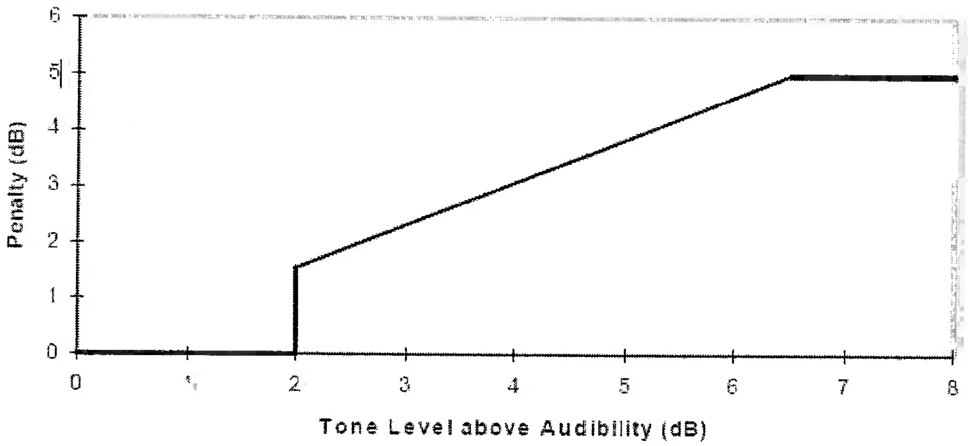
(e) Prior to the commencement of measurements the wind farm operator shall submit for the approval in writing of the local planning authority details of the proposed location of a data logging rain gauge which shall be installed during the course of the assessment of the levels of noise immissions. The data logging rain gauge shall record rainfall over successive 10-minute periods synchronised with the periods of data recorded in accordance with Note 1(d).

Guidance Note 2

(a) The noise measurements should be made so as to provide not less than 20 valid data points as defined in Guidance Note 2 paragraph (b).
(b) Valid data points are those measured in the conditions specified by the local planning authority under noise condition 24, but excluding any periods of rainfall measured in the vicinity of the sound level meter.
(c) For those data points considered valid in accordance with Guidance Note 2(b), values of the $L_{A90,10\text{-minute}}$ noise measurements and corresponding values of the 10-minute wind speed, as derived from the standardised ten metre height wind speed averaged across all operating wind turbines using the procedure specified in Guidance Note 1(d), shall be plotted on an XY chart with measured $L_{A90,10min}$ noise level on the Y-axis and the standardised mean wind speed on the X-axis. A least squares, "best fit" curve of an order deemed appropriate by the independent consultant (but which may not be higher than a second order polynomial) should be fitted to the data points and define the wind farm noise level at each integer wind speed.

Guidance Note 3

Where noise immissions at the location or locations where compliance measurements are being undertaken contain or are likely to contain a tonal component, a tonal penalty is to be calculated and applied using the following rating procedure.
(a) For each 10-minute interval for which $L_{A90,10\text{-minute}}$ data have been determined as valid in accordance with Guidance Note 2 a tonal assessment shall be performed on noise immissions during 2 minutes of each 10-minute period. The 2-minute periods should be spaced at 10-minute intervals provided that uninterrupted uncorrupted data are available ("the standard procedure"). Where uncorrupted data are not available, the first available uninterrupted clean 2-minute period out of the affected overall 10-minute period shall be selected. Any such deviations from the standard procedure, as described in Section 2.1 on pages 104-109 of ETSU-R-97, shall be reported.
(b) For each of the 2-minute samples the tone level above or below audibility shall be calculated by comparison with the audibility criterion given in Section 2.1 on pages 104 -109 of ETSU-R-97.
(c) The tone level above audibility shall be plotted against wind speed for each of the 2-minute samples. Samples for which the tones were below the audibility criterion or no tone was identified, a value of zero audibility shall be substituted.
(d) A least squares "best fit" linear regression line shall then be performed to establish the average tone level above audibility for each integer wind speed derived from the value of the "best fit" line at each integer wind speed. If there is no apparent trend with wind speed then a simple arithmetic mean shall be used. This process shall be repeated for each integer wind speed for which there is an assessment of overall levels in Guidance Note 2.
(e) The tonal penalty is derived from the margin above audibility of the tone according to the figure below.



Guidance Note 4

If the wind farm noise level (including the application of any tonal penalty as per Guidance Note 3) is above the limit set out in the conditions, measurements of the influence of residual noise shall be made in accordance with a methodology that has been previously submitted to and approved in writing by the local planning authority to determine whether or not there is a breach of condition. This may be achieved by repeating the steps in Guidance Notes 1 & 2 with the wind farm switched off in order to determine the residual noise, L_3, at the assessed wind speed. The wind farm noise at this wind speed, L_1, is then calculated as follows, where L_2 is the measured wind farm noise level at the assessed wind speed with turbines running but without the addition of any tonal penalty:

$$L_1 = 10\log\left[10^{L_2/10} - 10^{L_3/10}\right]$$

The wind farm noise level is re-calculated by adding the tonal penalty (if any) to the wind farm noise.

Appeal B: APP/X1545/A/12/2179484

1) The development hereby permitted shall begin not later than five years from the date of this decision.

2) The development hereby permitted shall be carried out in accordance with the following approved plans: Planning Application Boundary Drawing No.02340D2909-01 and Delivery Analysis Drawing No.02340D2414-01 Sheets 1 and 2, except in respect of the detail shown on Sheet 2 which shall be approved pursuant to Condition 3 below.

3) No development shall commence until a scheme has been submitted to and approved in writing by the local planning authority detailing:

(a) The works required to implement the permission, along with a timetable for implementation.

(b) Proposals to restore land outside the carriageway of the public highway (including new or replacement planting of trees and hedges).

(c) The maintenance of the restoration works for a period of five years from their completion.

(d) The method statement providing for works to manage and safeguard trees during implementation of the works.

The scheme shall be implemented as approved.

4) No development under this permission shall take place prior to the commencement of development of the wind farm granted planning permission under Appeal Reference: APP/X1545/A/12/2174982.

Appeal C: APP/X1545/A/12/2179225

1) The development hereby permitted shall begin not later than five years from the date of this decision.

2) The development hereby permitted shall be carried out in accordance with the following approved plans: Planning Application Boundary Drawing No.02340D2513-05 Sheets 1 and 2, Bridge Proposed Adjacent to Twizzlefoot Bridge Drawing No.02340D2413-06 Sheets 1 and 2, except in respect of the detail shown on Drawing No.02340D2413-06 which shall be approved pursuant to Condition 3 below.

3) No development shall commence until a scheme has been submitted to and approved in writing by the local planning authority detailing:

(a) The works required to implement the permission, along with a timetable for implementation.

(b) Proposals to restore land outside the carriageway of the public highway (including new or replacement planting of trees and hedges).

(c) The maintenance of the restoration works for a period of five years from their completion.

The scheme shall be implemented as approved.

4) No development under this permission shall take place prior to the commencement of development of the wind farm granted planning permission under Appeal Reference: APP/X1545/A/12/2174982.

APPEARANCES

FOR THE LOCAL PLANNING AUTHORITY:

Gwion Lewis of Counsel	Instructed by Solicitor for Maldon District Council.

He called

Dick Bowdler BSc FIOA CEng CPhys FCIBSE MCIArb	Noise consultant.
Nigel Cowlin BA(Hons) DipLA CMLI	Landscape planning consultant.
Roy Lewis BA(Hons) MA(Arch Cons) MRTPI IHBC	Director of Grover Lewis Associates Limited.
Clive Tokley MRTPI	Town planning consultant.

FOR THE APPELLANT:

Marcus Trinick QC	Partner Eversheds LLP.

He called

Dr Andrew Bullmore BSc(Hons) PhD MIOA	Managing Partner of Hoare Lee Acoustics.
Colin Goodrum BSc(Hons) DipLA CMLI	Senior Partner of LDA Design.
Simon Pryce BSc(Hons) FArborA CBiol MSB MICFor	Simon Pryce Arboriculture.
Dr Stephen Carter BSc(Hons) PhD MIfA FSA Scot	Senior Consultant of Headland Archaeology (UK) Limited.
David Stewart MA(Cantab) Dip TP MRTPI	David Stewart Associates.

FOR SIEGE Rule (6) party:

Michael Fry of Counsel	Instructed by SIEGE.

He called

John Holland	Local resident and retired electrical engineer.
Frederick Ayley	Local resident.
Peter Bateman	Local resident.
Stephen Thorogood	Chairman of SIEGE and local resident.

INTERESTED PERSONS:

James Cousins	Representing St Mary Church Council.
Eileen Rowlands	Local resident.
John Harrison BTech(Hons) CEng	Local resident.

PROOFS OF EVIDENCE (PoE), WRITTEN REPRESENTATIONS (WR) AND STATEMENT OF COMMON GROUND

Maldon District Council

PoE1	Summary, Proof and Appendices of Dick Bowdler
PoE2	Summary, Proof and Appendices of Nigel Cowlin
PoE3	Summary, Proof and Appendices of Roy Lewis
PoE4	Proof and summary by Clive Tokley

SIEGE

PoE5	Proof of John Holland
PoE6	Proof of Frederick Ayley
PoE7	Proof of Peter Bateman
PoE8	Proof of Stephen Thorogood
WR1	Written statement of Peter Giles local resident.
WR2	Written statement of Steve and Lesley Brock local residents.
WR3	Written statement of Helen Fisher local resident.
WR4	Written statement of Mania Row MA local resident.

Appellant

PoE9	Summary, Proof and Appendices of Dr Andrew Bullmore
PoE10	Summary, Proof and Appendix of Colin Goodrum
PoE11	Summary, Proof and Appendices of Simon Pryce
PoE 12	Summary, Proof, Rebuttal and Appendices of Dr Stephen Carter
PoE 13	Summary, Proof and Appendices of David Stewart
WR5	Written statement of David Broughton BSc MSc MPhil CEnv MIEEM on Ecology Matters.

Other representations

Written representations to the Council at the application stage - attached to Questionnaire.

Third party written representations about appeals - in Red folder.

SoCG Statement of Common Ground dated 26 March 2013.

DOCUMENTS SUBMITTED AT THE INQUIRY (ID)

Document	1	Opening statement on behalf of the appellant.
Document	2	Opening submissions of the Council.
Document	3	Opening statement of behalf of SIEGE
Document	4.1	Draft conditions – Appeal A.
	4.2	Draft conditions – Appeals B and C.
	4.3	Revised draft conditions with tracked changes – Appeal A.
	4.4	Revised draft conditions – Appeals A.
	4.5	Revised draft conditions – Appeals B and C.
	4.6	Revised draft conditions – Appeals A, B and C.
	4.7	Final version of suggested conditions – with appellant's and Council's suggested figures for Table 1 of noise condition.
Document	5	Appellant's proposed noise limits.
Document	6	Appellant's response to Council's proposed noise limits.
Document	7	Noise Common Ground v5.0.

Document	8	*Concerned about wind turbines in Aberdeenshire* prepared by Dick Bowdler.
Document	9	Tranquillity mapping.
Document	10	Viewpoint alignments and mast locations.
Document	11	Letter dated 19 April 2013 from Square One law LLP withdrawing objection by Mr John Boyce.
Document	12	*East Northamptonshire DC v SoS for CLG* CO/4231/2012 Barnwell Manor Wind Energy Limited.
Document	13	Definitive list of drawings.
Document	14	*Guidelines for Landscape and Visual Impact Assessment* Third Edition.
Document	15.1	Carriageway widening in vicinity of Tree 11 and Tree 12.
	15.2	Detail 9 – correct plot.
Document	16	Carlton Grange appeal decision Ref:APP/D2510/A/12/2176754.
Document	17	Comparative table of the assessment of effects on viewpoints – version 2.
Document	18	Calculation of the energy loss due to environmental noise curtailment.
Document	19	Amplitude Modulation (AM) noise condition suggested by SIEGE.
Document	20	Hockley Farm appeal decision Ref:APP/X1545/A/06/2023805.
Document	21	Photo locations Mr Pryce.
Document	22	Highway works views of Mr Cowlin, Mr Pryce, Mr Goodrum and matters in dispute.
Document	23	Maldon District Local Development Plan Preferred Options Consultation (2012).
Document	24	Revised extent of Middlewick medium magnitude effects (CD58 paragraph 19)
Document	25	Annotated version of viewpoint alignments and mast locations.
Document	26	Statement by Mr J Cousins on behalf of the Parochial Church Council of the Parish of St Mary the Virgin Burnham on Crouch, including photographs 1 and 2.
Document	27	Statement by Eileen Rowlands.
Document	28	Email dated 23 April 2013 from Highway Authority concerning adopted highway boundary east of Muscle bridge.
Document	29	Plan showing location of first two wind turbines erected at Bradwell.
Document	30	High Court judgment Spring Farm Ridge *South Northamptonshire Council and SoS CLG* Case No:CO/8849 and 89/2012.
Document	31	Extract from Essex & Southend-on-Sea Replacement Structure Plan April 2001 Policy CC1.
Document	32	Local Development Plan – Preferred Options Consultation (2012) Preferred Policy D4.
Document	33	Turncole Mitigation Options Paper, Osprey Consulting Services Ltd may 2013.
Document	34	Land Plan and Swept Path showing proposed lease plan for land at Fambridge Road.
Document	35.1	Emails to and from Strutt and Parker Farms dated June and August 2012 concerning access for delivery of components by boat.
	35.2	Emails to and from other farm owner dated August 2012

		concerning access for delivery of components by boat.
Document	36	Email from John Boyce dated 7 May 2013 concerning flying from Burnham site.
Document	37	Email from appellant concerning grid connection dated 7 May 2013.
Document	38	Closing statement on behalf of SIEGE.
Document	39	Closing submissions of the Council.
Document	40	Closing submissions on behalf of the appellant.

DOCUMENTS CONSIDERED AFTER THE CLOSE OF THE INQUIRY

Document	41	*A Good Practice Guide to the Application of ETSU-R-97 for the Assessment and Rating of Wind Turbine Noise,* Institute of Acoustics, 20 May 2013 (GPG).
	41.1	Letter from Secretary of State for Energy and Climate Change to President Institute of Acoustics dated 20 May 2013.
	41.2	Appellant's comments on GPG.
Document	42	*Anita Colman and SoS for CLG and North Devon DC and RWE* [2013] EWHC 1138 (Admin) Case No:CO/12831/2012.
	42.1	Email from appellant dated 21 May 2013.
	42.2	Email from Council dated 29 May 2013.
	42.3	Email from SIEGE dated 24 May 2013.
Document	43a	Written statement to Parliament Local planning and onshore wind, Dept for Communities and Local Government, 6 June 2013.
	43a.1	Letter to PINS from Secretary of State, 6 June 2013.
	43b	Written statement to Parliament, Written Ministerial Statement by Edward Davey: Onshore Wind, 6 June 2013.
	43.1	Comments by appellant.
	43.2	Comments by SIEGE.
Document	44	*Planning practice guidance for renewable and low carbon energy,* The Department for Communities and Local Government, 29 July 2013 (PPG).
	44.1	Comments by the appellant.
	44.2	Comments by the Council.
	44.3	Comments by SIEGE.
	44.4	Appellant's response to the Council and SIEGE comments on the new Planning Practice Guidance.

LIST OF PLANS

Appeal A
Planning Application Boundary (Site Location Plan) Drawing No.02340D2908-05.
Turbine Layout with Micro-siting Drawing No.02340D2107-05.
Infrastructure Layout Drawing No.02340D1001-14.

Appeal B
Planning Application Boundary Drawing No.02340D2909-01.
Delivery Analysis Drawing No.02340D2414-01 Sheets 1 and 2.

Appeal C
Planning Application Boundary Drawing No.02340D2513-05 Sheets 1 and 2.
Bridge Proposed Adjacent to Twizzlefoot Bridge Drawing No.02340D2413-06 Sheets 1 and 2.

CORE DOCUMENTS (CD)	
Planning Application Documents	
1.	Planning Application Form – Turncole Wind Farm dated 14th Feb 2011 (inc. Certificate B, Agricultural Holdings Certificate)
2.	Planning Application Form – North Fambridge dated 9 February 2012 (inc. Certificate B, Agricultural Holdings Certificate)
3.	Planning Application From – Twizzlefoot Bridge dated 6 October 2011 (inc. Certificate B, Agricultural Holdings Certificate)
4a.	Local Authority Decision Notice Turncole Wind Farm (25 October 2011)
4b.	Local Authority Decision Notice North Fambridge (16 May 2012)
4c.	Local Authority Decision Notice Twizzlefoot Bridge (23 May 2012)
5.	Site Location Plan 02340D2908-05 (Turncole Wind Farm)
6a.	Planning Statement dated October 2010
6b	Addendum Planning Statement dated February 2011
7.	Design and Access Statement dated 2010 (Turncole Wind Farm)
8a.	Environmental Statement – Volume 1 Non-Technical Summary
8b.	Environmental Statement – Volume 2 Main text
8c.	Environmental Statement – Volume 2 Appendices
8d.	Environmental Statement – Volume 3 (Figures) dated 2010
9.	Site Plan 02340D2909-01 (North Fambridge)
10.	Design and Access Statement dated 2010 (North Fambridge)
11.	Site Plan 02340D2513-05 (Twizzlefoot Bridge)
12.	Design and Access Statement dated 2011 (Twizzlefoot Bridge)
13a.	Supplementary Environmental Information –Non-Technical Summary dated October 2012
13b.	Supplementary Environmental Information – Volume 1 Text
13c.	Supplementary Environmental Information – Volume 1a Text
13d.	Supplementary Environmental Information – Volume 1 Appendices
13e.	Supplementary Environmental Information – Volume 2 Figures
14.	Maldon District Council Committee Report for Turncole Wind Farm dated 24 October 2011
15.	Maldon District Council Committee Report for North Fambridge dated 14 May 2012
16.	Maldon District Council Committee Report for Twizzlefoot Bridge dated 21 May 2012
17.	Maldon District Council Committee Report for Turncole Wind Farm dated 17 January 2013
18.	Maldon District Council Committee Report for North Fambridge dated 14 January 2013
19.	Maldon District Council Committee Report for Twizzlefoot Bridge dated 7 January 2013
20.	Agreed Council Updated Reasons for Refusal
Planning Policy Documents	
21.	East of England Regional Spatial Strategy May 2008
22.	Essex and Southend Structure Plan
23a.	Maldon District Replacement Local Plan 2005
23b.	Maldon LDF Core Strategy (Draft) – December 2010
24.	National Planning Policy Framework (March 2012)
25.	UK Renewable Energy Strategy 2009

26.	Overarching National Policy Statement for Energy (EN-1) (Version for Approval) (June 2011)
27.	National Policy Statement for Renewable Energy Infrastructure (EN-3) (Version for Approval) (June 2011)
28a.	UK Renewable Energy Road Map – July 2011
28b.	UK Renewable Energy Road Map - 2012 update
29.	ARUP Report – *Placing Renewables in the East of England* - 2008
30.	*East of England Renewable and Low Carbon energy Capacity Study* – AECOM – April 2011
31.	PINS Advice for Inspectors: Regional Strategies – Impact of Cala Homes Litigation (24 March 2011)
32.	Letter dated 6 July 2010 from the Secretary of State for Communities and Local Government to all Chief Planning Officers
33.	Localism Act, PINS Guidance for Appeal Parties, 7th December 2011
34.	Committee on Climate Change - *Renewable Energy Review* May 2011
Court of Appeal and High Court Decisions	
35.	*The Queen on the Application of Cala Homes (South) Limited v Secretary of State for Communities and Local Government & Anr* [2011] EWCA Civ 639 – Decision of 27th May 2011
36.	*(1) Derbyshire Dales District Council (2) Peak District National Park v (1) Secretary of State for Communities and Local Government (2) Carsington Wind Energy Limited* [2009] EWHC 1729 (Admin)
37.	Bradwell High Court Decision March 2011
Appeal Decisions	
38.	*Den Brook* APP/Q1153/A/06/2017162
39.	*Den Brook* APP/Q1153/A/06/2017162 second decision & Den Brook High Court decision on second appeal
40.	*Cotton Farm* (APP/H0520/A/09/2119385)
41.	*Sober Hill* (APP/E2001/A/09/2101421)
42.	Carsington Pastures (APP/P1045/A/07/2054080)
43.	Carsington Pastures high court decision [2009] EWHC 1729 Admin
44.	Yelvertoft APP/Y2810/A/10/2120332
45.	Wadlow Farm APP/W0530/A/07/2059471
46.	Rochdale, Rossendale & Calderdale
47.	Burnthouse Farm, APP/D0515/A/10/2123739
48.	Spaldington APP/E2001/A/10/2137617 & 2139965
49.	*Lilbourne* APP/Y2810/A/11/2164759
50.	*Chelveston* APP/G2815/A/11/2160078
51.	*Spring Farm Ridge* APP/Z2830/A/11/2165035
52.	*Winwick* APP/Y2810/A/11/2156527
53.	*Woolley Hill* APP/H0520/A/11/2158702 230312
54.	*Kelmarsh* APP/Y2810/A/11/2154375
55.	*Croft* APP/D2510/A/04/1155199
56.	*Watford Lodge* APP/Y2810/A/11/2153242
57.	*Bradwell* 2007 APP/X1545/A/06/2023805
58.	*Middlewick* APP/X1545/A/10/2140423
59.	*Jacks Lane and Chiplow* APP/V2635/A/11/2154590
60.	*Barnwell Manor* APP/G2815/A/11/2156757
61.	*Brightenber* (APP/C2708/A/09/2107843)

62.	*Carland Cross* (APP/D0840/A/09/2103026)
63.	*Knabs Ridge* (APP/E2734/A/04/1161332)
64.	*Withernwick* (APP/E2001/A/05/2088796)
65.	*Swinford* (APP/F2415/A/09/2096369)
66.	*Hempnall* (APP/L2630/A/08/2084443)
67.	*Low Spinney* (APP/F2415/A/09/2109745)
68.	*Enifer Downs* (APP/X2220/A/2071880)
69.	*Sillfield* (APP/M0933/A/09/2099304)
70.	*Frodsham* (DP1/A0655/11/13)
71.	*Middlemoor* (ELEC/2005/2004 - GDBC/001/00245C)
72.	*Flixborough Grange* (APP/Y2003/A/09/2105130)
73.	*Cleek Hall* (APP/N2739/A/12/2172629)
74.	*Cottam* (APP/A3010/A/11/2146094)
75.	*Berkeley Vale* (APP/C1625/11/A/2155923)
76.	*Watford Lodge* (APP/Y2810/A/11/2153242)
Landscape and Visual Documents	
77.	Landscape Institute and Institute of Environmental Management and Assessment (Second Edition 2002) *Guidelines for Landscape and Visual Impact Assessment*
78.	Draft 3rd Version of the Guidelines for Landscape and Visual Impact Assessment (extracts)
79.	Scottish Natural Heritage and The Countryside Agency Landscape Character Assessment Series (2004) Topic Paper 6: *Techniques and Criteria for Judging Capacity and Sensitivity*
80.	Scottish Natural Heritage - *Assessing the Cumulative Effect of Onshore Wind Energy Developments* March 2012
81.	Scottish Natural Heritage *Visual Representation of Windfarms - Good Practice Guidance*, Natural Heritage Management Series (2006)
82.	Countryside Agency and SNH (2002) *Landscape Character Assessment Guidance for England and Scotland*.
83.	"Siting and Designing Windfarms in the Landscape". SNH December 2009
84.	Landscape Institute Advice Note 01/11 Photography and photomontage in landscape and visual impact assessment
85.	*Companion Guide to PPS 22: Renewable Energy* (2004) (Extract – Technical Annex on non wind matters excluded)
86.	Landscape Character Assessment Guidance for England and Scotland – Topic Paper 9 – *Climate Change and Natural Forces – the consequences for landscape character* – Produced by The Countryside Agency and SNH
87.	East of England Regional Assembly. *Placing Renewables in the East of England*. February 2008.
88.	*Countryside Character Initiative, Volume 6: East of England*, Countryside Agency 1999
89.	Essex Landscape Character Assessment, Chris Blandford Associates, 2003
90.	Extracts from Essex Countryside Conservation Plan (1986)
91.	Maldon District Landscape Character Assessment (2006)
92.	Maldon District Historic Environment Characterisation (HEC) Project

	(2008)
93.	Nigel Cowlin's responses to ES and SEI
94.	Natural England's responses to ES and SEI
95.	Joint Character Area 81: Greater Thames Estuary (Natural England)
96.	Joint Character Area 111: Northern Thames Basin (Natural England)
Ecology	
97.	British Standard 5837:2012, *Trees in relation to design, demolition and construction.*
98.	British Standard 3998:2010, *Recommendations for treework.*
99.	Highways Act 1980, ss41 and 154
100.	Essex County Council Highway Maintenance Strategy, April 2008 (Appendix 3 of Simon Pryce Proof)
101.	Collett Transport Test Drive Report no 20513 - for RES Ltd, March 2010
Noise	
102.	*The Assessment and Rating of Noise from Wind Farms 1997* (ETSU-97-R)
103.	Noise Policy Statement for England (NPSE)
104.	ISO 9613 Part 2 Noise Propagation Model
Cultural Heritage	
105.	*Wind Energy in the Historic Environment* English Heritage Guidance - October 2005
106.	*Conservation Principles, Policy and Guidance* English Heritage Guidance - April 2008
107.	*The Setting of Heritage Assets English Heritage Guidance* - October 2011
108.	*Planning Practice Guide to PPS 5: Planning for the Historic Environment* - 2010
Miscellaneous Documents	
109.	Proposals Map from Maldon Local Plan
110.	Calculation of the Energy Loss due to Environmental Curtailment at the Proposed Turncole Wind Farm
111.	Appeal decision *Tunstall* APP/E2001/A/10/2130670
112	Appeal decision *Benington* APP/J1915/A/09/2104406
113	Appeal decision *Dawes Lane* APP/Y2003/A/12/2169774
114	Appeal decision *Truthan Barton Farm* APP/D0840/A/11/2163691
115	Middlewick ES Chapters LVIA, Cultural Heritage & Noise on CD

Department for
Communities and
Local Government

RIGHT TO CHALLENGE THE DECISION IN THE HIGH COURT

These notes are provided for guidance only and apply only to challenges under the legislation specified. If you require further advice on making any High Court challenge, or making an application for Judicial review, you should consult a solicitor or other advisor or contact the Crown Office at the Royal Courts of Justice, Queens Bench Division, Strand, London, WC2 2LL (0207 947 6000).

The attached decision is final unless it is successfully challenged in the Courts. The Secretary of State cannot amend or interpret the decision. It may be redetermined by the Secretary of State only if the decision is quashed by the Courts. However, if it is redetermined, it does not necessarily follow that the original decision will be reversed.

SECTION 1: PLANNING APPEALS AND CALLED-IN PLANNING APPLICATIONS;

The decision may be challenged by making an application to the High Court under Section 288 of the Town and Country Planning Act 1990 (the TCP Act).

Challenges under Section 288 of the TCP Act

Decisions on called-in applications under section 77 of the TCP Act (planning), appeals under section 78 (planning) may be challenged under this section. Any person aggrieved by the decision may question the validity of the decision on the grounds that it is not within the powers of the Act or that any of the relevant requirements have not been complied with in relation to the decision. An application under this section must be made within six weeks from the date of the decision.

SECTION 2: AWARDS OF COSTS

There is no statutory provision for challenging the decision on an application for an award of costs. The procedure is to make an application for Judicial Review.

SECTION 3: INSPECTION OF DOCUMENTS

Where an inquiry or hearing has been held any person who is entitled to be notified of the decision has a statutory right to view the documents, photographs and plans listed in the appendix to the report of the Inspector's report of the inquiry or hearing within 6 weeks of the date of the decision. If you are such a person and you wish to view the documents you should get in touch with the office at the address from which the decision was issued, as shown on the letterhead on the decision letter, quoting the reference number and stating the day and time you wish to visit. At least 3 days notice should be given, if possible.

https://www.gov.uk/government/organisations/department-for-communities-and-local-government

DEPARTMENT FOR BUSINESS
ENTERPRISE & REGULATORY REFORM

Research into aerodynamic modulation of wind turbine noise

Report by University of Salford

URN 07/1235

BERR

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University of Salford
A Greater Manchester University

Research into Aerodynamic Modulation of Wind Turbine Noise: Final report

July 2007
Contract no NANR233

Prepared for Defra by
Dr. Andy Moorhouse, Malcolm Hayes, Dr. Sabine von Hünerbein,
Ben Piper, Dr. Mags Adams

CONTENTS

1. Summary

The study described in this report has been commissioned by Defra, BERR (formerly DTI) and CLG. It follows on from a report by the Hayes McKenzie Partnership to DTI in 2005 in which reports of low frequency noise emission from windfarms were investigated. Their report concluded that the complaints were not caused by low frequency noise, but by amplitude modulation of aerodynamic noise (AM) from the wind turbines. The term AM indicates aerodynamic noise from wind turbines, but with a greater than normal degree of regular fluctuation at blade passing frequency, typically once per second. The aims of this current study are to ascertain the prevalence of AM on UK wind farm sites, to try to gain a better understanding of the likely causes, and to establish whether further research into AM is required. The study was carried out in four parts, a survey of local authorities with windfarms in their areas, further investigation of sites for which AM was identified as a factor, a literature review and a survey of wind turbine manufacturers.

The survey of local authorities was in two parts, a scoping survey aimed at identifying problem sites, and a detailed survey to establish whether AM could have been a factor in causing complaints. The response to both parts of the survey was 100%, although full information was not available for all sites at the detailed stage. The results showed that 27 of the 133 windfarm sites operational across the UK at the time of the survey had attracted noise complaints at some point. An estimated total of 239 formal complaints have been received about UK windfarm sites since 1991, 152 of which were from a single site. The estimated total number of complainants is 81 over the same sixteen year period. This shows that in terms of the number of people affected, wind farm noise is a small-scale problem compared with other types of noise; for example the number of complaints about industrial noise exceeds those about windfarms by around three orders of magnitude. In only one case was the windfarm considered by the local authority to be causing a statutory nuisance. Again, this indicates that, despite press articles to the contrary, the incidence of windfarm noise and AM in the UK is low.

AM was considered to be a factor in four of the sites, and a possible factor in another eight. Regarding the four sites, analysis of meteorological data suggests that the conditions for AM would prevail between about 7% and 15% of the time. AM would not therefore be present most days, although it could occur for several days running over some periods. Complaints have subsided for three out of these four sites, in one case as a result of remedial treatment in the form of a wind turbine control system. In the remaining case, which is a recent installation, investigations are ongoing.

The literature review indicated that, although there has been much research into the general area of aerodynamic noise it is a highly complex field, and whilst general principles are understood there are still unanswered questions. Regarding the specific phenomenon of AM there has been little research and the causes are still the subject of debate. AM is not fully predictable at current state of the art. The survey of wind turbine manufacturers revealed that, although there was considerable interest, few have any experience of AM.

The low incidence of AM and the low numbers of people adversely affected make it difficult to justify further research funding in preference to other more widespread noise issues. On the other hand, since AM cannot be fully predicted at present, and its causes are not fully understood we consider that it might be prudent to carry out further research to improve understanding in this area.

2. Introduction

In 2005 the DTI commissioned the Hayes McKenzie Partnership to investigate claims in the press that infrasound or low frequency noise emitted by wind farms were causing health effects. Their report, published in 2006, concluded that there was no evidence of health effects arising from infrasound or low frequency noise generated by wind turbines. The report went on to note that the cause of complaints was not low frequency noise or infrasound, but was audible modulation of aerodynamic noise, i.e. aerodynamic noise which displays a greater degree of fluctuation than usual. This phenomenon is referred to as AM in the rest of this report. This AM was, in some isolated circumstances, occurring in ways not anticipated by the government guidance document on noise from windfarms known as ETSU-R-97. The Government therefore took the view that more work was required to determine whether or not AM is an issue which may require attention in the context of the rating advice given in the ETSU guide.

2.1. *Aims and objectives*

The aims of this study are to ascertain the prevalence of AM from UK wind farm sites, to try to gain a better understanding of the likely causes, and to establish whether further research into AM is required.

The objectives of the study are as follows:

(a) To establish the levels and nature of the reported noise complaints received across the UK relating to noise issues from wind farms, both historic and current, and determine whether AM is a significant effect;

(b) To review and understand the level of knowledge/understanding that exists throughout the world on AM, and whether AM can be predicted;

2.2. Organisation of the project

The study has been organised into four main tasks in order to achieve these objectives:

a. Survey of Local Authorities;
b. Further investigation into sites with AM
c. Worldwide literature search;
d. Survey of Manufacturers Worldwide;

Sections 3-6 of this report describe tasks a-d respectively, followed by overall Conclusions in Section 7.

3. Survey of Local Authorities

A two-stage survey of local authorities was conducted with the aim of establishing the presence of noise complaints, in particular about AM, from UK windfarms. A database of all operational wind farms in the UK was provided to us by BWEA. This gave us a total of 136 wind farms that were operational at the end of December 2006 to investigate. Four of these are offshore sites, which were initially excluded from the survey on the grounds that they are far from habitation, but were later included after it emerged that one of them had in fact received complaints (which later turned out to be from foghorns, not the wind turbines). The BWEA list includes some windfarms, that are extensions of existing sites, as separate developments. Such extensions are not considered as separate sites by the local authority, and so were merged together on the database. The total number of separate windfarm sites then becomes 133, of which 4 are offshore. Smaller wind energy developments, for example single wind turbines, were not included in the survey because there is no is no definitive list of such developments and it would therefore be difficult to ensure we were dealing with a representative sample.

The BWEA database also provided information about the number of wind turbines in each wind farm, their capacity, the name of the developer, the country and county of location within the UK and the LA responsible for giving planning permission.

We confirmed that noise nuisance is dealt with by either Unitary Authorities or District Authorities and then identified specific contacts within each local authority. It was felt that where possible we should identify a named individual within the local authority rather than sending a general enquiry to the head of department or 'enquiry' email address. Using the membership list of the Institute of Acoustics we identified names, email addresses and telephone numbers of Environmental Health Officers within each local authority with expertise in noise and acoustics. We also used the Noise Abatement Society's on-line database of local authority contacts for noise complaints to identify contact details for local authorities which did not have individual members of the IoA. We also used a database of Local Authorities held at the University of Salford. If no contact was found we directed our enquiries to the head of the Pollution Control Section or Environmental Health. Any missing contacts were identified by phone calls to the local authority.

On a map we identified all wind farms that were on local authority borders so that we could check if any noise complaints were received by neighbouring local authorities. 47 windfarms were identified as being close to the border with a neighbouring authority, and these authorities were added to the database of local authorities to be contacted.

To respect confidentiality the names of individual windfarms will not be used in this report, nor will the names of specific local authorities or their members of staff. Each windfarm will be referred to by a letter or letters of the alphabet.

3.1. Scoping survey

The first stage of the survey, a scoping survey, aimed to identify those local authorities who had received complaints about windfarm noise. The questionnaire was sent out by email to named individuals and was designed to be as simple as possible to answer with a simple Yes/No, so as to maximise the chances of a reply.

Several points on the questionnaire required careful consideration. One of the main decisions was the question of how far back to go with complaints. It is known that some early installations produced complaints about tonal noise from wind turbine nacelles, which are not related to AM. After some discussion it was decided that to specify a start date might weaken any conclusions that could be drawn. On the other hand, not to specify any date could lead to inconsistencies in the responses. It was therefore decided to specify that complaints should be included from any time since the windfarms have been operational.

A copy of the final phase 1 questionnaire is shown in Figure 1.

Dear NAME

We at Salford University in conjunction with Hayes McKenzie have been appointed by the UK Government (funded by Defra, DTi, and DCLG) to undertake research into noise from windfarms. For details of why this work was commissioned please see http://www.dti.gov.uk/files/file35043.pdf . The aim of the work is to provide clearer advice to planning authorities about wind turbine planning applications.

We would appreciate it if you could take a couple of minutes to answer the following question.

Have you had any noise complaints about any of the wind farms in your area or any windfarms in a bordering authority any time since they have been operational?

If the answer is 'NO' please respond by pressing REPLY in your browser window and simply type NO. We will not trouble you further.
If the answer is 'YES' please respond by pressing REPLY in your browser window and simply list the names of the windfarms about which there have been noise complaints. If the answer is 'yes' then we will need to follow up with a further survey in which we will ask for further details.

We appreciate your help with this matter as the Government wants a 100% response to this question and would be grateful if you could reply by DATE.

Sincerely, Anne Marie Lavin

Sent on behalf of
Head of Survey of Local Authorities
Government Survey into Noise from Wind Turbines (REF: NANR233)
Dr Mags Adams
Senior Research Fellow
Acoustics Research Centre
University of Salford M5 4WT

Figure 1 Phase 1 scoping survey questionnaire

After some follow up emails and, where needed, telephone reminders we were successful in achieving a 100% response to the scoping survey.

3.2. Detailed survey

The aim of the detailed survey was to obtain information about the number and nature of complaints, and in particular to establish the contribution of AM. Every local authority that responded with a positive noise complaint in the scoping survey was sent the detailed questionnaire, to be completed for each wind farm in their area for which they had received noise complaints. In total, 23 LAs were contacted about 27 windfarms.

The detailed questionnaire was developed by the team at Salford, was reviewed by EHOs on the Noise Working Group and by the Hayes McKenzie Partnership, and then sent out via email to the Local Authorities. A complete copy of the final questionnaire is given in the Appendix. The questions include a combination of open and closed questions with tick-boxes to simplify responses where possible. It was decided not to mention AM until the final question so as to encourage EHOs to provide information about all noise complaints and not just to focus on those that might fit the description of AM problems.

Details about the number of complaints and number of complainants were requested along with detailed descriptions of the noise itself and the investigation that took place. A list of terms to describe noise from wind turbines was provided and the EHOs were requested to indicate which of them corresponded to the complaints they had received from each wind farm. Details of any action that had been taken was also requested. Finally, the EHO was asked to indicate whether they felt that the complaint conformed to a description of Amplitude Modulation of Aerodynamic Noise.

Local Authorities were asked to respond within a week and were sent a reminder email and follow up phone calls as necessary.

3.3. *Survey results and analysis*

We obtained a 100% response rate from both the scoping and detailed questionnaires. However, complete information for the detailed survey was not always available. This was particularly the case for complaints from the 1990s since many local authorities did not keep computer records at that time.

Number of complaints and complainants

From the results of the scoping survey we determined that 27 out of the 133 windfarms operating in the UK at the time of the survey have attracted formal complaints about noise. This represents 20% of the total, i.e. one in five windfarms has attracted complaints about noise at some point. One other site, an offshore site, received complaints about foghorns, and this case has been excluded in the statistics since the wind turbines themselves did not generate the noise. These figures are based on 100% returns from local authorities throughout the UK over the entire period since the first windfarms became operational in 1991, and can therefore be treated as a comprehensive and definitive picture of formal noise complaints about windfarms in the UK.

Complete results obtained for the numbers of complaints, numbers of complainants, and the years in which complaints were received are shown in Table 1. Note the distinction between complainant and complaint, where complainant refers to the individual who makes the complaint and complaint refers to each time they log a complaint with the local authority. One complainant may make a number of complaints and therefore the number of complaints can exceed the number of complainants. In order to provide some context for the complaint histories the bottom row of Table 1 gives the number of sites on-line at the end of each year.

We have specific information on the number of complaints from 19 of the 27 windfarms. The total number of complaints received by local authorities relating to these 19 sites was 206, 152 of which were received for a single windfarm. By excluding this untypical figure we see the number of noise complaints about each windfarm varied between 1 and 10 with an average of 3. We can use this to estimate the total number of complaints across the UK by assuming that this average number also applies to the eight sites for which no specific complaint data was available. The result of this projection is that the total number of complaints across the UK is approximately 230 since records began, 152 of which were from a single site. These statistics about the number of complaints should be treated with some caution because there is not complete consistency in the way local authorities count complaints: some would count several complaints from the same person as a single complaint, others would log each separate complaint individually. For this reason it is probably more reliable to count the number of premises affected, i.e. the number of *complainants* as described in the next paragraph.

We now consider the results for the number of complainants. The number of complainants will generally be less than the number of complaints because the same complainant may make several complaints. We have firm information about the number of complainants from 16 sites, with a total of 53 complainants (these are the entries in the rightmost column of Table 1 without an asterisk). No complainant data was available for the remaining 11 sites. For sites marked with an asterisk in the rightmost column of Table 1 the number of complainants was estimated. We did this by making the conservative estimate that each complaint was made by a different complainant. These estimates may be slightly on the high side, but since in every case the numbers are low we would not expect this to have a large influence on the totals. Using this approximation we estimate the number of complainants relating to the 25 windfarms for which we have either complainant or complaint data to be 75. The number of complainants per windfarm varied from 1 to 9 with an average of 3. As before, we can project the total number of complainants across the UK by assuming this average applies to each of the two sites for which no definitive information is available. The final result is that an estimated total of 81 households have complained about windfarms in the UK since records began in 1991.

Complaints per year and total complaints																		
2007	2006	2005	2004	2003	2002	2001	2000	1999	1998	1997	1996	1995	1994	1993	1992	Year of complaints	No of complainants	
	2	1														2005	3	*
		10														2005	1	
													1			1994	1	
1	7	10	9	52	50	23										2001	9	
		3		1												2003	4	*
									1		1					1996,1998	2	
	1	1			1		1									2000, 2002, 2005, 2006	2	
		1														2005	1	
																before 2003	1	
		2														2005	2	*
	7															2006	7	
			2													2004	2	*
	1	1							1	1						1997,1998,2000,2004	4	*
	1				1											2002, 2006	2	*
1																2007	1	*
																1993,1994,1995,1996	5	
																2001, 2002, 2003, 2004	4	
																1992,1993	10	
																before 1997	2	
	1															2006	1	
			1													2004	1	
2																2007	2	*
	2															2006	2	
						1	1									2000, 2001	2	*
	1	3														2005, 2006	4	
																No of entries	25	
																No of windfarms	27	
																% coverage	93%	
4	23	32	12	53	52	24	2	0	2	1	1	0	1	0	0	Total complainants	75	
3	16	16	3	1	2	1	2	0	2	1	1	0	1	0	0	Average per windfarm	3.0	
																Total projected	81	
	136	114	95	83	75	64	56	45	40	36	31	24	18	14	7			

*No separate information given on number of complainants, assumed same as number of complaints.

ılainant history data. Shading indicates the years in which complaints occurred when year by year numbers are not known. Blank entries indicate no data was available.

Beat	Beating	Throbbing	Lapping	Wooshing	Swish	Swoosh	Ghostly noises	Wooh Wooh	Grinding	Rumbling	ike motion sickness'	Whistling	Other please list	Other (describe)	Noise heard by EHO?	Noise nuisance	EHO suspects AM?	AM
		Y		Y	Y				Y				Y	aircraft landing, distant jet, rhythmical	Y	P	DK	N
	Y	Y	Y	Y	Y					Y						N	DK	N
															N	N	DK	N
[illegible]	Y			Y	Y	Y							Y	train in next field, percussive	Y	Y	Y	Y
				Y									Y	churning head	Y	P	DK	M
															Y		N	N
																	N	N
																		M
																		M
		Y		Y	Y	Y							Y	mechanical	Y	P	DK	M
[illegible]	Y			Y	Y	Y							Y	aeroplane overhead doesn't disappear	Y	N	N	M
							Y						Y	low frequency droning	N	N	N	N
[illegible]	Y			Y	Y	Y									Y	N	Y	Y
													Y	whine	Y	N	N	N
	Y			Y	Y	Y		Y							Y	N	DK	N
																N	DK	M
															Y	N	Y	Y
																N		N
																N	DK	N
																		N
						Y							Y	Mechanical whine and monotonous drone	N	N	N	N
	Y														N	N	N	N
															N	N	DK	DK
	Y	Y		Y	Y	Y		Y	Y	Y			Y	Hum	Y	P	Y	Y
																		N
				Y			Y						Y			N	DK	M
													Y	like a washing machine	Y	N	N	M
															NO	16	8	14
															YES	1	4	4
															Don't know (DK)	0	10	1
															Maybe (M)	0	0	8
															Pending (P)	4	0	0
															Total	21	22	27

ummary of detailed survey returns and analysis to determine the prevalence of AM

Prevalence of AM

In this section we consider the extent to which AM may have been a factor in the complaints. Summarised in Table 2 are the results from the part of the survey where local authorities categorised the noise associated with each site based on complainants' descriptions. Also given in this table are columns indicating whether the investigating environmental health officer (EHO) heard the noise, whether they considered it a nuisance and whether they considered the noise to be consistent with the description of AM.

In order to determine whether AM was a factor for each site we took into account several pieces of information: the tick box descriptions of the noise, any other description of the noise, general descriptions of the EHO's investigation, the timing of the complaints, and in some cases a personal knowledge of the site in question. We also considered the EHO's opinion as to whether the noise was consistent with AM, and this information was assigned more confidence if they had heard the noise themselves.

Columns 2-20 are the results from the tick box questions on the survey. The columns have been arranged so that those on the left are the most likely to indicate AM, i.e. "like a train that never gets there", "distant helicopter", "thumping", "thudding", "pulsating", "thumping", "rhythmical beat", and "beating" could be indicative of AM. The terms on the right are generally associated with some other noise source such as gear box noise or blade resonance.

For several sites, particularly early ones, the complaint was cause by a mechanical fault or a gearbox and therefore AM can be excluded. Five sites (F, G, M, N and T) were clearly stated in the returns to be in this category, and four others were possible or probable (P, R, S and Y) on the grounds that they were early problems that have not attracted complaints in recent years. AM was therefore not considered to be the cause of these complaints, the only exception being site M where there were two types of complaint, one indicating mechanical sources and the other indicating possible

AM[1]. From the tick-box descriptions we also concluded that sites L and U were unlikely to involve AM. The 'other' descriptions given by complainants further suggested that mechanical noise was a factor for sites J, L, N, and U. Altogether, AM could be excluded as a factor from eleven sites on the grounds that the complaints were about mechanical noise sources.

The penultimate column of Table 2 indicates that of the 27 sites considered, eight EHOs said AM was not a factor, four said it was, ten did not know whether it was a factor or not and five offered no opinion. The final column in Table 2 gives our opinion as to whether the complaints could be associated with AM taking into account all the information available. In all cases, except one, where the EHO had given a clear Yes or No answer to whether AM was a feature our opinion was consistent with theirs. The one exception was for windfarm AA where the EHO's opinion was 'No' but where we felt that some of the descriptions could have indicated AM. We therefore entered this site as a 'Maybe'.

The final tally is that AM is thought to be a factor in four cases, is not a factor in fourteen, and eight cases are marginal. One is too recent to have sufficient information to form an opinion and has been entered as 'Don't know' on Table 2.

Significance of complaints

In this section we discuss the significance of the complaints by comparing statistics for windfarms with similar statistics for other noise sources. There are two possible ways in which to make comparison, in terms of absolute numbers of complaints, or in terms of the relative number of installations attracting complaints.

Considering a comparison in terms of absolute numbers of complaints, the Chartered Institute of Environmental Health (CIEH) publishes statistics annually on the number

[1] This site is the only site in the UK still to employ outdated two-bladed rotors, which are known to cause greater modulation than more modern three-bladed machines. AM is therefore a potential explanation of complaints in this case, but this does not cause concern about the future.

of noise complaints and nuisances throughout England and Wales. A summary of some of the results from 2004/2005 is given in Table 3.

The number of households complaining to local authorities about noise from windfarm sites throughout the UK since 1991 has been calculated in the preceding section as 81, which corresponds to an average of approximately 5 per year. The number of complaints was projected as 230, an average of about 14 per year, although we have less confidence in this figure than that for the number of complainants. From Table 3 the number of complaints about industrial noise (probably the most comparable category with windfarms at least in terms of the character of the noise) was 7,522 in a year. The total number of complaints about noise was 286,872. It should be noted that the figures from Table 3 are based on returns from 69% of local authorities in England and Wales, whereas the figures for windfarms are from 100% of local authorities throughout the UK (i.e. also including Scotland and Northern Ireland), so that the comparison will tend to overstate the significance of windfarm noise in relative terms.

	Industrial	Commercial/ leisure	Domestic	Construction/ demolition	Vehicles machinery and equipment in streets	Miscellaneous	Total
Noise incidents complained of	7.5	35.8	206.1	11.7	11.3	14.5	286.9
Nuisances	1.4	6.0	27.6	1.8	1.7	1.0	39.5

Table 3 Summary of CIEH statistics on noise complaints and confirmed nuisances (thousands) from 2004/2005 for 69% of local authorities in England and Wales.

It is clear that complaints about noise from windfarms make up an extremely small proportion of the total noise complaints: complaints about industrial noise exceed those from windfarms by around three orders of magnitude, and complaints about noise in general exceed those from windfarms by between four and five orders of magnitude. We would stress that this does not imply that individual complaints about windfarms are less important than about other noise sources, but rather that the scale of the problem in absolute terms is significantly smaller than for other categories of noise.

Clearly a major factor in the small number of complaints relating to windfarms is the relatively small number of sites compared to, say, industrial sites in general. It would be interesting to make a comparison in terms of the proportion of sites of a particular type that attract complaints. However, whilst we know from this study that about one in five windfarms attracts complaints at some point, we do not have comparable figures for other types of site and we are not therefore able to compare in relative terms.

We can gain further insight into the significance of windfarm noise by looking at nuisance statistics. We note from Table 2 that for 16 windfarm sites the local authority considered the noise from the windfarm not to be causing a nuisance, four cases were pending at the time of the survey, i.e. the local authority had not yet reached a formal decision, and in only one case was the noise judged to be causing a statutory nuisance. There are several categories of nuisance in law, and in order for a noise to be actionable by a noise abatement notice it must be categorised as a 'statutory nuisance' a formal definition of which is given in the Environmental Protection Act 1990. We confirmed that the one 'Yes' site had been categorised by the local authority as a 'statutory nuisance'. For the 16 sites not considered to be causing a 'nuisance' it can be taken that there was also no 'statutory nuisance'. Therefore, there is only one confirmed case of statutory nuisance from the 17 sites for which data is available. Note again that these figures cover a 16 year period. In comparison, Table 3 shows that there were a total 39,508 confirmed noise nuisances in 2004/2005, of which 1,401 related to industrial noise. Again, it is clear that windfarm noise is an extremely small-scale problem compared with other types of noise, particularly since the figures for other sources are an underestimate for the UK as a whole as remarked earlier.

One further observation from the nuisance statistics is that the proportion of complaints which were subsequently confirmed as causing a nuisance is smaller for windfarms than for any of the other categories of noise as used by the CIEH and given in Table 3. The proportion for industrial noise was about 19% in 2004/2005, and for noise complaints in general it was about 14%. The comparable figure for windfarms is about 6% based on one nuisance per 17 cases for which we have firm data from Table 2. These figures could be interpreted in several ways, although one should be aware that the number of results is too small to draw firm conclusions, and also that the picture could change if some of the four pending cases is eventually judged a nuisance. One possible interpretation is that expectations are higher for windfarm noise than for other categories of noise. If so, we might speculate that the newness of windfarms as a noise source might be a relevant factor. Another possible interpretation might be that local authorities are somehow more lenient for windfarms than for other categories of noise sources, although this seems unlikely since the role of an Environmental Health Officers is to act as an independent judge. We might also speculate that Environmental Health Officers may not have the expertise or confidence in their experience to challenge an ETSU report and are therefore more reluctant to declare a nuisance compared with less complex and better understood noise sources. Again, the fact that windfarm noise is relatively recent phenomenon could be a factor here. Several other factors might influence the decision of the investigating officer, but these are not particular to windfarms so will not be discussed here as they would not explain differences in the proportion of nuisances between categories.

Comments on the use of complaint statistics

One should, of course, be cautious about placing too much reliance on data derived purely from reported complaints. The first reason is that not everyone who is adversely affected by a noise goes to the trouble of making a formal complaint. Thus, complaint statistics tend to underestimate the number of people adversely affected. This is a recognised effect, and applies to all noise sources, but to different extents. For example there is evidence that people tend to complain less about traffic noise than other noise sources for the same degree of annoyance because they do not feel that it will have any effect. It seems likely that, if anything, people might be more inclined to complain about windfarms than about other noise sources because of the high level of publicity surrounding the issue, but we have no definitive information on this question. Therefore, we have no basis for assuming that windfarm noise is any different to, say, industrial noise in this respect.

The second reason for caution is that there is no control on complaints: anyone may make a complaint whether or not they have reasonable cause for dissatisfaction. People can, and frequently do, use noise as a proxy for some other grievance, and thus a proportion of noise complaints may be motivated by some other factor entirely. Thus, the fact that a site receives complaints does not imply that the noise situation is unsatisfactory. Conversely, a lack of complaints is no guarantee of a satisfactory situation. Although we did not ask specifically about other motivations in the questionnaire, some local authorities volunteered the view that ulterior motives were a factor, although not necessarily the only factor, in the complaints they had received. This was the case for three sites, and in one of these it was felt to be a strong factor. The same conclusion may apply to other sites but we have no definitive information.

The third reason for caution is that some complaints may go direct to windfarm operators without being recorded by local authorities. Many local authorities now require, as part of planning permission, the operators to undertake noise monitoring and will forward details of complaints to the operator for further investigation. If complainants were to go directly to the operator rather than via the local authority then some complaints may not have been recorded by the local authorities. There is no legal requirement on the part of the operator to report noise complaints that are made directly to them to the local authority.

In order to try to estimate the scale of this effect we carried out a telephone follow-up to the detailed survey, in which we asked four local authorities, between them responsible for 10 of the 27 complained-about windfarms, if they thought it likely that they had missed many complaints. The answers were consistent. Firstly, none of the local authorities had formal procedures by which the operator was required to forward details of any complaints to them, and therefore they could not guarantee that they had records of all complaints. However, all four local authorities also felt it unlikely that many, if any, complainants had escaped their records entirely. In some cases they felt that local residents would not know who the operator was, so would complain first to the local environmental health department. Some felt that since they were in close and open contact with developers to try to resolve known problems that they would have become aware of additional complaints. Others commented that they specifically requested complainants to contact them again if the problem was not resolved to their satisfaction.

Therefore, whilst it is possible that there have been some noise problems that are not reflected in the results of the detailed survey, we consider it unlikely that significant numbers of complainants have escaped local authority records. In any case, windfarm noise is no different to other types of noise in this respect: for example, a complaint about industrial noise may be directed to the operator of the site and may never feature on local authority records, particularly if the problem is resolved. Therefore, the comparisons with other noise sources in the previous section should be reliable.

Other factors arising from the survey

Some other possible causes of noise complaints emerged as part of this exercise. 'Unrealistic expectations' was thought to be a factor in at least one case, i.e. the complainant believed that the noise would be less noticeable than it actually proved to be. In this case the local authority considered that the complaint could possibly have been avoided by more accurate information from the developer at the planning stage. Another possible cause is that complaints are being prompted by planning applications to build other sites nearby. This was mentioned as a factor in two or three cases. In one further case the sheltered location of the complainant's property was identified as contributing to the complaint, i.e. the background noise at the property, which normally helps to mask noise from the windfarm, does not increase when conditions are windy at the wind farm.

Finally, for five of the sites having received complaints EHOs commented that the site met planning conditions. In one of these cases AM was a factor, in three it was not, and in the fifth it was possible. We do not know whether these comments indicate that complaints were unjustified, or alternatively that planning conditions were too lenient.

4. Further investigation of sites with AM

In the previous section the prevalence of AM in terms of the number of sites affected was determined. In this section we evaluate in more detail the four sites for which AM is thought to contribute to complaints, with the aim of obtaining an estimate of the proportion of time for which AM might occur. This estimate has to be based on complaint data, since it is beyond the scope of this project to take measurements. Using the complaint data we can carry out the following steps:

a. obtain complaint logs;
b. determine the range of wind speed and direction prevailing at times when complaints occur;
c. obtain continuous records of wind speed and direction occurring at the site;
d. calculate, by comparing b. and c., the proportion of the time for which the wind conditions associated with complaints prevail.

A second aim of this section is to determine whether complaints at these sites are historic or ongoing.

4.1. First site

For the first site, a complaints log was available giving date and time of complaints, together with wind speed and direction. Within this five month period complaints were registered for 61 hours out of 2510. Hourly averaged wind data from the MIDAS Weather Station nearby were also obtained. Both the complaints and MIDAS data are plotted on Figure 2. The high degree of agreement between the MIDAS and complaint log data gives confidence that the data from the Weather Station are representative for the wind farm site. Figure 3 gives the same wind direction data, plotted in a different format: the distance from the centre of the plot indicates the proportion of the time for which the wind was from the given direction. The purple line is from the weather station data and shows that over the whole period the prevailing winds were fairly evenly distributed between 150° and 340°. The blue line relates to the complaints and indicates that most complaints occur for directions around 200°.

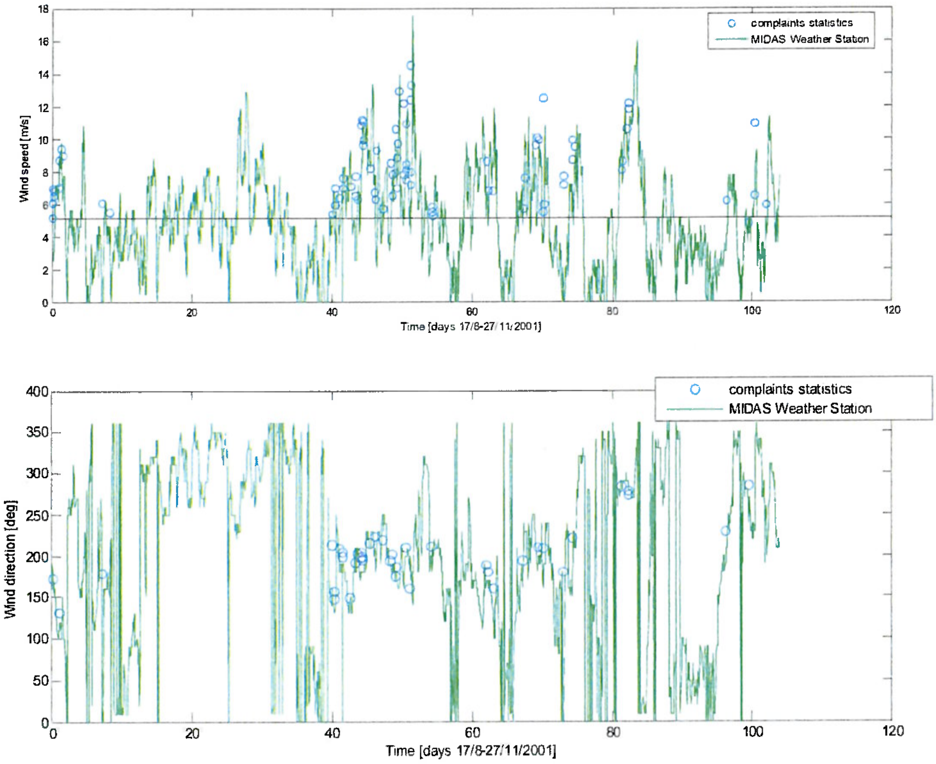

Figure 2 Time series of wind speed (top) and direction (bottom) for MIDAS data (green line) and data from the complaints log (blue circles) at first site.

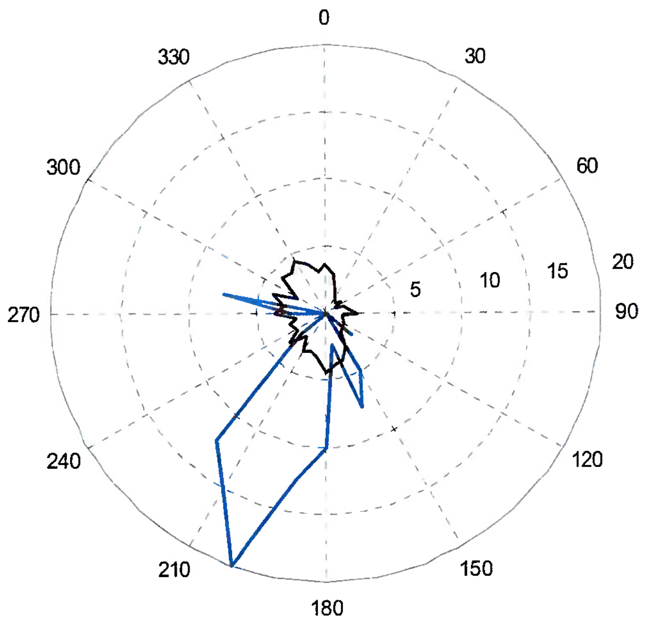

Figure 3 Distribution of hourly wind direction averages at first site: % for complaints (blue solid line); % for weather station data during the whole analysis period from Figure 2 (black dotted line).

From the data in Figure 2 and Figure 3 we can now try to give a figure for the proportion of time for which wind conditions associated with complaints are likely to arise. First, we note that complaints only occurred for wind speeds exceeding 5m/s, which is the cut-in speed of the turbines. Second, all complaints occurred for wind directions in the range 140° to 270°, i.e. for a 130° arc encompassing southerly and westerly directions. However, looking further at Figure 2 and Figure 3 we see that all parts of this range are not equally important, with the majority of complaints (73%) occurring within a narrower 40° arc between 180° and 220° (as shown by prominent lobe in Figure 3). Wind directions within this 40° arc were consistently associated with complaints whereas angles of between 220° and 270° were sometimes, but not always, associated with complaints. Furthermore, when complaints occurred at the higher values of wind direction the descriptions from the complaint logs are generally less suggestive of AM as a cause. Thus, the 130° arc is probably conservative because it includes conditions which do not consistently yield complaints and the complaints do not tend to suggest AM. On the other hand, the 40° arc includes most but not all complaints so might be slightly unconservative.

The weather station data has been analysed taking the wind conditions characteristic of complaints to be: speed above 5m/s and direction 140° to 270° i.e. the 130° arc. These meteorological conditions were met in 580 hours out of the 2510 hours of monitoring, which corresponds to 23 % of the time. Taking the smaller 40° arc as characteristic of complaints, the corresponding figure is 5.3%. As weather conditions change with the seasons and sometimes even from year to year a period of several years (1/1/2000-1/1/2007), was analysed for the Weather Station. The wind direction data for this period are shown in Figure 4 and Figure 5. The identified meteorological conditions during this period were met for 25% of the time taking the 130° arc, and 9% taking the 40° arc. If we assume that the complaints were caused exclusively by AM then we can conclude that meteorological conditions likely to cause AM occur for more than 9% and less than 25% of the time at this site, with the true value probably towards the lower end of this range, say about 15% as an overall figure. We can therefore say that the conditions associated with AM would occur on average about one day in seven. However, it should be noted that these are average figures and that in reality the characteristic conditions might occur quite irregularly. This is shown in Figure 5 which plots the wind speed for periods when the wind direction was within the 130° arc as mentioned above. It is seen that the characteristic conditions might occur for several days running followed by a longer period with no such conditions.

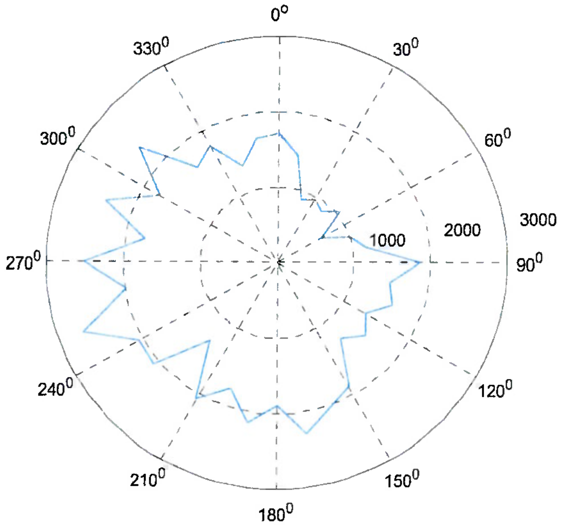

Figure 4 Distribution of hourly wind direction averages averaged over a seven year period for first site.

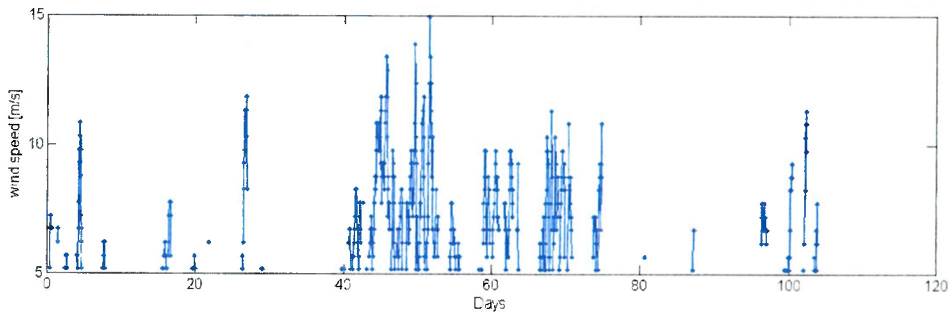

Figure 5. Wind speed for the periods when AM might occur at first site, i.e. wind speed >5m/s and direction between 140° and 270°.

The final question about this site concerns whether AM is historical or ongoing. The Local Authority for this site has reported that there have been no complaints since 2004, suggesting either that the problem has been alleviated, or that people have become accustomed to it, or a combination of both.

4.2. Second Site

For the second site a complaints log was available prior to 2003. This site was the subject of complaints associated with a number of wind directions, however, it was generally agreed that AM occurred specifically for Easterly winds and for speeds from the cut-in speed, of around 5m/s, up to 10 m/s measured at a height of 10m above ground level. Above 10m/s (which corresponds to about 13m/s at hub height) the noise of wind in the trees would start to mask the sound of the wind farm. No wind data was available for this site; generally in the UK easterly winds are relatively uncommon suggesting that the conditions for AM would not be present most days of the year, although there could be periods of continuous easterly winds for several days at a time.

AM on this site was associated with three specific wind turbines. To alleviate the problem, a turbine control system was programmed to shut down these three machines for wind directions between 55° and 130°, and for wind speeds from the cut-in speed to a hub height wind speed of 13 m/s. The benefits of this system may be seen in the reduction of complaints which reduced from 50 – 52 per year for 2002 – 2003 to 7 – 10 per year between 2004 and 2006. The residual complaints may be associated with westerly winds rather than the easterly wind which resulted in the audible AM. We might cautiously conclude that the AM problem on this site has been solved, or at least substantially alleviated by these measures.

4.3. Third Site

For the third site a complaints log was available for the period when the wind farm commenced operation to date. The log details a number of sounds that are audible at the property. The complainant describes periods of operation when amplitude modulation of the aerodynamic noise (AM) is clearly audible inside and outside the building. When the AM is described, the common factor between different days is the wind direction, which falls into a narrow range between 140° and 170°, i.e. a SSE wind tending to a Southerly wind direction.

Analysis of the historical wind rose (Figure 6), which was supplied by the wind farm operator and which is based upon the 10 year average data supplied by the Meteorological Office for a nearby reference site and the on-site wind speed measurements undertaken by the developer for a one year period, indicate that this range of wind directions would be expected to occur for 7 – 9% of the year. This does not account for the range of wind speed likely to cause AM, i.e. at very low wind speeds the turbines would not be operating and at very high wind speeds the natural background noise would tend to mask wind turbine noise. With periods of very high and low wind speed removed, the average year will see the wind from this direction for 7% of the time. We therefore conclude that the conditions likely to cause AM on this site will be present for approximately 7% of the time. It should be mentioned that other noise issues are also reported at this site, but these are not considered in this report which focuses on the issue of AM.

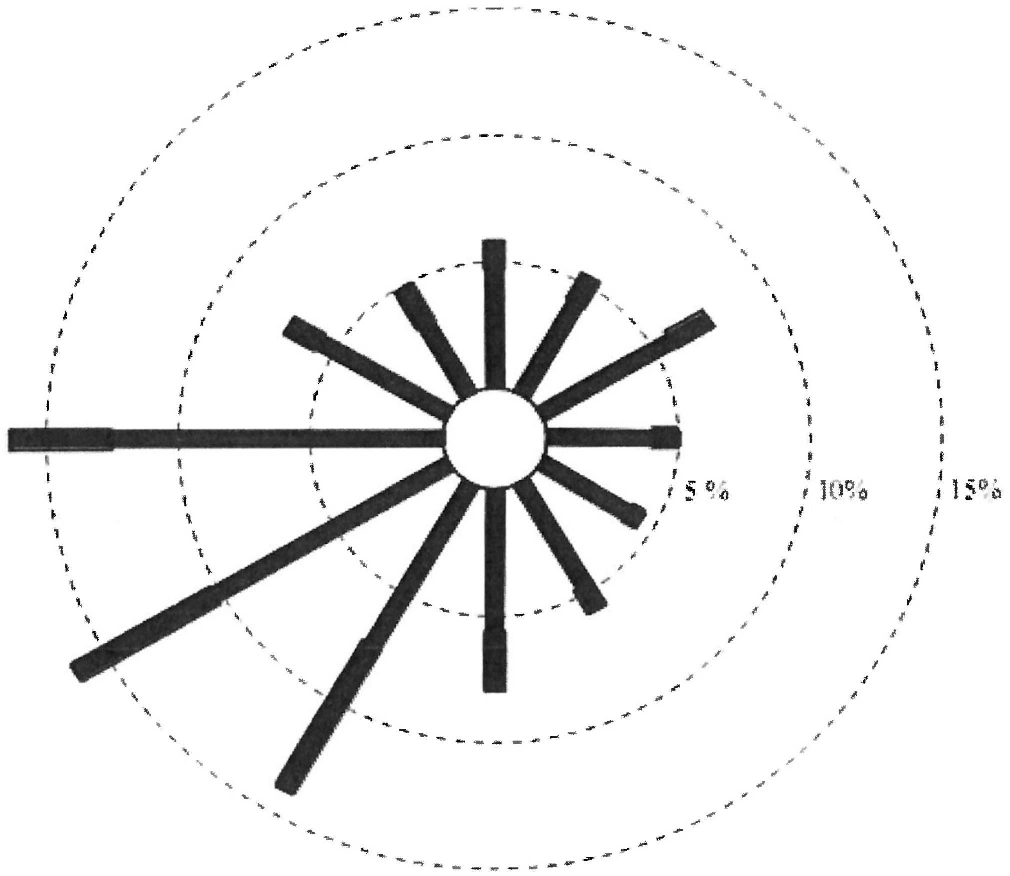

Figure 6 Wind farm rose for third site

4.4. Fourth Site

No complaints logs were available from the fourth site from which to ascertain the characteristic meteorological conditions, and therefore the prevalence of AM could not be determined. Regarding the question of whether the problem has been solved, complaint history suggests that the problem is not a continuing one since the last complaint relating to AM was in 1998. There have been other complaints since then, but relating to specific fault conditions (not associated with AM) which were rectified. According to the Local Authority, AM probably does occur at this site, i.e. there is significant modulation of the aerodynamic noise from the windfarm, but the noise levels are not sufficient at nearby properties to cause a significant problem. Furthermore, the site is operating within its planning conditions, and in this respect the Local Authority does not consider the site to be a continuing problem. Other than regular noise monitoring the operator has not made any remedial works to the site that would have caused the complaints to subside. Therefore, it is possible that the initial complaints, which occurred when the site was still new, were due to the unfamiliarity of the noise.

To conclude, whilst it appears that AM does occur at this site, it also appears to be at most a marginal problem.

4.5. Conclusions from AM sites

To summarise, the meteorological conditions associated with AM have been assessed for two sites, and are likely to occur between 7% and 25% of the time, although the latter figure is on the conservative side. Of the four sites where AM was judged by the Local Authority to be present in only one case, which is a recent installation, is there an ongoing investigation. In two cases complaints have largely or completely subsided, in the final case a turbine control system has been installed and, although there are some ongoing complaints, AM is probably not the cause.

5. Worldwide literature survey

The aim of the literature survey is to summarise the current scientific knowledge about AM and immediately related subjects. Our main information sources were peer-reviewed documents, that is reliable, independently checked sources, such as books, government reports and journals. Where necessary, proceedings from scientific conferences are also considered. Under the References headline we list all the publications we have found and read but not necessarily explicitly cited in the text.

The subjects in the literature review cover how AM is accounted for in government guidelines and regulations, how noise in general and AM in particular are generated by wind turbines, how the immission of noise is influenced by propagation and why psychoacoustics is important to interpret measurements and complaints correctly.

5.1. Search terms

Some thought was given to search terms since AM is not a widely recognised phenomenon and might be reported under different names. The following English search terms were used:

Amplitude Modulation
Aerodynamic Modulation
Modulated Noise
Wind Noise
Turbine Noise
Wind Farm Noise
Aero(-)acoustic Noise
Rotor Noise
Tonal Turbine
Fluctuating Noise
Swish.

5.2. *Information sources*

The following journals were searched with the above terms.

Journals searched

1. Journal of the Acoustical Society of America
2. Journal of Sound and Vibration
3. Journal of Low Frequency Noise, Vibration and Active Control
4. Applied Acoustics
5. Technical Acoustics
6. Acoustical Science and Technology (Formerly Acoustical Society of Japan)
7. Journal of Vibration and Acoustics
8. Noise and Vibration Worldwide
9. Renewable Energy
10. Wind Energy
11. Renewable and Sustainable Energy Reviews
12. Energy
13. Journal of wind engineering and industrial aerodynamics
14. Journal of solar energy engineering
15. Applied energy
16. All relevant IEEE Journals
17. Some papers which appear as abstracts only in JASA
18. International Journal of Energy Research,
19. American Institute of Aeronautics and Astronautics Journal
20. Transactions of the ASME: Journal of Dynamic Systems Measurement and Control and Renewable Energy.

Conference proceedings search

1. Wind Turbine Noise 2005
2. Internoise 1996
3. Euronoise 2003 & 2006
4. BWEA Wind Energy Conferences 1997 - 2005

5. Forum Acusticum 2003-2006

Other Sources Found

1. Government Reports – Scotland, Denmark, Wales, Sweden etc
2. Books
3. General public reports

Because there have been major wind energy developments in Germany in the recent past, articles in German – using German search terms – were also searched. There are no likely journal sources in German, and the only likely conference (DAGA) only publishes abstracts rather than full papers. Therefore the German language search focussed on the internet. Only two papers have been found in this way which were from the mid 1990s and in English.

5.3. Government reports and regulations

The current British guidelines and regulations are detailed in PPS2 (2004) for England, PAN45 (2002) for Scotland and TAN8 (2005) for Wales which can all be traced back to ETSU-R-97 (1997). The general role of these is to define acceptable noise levels for the protection of the population, to introduce consistent procedures for establishing and rating noise levels and to minimise noise levels from wind turbines. These documents were thoroughly reviewed in Hayes (2006).

Separate noise limits are applied for daytime and night-time. ETSU-R-97 indicates that the purpose of these different noise limits is that for night-time periods, the emphasis is on the prevention of sleep disturbance, whereas, the daytime noise limits are to protect the amenity value of the area and of a property in particular.

The noise limits take the form of a fixed level for periods when background L_{A90} noise levels are very low and a margin above the background once background noise levels increased due to wind effects. The daytime noise criterion is defined as "the greater of 35-40 dB L_{A90} or background + 5 dB" and for the night-time period "the greater of 43 dB L_{A90} or background + 5 dB".

ETSU-R-97 has summarised the issue of blade swish/AM as follows: "*The noise levels recommended in this report take into account the character of noise described as blade swish. Given that all wind turbines exhibit blade swish to a certain extent we feel this is a common-sense approach given the current level of knowledge.*" The character of blade swish is described as "*irregular enough to attract attention*", " *to a degree, turbine-dependent*" and "*dependent upon the position of the observer*".

Since the publication of ETSU-R-97 a further review of European policies regarding wind turbine noise has been carried out by Pedersen (2003). Of particular interest are German legislation from 1999 and Dutch Legislation from 2001 as these were not reviewed in ETSU-R-97. In German legislation different noise limits are applied to different areas. The areas are industrial, mixed, residential and sensitive (for example, hospitals or health resorts). In Dutch legislation wind turbine noise limits are based upon a wind speed dependent curve which starts at 40dB (A) at night time, 50 dB (A) during the day and 45 dB (A) during the evening. None of these regulations makes any special allowances for AM.

5.4. Generation of wind turbine noise

There is a large body of literature relevant to noise generation by wind turbines. For example, there are many publications concerning noise from aerofoils, propellers, fans and helicopters which may be relevant. Fortunately, the fundamental issues for windturbines have been summarised in two text books, and most of the following few paragraphs are a distillation from these references.

Noise sources on wind turbines fall into two main categories: aerodynamic and mechanical. Mechanical noise sources are primarily connected with the electrical generation parts of the turbine, the gear box and the generator. These sources are generally located in the nacelle. The character of the noise generated is similar to that from other types of rotating machinery, and often includes an audible tone or note that might be described as a 'whine' or 'hum'. Noise with a pronounced tonal feature is generally recognised to be more annoying than noise of a comparable level but with neutral character. This subjective effect is recognised in the ETSU guidelines where a penalty is added which is related to the audibility of the tone. Mechanical noise was audible from early turbine designs. On modern designs the problem has been almost completely eliminated, although it may arise temporarily if there is a mechanical fault, such as worn bearings within the gear box/generator, worn teeth within the gear box, or misalignment of the generator drive shaft. This discussion of mechanical noise does not shed light on the causes of AM noise, but it does help to interpret some of the complaint statistics, many of which were from early turbine designs or due to a fault condition.

Apart from occasional fault conditions creating mechanical noise, the dominant noise generating mechanisms on modern turbines are aerodynamic. Aerodynamic sound is generated by pressure variations within the air which fluctuate at acoustic frequencies, i.e. between about 20 and 20,000 times per second. In wind turbines such fluctuating pressure is caused by flow turbulence. If hypothetically the flow of air into, and over the blades could be made completely smooth the major noise sources would disappear. In practice, the flow is generally turbulent and so some noise generation is inevitable.

First, air flowing into the blades due to wind is not completely smooth, but contains turbulent eddies of a range of sizes. These eddies are 'ingested' into the blade region and generate *inflow turbulence noise* as the blades chop through them. Second, as air flows over the surface of the blades, turbulence is generated close to the surface in the so called boundary layer. This boundary layer turbulence generates noise, particularly when it interacts with the trailing edge of the blade, which is therefore known as *trailing edge noise*. This is often the principal noise generating mechanism on wind turbines. Other types of turbulence are the vortices shed from the tip which generates *'tip noise'* or from the trailing edge of the blade. Trailing edge vortices are stronger for blunt trailing edges and the associated noise is therefore called *blunt trailing edge noise*. The above four mechanisms, inflow turbulence, trailing edge noise, tip noise and blunt trailing edge noise, account for the majority of the noise from wind turbines, and on modern design blunt trailing edge noise is not a significant effect.

Other types of turbulence may also generate noise, but can be avoided. A condition known as 'stall' may occur and indeed is used to regulate rotational speed and power generation for some designs. This can generate noise up to 10dB higher than without stall. However, manufacturers are increasingly tending to move away from stall-regulated machines, particularly for machines of higher power, one of the main reasons being the higher noise levels they generate. Another possible cause of noise is flow over imperfections in the blade surface, for example damage due to holes in blades has been known to cause strongly noticeable tones. For large wind turbines with good manufacturing quality control, such imperfections would be considered a fault condition.

The frequency of the noise generated depends on the size of the turbulent eddies; broadly speaking large eddies produce low frequency noise and small eddies generate higher frequencies. Mostly, the character of aerodynamic noise is broad band, i.e. it does not contain a distinguishable note or tone, but is of more random character such as noise from rustling leaves, waterfalls, rain etc. The dominant character of the combined aerodynamic noise as described above is therefore a 'swish', which is familiar to most people who have stood near to a large wind turbine. Blade swish is not completely steady, but is modulated (fluctuates) at the rate at which the blades pass a fixed point, i.e. there is a cycle of increased and then reduced level which typically at the blade passing frequency of around once per second. In the majority of installations the modulation depth is a few dB which is subjectively acceptable. It is not clear why in some situations the modulation depth increases to the point where it becomes subjectively unacceptable, and therefore potentially annoying. In early wind turbine designs, where the rotor was positioned downwind of the tower, a pronounced 'thump' was caused as each blade passed through the wake shed from the tower. However, this effect is eliminated completely for the upwind rotor designs found on all new windfarm developments since the large scale uptake of wind energy development in the UK, and does not therefore explain the occurrence of AM.

It seems likely that AM is due to fluctuation in the strength of some of the above mechanisms rather than to some completely new mechanism. Aerodynamic noise generation depends primarily on the rotor tip speed, but there is also some dependence on wind speed. Therefore, if wind speed is not even across the rotor plane then some fluctuation in level can be expected as the blade turns. Van den Berg has investigated this possibility and has postulated that in stable atmospheric conditions the difference in wind speed between the top and bottom of the rotor is relatively high. Therefore, the wind speed seen by a blade varies cyclically, which in turn may cause the noise level to vary once per revolution. This work is discussed in more detail in the next section.

Sound generation by turbulence is a highly complicated phenomenon that is still not completely understood despite a great deal of research into noise from fans, aircraft, and propellers, and great advances since the 1950s. Mathematical models for turbulence and turbulence generated noise have been developed but not to the stage where reliable prediction is possible from the drawing board. The occurrence of AM implies that fluctuations are occurring in the generating mechanisms, and the causes of such variations are still less well understood. There are no existing models by which AM can be predicted.

5.5. *Propagation of wind turbine noise*

In general noise propagation from wind turbines is determined by source directivity, geometric spreading and atmospheric absorption, ground reflections and absorption, meteorological effects and terrain complexity. The audibility of noise from wind turbines is then determined by the ratio between turbine and background noise, the so-called masking effect.

According to Oerlemans and Lopez (2005) AM noise from wind turbines is not equally loud in all directions but is radiated primarily from the outer part of the downward moving blade in the downward direction. This is the reason that AM noise can often be heard underneath the turbine but not further away because at a considerable distance the recipient is more in line with the horizontally propagated – weaker – noise.

This directional sound is then spreading as it travels away from the turbine. The so called geometric spreading decreases sound levels with increasing distance from any source. Atmospheric absorption also reduces the sound level with distance but is more effective at high frequencies with the consequence that low frequency sound travels further.

The main influence of meteorology is the change in sound speed profile due to wind shear and temperature profiles which is well described in Wagner et al. (1996). Most pronounced is the "shadow zone" upwind of the noise source and the increased noise levels in the down wind direction. In extreme inversion conditions sound rays from elevated sources can be bent back down to the ground downwind and create focussing effects at considerable distances from the sound source resulting in slightly enhanced noise immission relative to no-wind, no-inversion conditions (e.g. ISVR, 1991)..

To predict noise levels from wind turbines the wind speed is measured at 10 m height. Using a typical wind profile for neutral atmospheric conditions the wind speed is then extrapolated to hub height. In situations with large wind shear – low wind speed near the ground and high wind speed at hub height – the background noise created for example by vegetation noise close to the ground is small. The turbine blades experience a higher wind speed resulting in unexpectedly high aerodynamic noise levels. The lack of background noise then leaves the turbine noise more audible. Several authors report this reduction of the masking effect (Harders and Albrecht, 2005, Sloth, 2005, Golec and Golec, 2005, van den Berg 2003, 2004, 2005a). Both Klug (2005) and van den Berg (2003, 2004, 2005, 2005a, 2005b) find that high wind shear situations occur frequently during the night time in so called stable atmospheric conditions.

Because of its complex nature, the most debated meteorological influence on outdoor sound propagation is that from atmospheric turbulence. In the noise shadow, turbulence can lead to enhanced noise levels (Wilson 2000) compared to the high levels of attenuation normally found upwind of a noise source. It also spreads the sound more widely leading to a net-attenuation of highly directional noise (Salomons, 1994).

Many wind farms in countries like The Netherlands and Germany are situated in very flat terrain with no obstacles to influence sound propagation between the turbines and the immission sites. In the UK many sites are a lot more complex than that; partly in hilly or even mountainous terrain or in the middle of a forest. For these sites the sound propagation becomes a lot more complicated too. Bolin (2005) dedicates an entire publication to the systematic deployment of vegetation noise to mask turbine noise. Apart from absorption and reflections from obstacles which attenuate and enhance noise respectively, complex terrain also provides obstacles that act as a "noise screen" (Jacobsen, 2005, Prospathopoulos and Voutsinas, 2006). This effect is frequency dependent. If the size of the obstacle is a lot bigger than the wavelength it is an effective screen. For very low frequencies and small objects this is not always the case (Jacobsen, 2005).

One propagation phenomenon relating to AM noise is not yet well understood: In some situations AM noise seems to travel and can be heard at a considerable distance from the turbines. First explanation attempts have been published by van den Berg (2003, 2004, 2005) and it appears likely that a combination of generation and propagation mechanisms is responsible for this effect. Further studies are needed to explain and predict the observed noise levels.

5.6. Amplitude Modulation of Wind Turbine Aerodynamic Noise

Amplitude modulation of the noise associated with the operation of wind turbines was identified within the Report "*The measurement of low frequency noise at three UK wind farms: URN No: 06/1412*" issued by the DTI in July 2006. Within the conclusions of this report, the following were identified:

- Infrasound associated with modern wind turbines is not a source which will result in noise levels which may injurious to the health of a wind farm neighbour;
- Low frequency noise was measurable on a few occasions, but below the existing permitted Night Time Noise Criterion;

- That the common cause of complaint was not associated with LFN, but the occasional audible modulation of aerodynamic noise, especially at night.

The measurements undertaken and reported within the DTI Report identified periods during wind turbine operation when noise associated with the operation of the wind turbines varied in level at the blade passage frequency[2] of the wind turbines. When this variation in the noise associated with the operation of the wind turbines was noted by neighbouring residents, it was described as "*a distant train*" or "*distant piling*".

Measurements of the internal noise levels during these periods of wind farm operation indicate that A-weighted noise levels are subject to amplitude modulation levels of between 3 – 5 dB(A). Analysis of these periods using third octave band analysis indicates that between 200 – 800 Hz, noise levels in specific frequency bands may change between 8 – 10 dB. External measurements indicate that, for external A-weighted changes in level of 3 – 4 dB(A), third octave band levels may change by between 7 – 9 dB. Measurements reported for Wind Farm D (Table 1) have indicated that third octave band levels when complaints were received before the implementation of wind turbine control features, indicated level changes of 12–15dB. (All the above figures are ranges from peak to trough).

The finding that this modulation is concentrated between the frequency bands of 200 – 800 Hz is significant in that this is generally generated by the trailing edge of a wind turbine blade. This has been identified as one of the main sources of aerodynamic noise associated with the operation of wind turbines (Oerlemans and Lopez, 2005).

Trailing edge noise was identified by van den Berg (2006) as the most likely source of the modulation which he observed at a wind farm on the Dutch/Germany border. However, van den Berg postulates that the increased levels of modulation which he observed were associated with the change in the aerodynamic environment seen by a wind turbine blade as it passes in front of the wind turbine tower. He postulates that when the turbine is at this point, a decrease in the wind speed associated with the

[2] Blade passage frequency is the frequency at which the wind turbine blades pass a fixed point on the wind turbine rotor, typically assumed to be the wind turbine support tower. For a wind turbine operating at 30 rpm, with a three bladed rotor, this would equate to 90 blade passes a minute, or a blade passage frequency of 1.5 Hz.

presence of the tower will result in a change in the aerodynamic properties and therefore the noise generated by the wind turbine. Van den Berg considers that this is exacerbated by the increased atmospheric stability which occurs for his test site during the night hours. With increased atmospheric stability, the wind speed seen at the hub height of the wind turbine may be appreciably higher than that found at the lowest part of the rotor path, which is also where the effect of flow disturbance around the support tower is felt. Van den Berg's analysis indicated that the maximum change in noise levels based upon these conditions was from 2 ± 1 dB for neutral conditions increasing to 4.8 ± 1.7 dB for very stable atmospheric conditions. To achieve the levels of modulation that van den Berg measured on the façade of neighbouring dwellings, he suggests that multiple sources have added together to obtain increased levels of modulation which "phase" in and out to give increased periods of modulation of the aerodynamic noise.

However, measurement of the aerodynamic noise sources within Oerlemans and Lopez (2005) indicate that the tower/blade interaction is a source which is at least 12 dB below that associated with the downward sweep of the turbine blade. It is recognised that these measurements were undertaken in neutral atmospheric conditions for a location relatively close to the wind turbine, however, there is almost no indication of the presence of the wind turbine tower within the data. Therefore, the effect of the tower on an upwind wind turbine noise emission character as postulated by van den Berg is not borne out by measurements in the field.

Measurements of wind farm noise at sites in the UK indicate that where a wind farm has periods of increased AM, these are not necessarily related to periods of high wind shear. Wind Farm Site D, for example (see Table 1 above), is subject to periods of increased amplitude modulation when the wind is blowing from the east. An easterly wind does not increase the stability of the atmosphere seen by the wind turbines as this noise is associated with day and night-time operations, however, topographical effects result in some wind turbines being 'unsure' as to the wind direction. This is caused by the wind turbine wind vane being influenced by the wind direction at the hub height of the rotor but the wind direction at the lower arc of the rotor may be from a different direction. When specific wind turbines are stopped from operating the modulation all but disappears. Wind speed measurements from tall free-standing anemometer masts located atop hills indicate that there is little change in atmospheric stability between the day and night-time periods. However, locations in flat landscapes do indicate an increase in the wind shear which is associated with stable atmospheric conditions but not to the level described by van den Berg (2006).

On the basis of the above discussion, it is clear that the observed effects of amplitude modulation which is sufficient in level to initiate complaints associated with this acoustic feature is still not understood in sufficient detail to provide design guidelines to minimise the potential for such a feature and is also still subject to debate.

5.7. Psychoacoustics

There are two sets of psychoacoustic related literature which are of interest when considering the problem of AM noise emissions from wind farms; those which examine the effect of modulated noise on listeners and those which examine psychoacoustic phenomena directly caused by wind farms.

The perception of loudness is described in Moore (2004). The perceived loudness of a sound is found to be dependent upon intensity and frequency content. It is also different for different listeners. For wideband noise the smallest detectable amplitude change amounts to 0.5-1 dB depending upon the sensitivity of the listener.

The effect of amplitude modulation within diesel locomotive noise with respect to the annoyance it causes for humans is examined in Kanteralis and Walker (1988). It was found through subjective tests that the noise from a diesel locomotive type was rated as being annoying compared to an electric type locomotive despite both having similar low frequency content. The testing was carried out in a situation which replicates the listening conditions of a typical living room. The difference in annoyance was found to be related to a pulsing effect or amplitude modulation in the diesel engine case that occurred at the firing frequency of the diesel engine. The authors comment that if the modulation frequency is increased above 12 Hz the annoyance is decreased. However, as typical wind turbine blade passing frequencies are of the order of 1Hz this does not give much insight into the situation for wind turbine noise.

In a paper on the annoyance and known psychoacoustic effects for wind turbine noise Persson-Waye and Ohstrom (2002) report how the character of the noise from wind turbines built by five different companies is perceived by a small number of listeners. They conclude that levels of annoyance cannot be explained by the psychoacoustic parameters loudness, sharpness, fluctuation strength and modulation. Several studies, including Pedersen (2003), mention that although there is correlation between annoyance levels and sound levels, the annoyance is also influenced by visual factors and attitude to wind turbines.

Three publications by Pedersen and Persson-Waye (2004, 2005, 2006) report a significant relationship between A-weighted sound pressure level and annoyance and unexpectedly high annoyance levels. Apart from the given explanation of visual factors their methodology of using prediction models to determine the sound pressure levels could have been responsible for these results.

In summary, every psychoacoustic factor mentioned does not seem to be able to predict annoyance levels for wind turbines. The images used in descriptions of wind turbine noise and the fact that tonal and impact noise are perceived as more annoying than broadband noise suggests that information content in noise might be a key to understanding annoyance levels.

6. Survey of manufacturers worldwide

A survey of manufacturers of wind turbines was undertaken to determine whether AM has been identified by wind farm manufacturers as a potential source of annoyance, whether they have any understanding of its causes or possible mitigation measures.

A list of turbine manufacturers was obtained from the BWEA. The definition of a turbine manufacturer was a supplier of wind turbines with a minimum generating capacity of 250 kW. This rules out domestic scale wind turbines which are less likely to exhibit the type of noise under investigation due to the increased rotor speeds (higher blade passage frequencies) and potentially increased number of turbine blades.

Each wind turbine manufacturer listed in Table 2 below was contacted to obtain a relevant contact within the companies. The manufacturers with which contact was made are identified within Table 2 below.

Mkt Share	*Company*
12.9%	Gamesa Energy UK
17.7%	GE Energy
2.6%	Nordex UK Ltd
3.2%	REpower UK Ltd
5.5%	Siemens Wind Power
27.9%	Vestas Wind Systems a/s, Denmark
13.2%	Enercon GmbH, Germany
6.1%	Suzlon energy india
2.1%	Ecotechnia, Spain
2.0%	Mitsubishi, Japan
	Acciona, Spain
	Clipper Windpower USA
	EU Energy Germany
	Harokasan BV Netherlands
	Leitner AG Italy
	M. Torres, Spain
	Multibrid germany
	ScanWind Norway
	Vensys GmbH, Germany
	WinWinD, Finland

Table 4 Manufacturers of large turbines: World-wide market share

Of the manufacturers which were contacted through an e-mail request which outlined the scope of the study and which provided relevant background information, five manufacturers offered comments with respect to their experience. The majority of the other responses indicated that the contact, although being responsible for noise emissions testing for the turbines, had little or no knowledge of the issue of aerodynamic noise generation from a turbine.

It was commented upon by manufacturers that there is no need to assess the potential for high levels of modulation associated with the aerodynamic noise emissions of a wind turbine within IEC61400-11.

However, a German manufacturer indicated that analysis of the impulsivity of the emitted noise is undertaken for some wind turbine tests following the guidance used in Germany[3]. These measurements have been used for the reporting of impulsivity of the noise emitted by wind turbines and which are for installation within the German market. The method determines the Rating Level, L_r, of a single noise source or of an installation of similar sources or all sources from a noise source having an impact at a specified location. The Rating Level is determined from the following equation:

$$L_r = L_{eq} + K_I + K_T + K_R + K_S$$

where

L_{eq} is the equivalent continuous sound pressure level, as in DIN 45641, for the rating time, T_r;

K_I is the impulse adjustment;

K_T is the tone adjustment;

K_R is the adjustment for rest periods;

K_S is the adjustment allowing for special conditions.

[3] DIN 45645-1 Ermittlung von Beurteilungspegeln aus Messungen, Teil1: Geräuschimmissionen in der Nachbarschaft: July 1996: DIN 45646-1 Determining noise rating levels from measured data: Part 1: Environmental Noise

Of particular interest when assessing the potential for modulation of the aerodynamic noise is the impulse adjustment which is defined within the Standard as follows:

$K_I = L_{FTeq} - L_{eq}$

where

L_{FTeq} is defined as the "Time-averaged maximum A-weighted level which is the maximum A-weighted level averaged over the measurement time interval, T";

The interpretation of this statement used in practice is to measure the difference between the maximum and average sound pressure level over 5 seconds and then to average all the 5 second values obtained during one minute. In formal terms this means that the 5 second value of $L_{FT(t)} - L_{eq(t)}$ is measured (where $L_{FT(t)}$ is the maximum A-weighted sound pressure level using a Fast time weighting) and the average of 20 subsequent values is then obtained. The one minute period is used because this accords with the time averaging period to determine the source noise levels of the wind turbine.

The Impulse adjustment K_I is equal to the level difference between L_{FTeq} and L_{eq}. If K_I is no greater than 2 dB, then no adjustment is made. When the difference is greater than 2dB, then the calculated value is applied as the appropriate correction.

The results of such measurements indicate that wind turbines rarely attract an acoustic feature correction associated with impulsivity as the rise time for the sound source is not sufficiently short, i.e. the onset of the sound is not sufficiently rapid. However, it should be noted that measurements are usually undertaken close to the wind turbine; if AM is caused by interaction between turbines, or is an effect concerned with sound propagation rather than with noise generation then measurements close to a turbine might not pick up an AM problem as perceived at a receiver location. Therefore, analysis of noise at receptor locations may lead to a different assessment as to the need for an adjustment for impulsivity.

A final comment is that the German impulsive correction as described above is intended as a rating method for an existing noise, rather than as a prediction method. It is not clear whether it could be used as a rating method suitable for AM, but this would warrant further investigation.

A Danish wind turbine manufacturer indicated that extreme wind shear may lead to local stall phenomena when the blade is in the top azimuth position. This might lead temporarily to increased levels of aerodynamic noise at the top of the rotor arc which would give modulated noise output consistent with AM. It was also indicated that assuming a neutral atmospheric condition may underestimate the source noise level of a wind turbine in actual conditions. In these circumstances, wind turbine noise immission levels would be higher than predicted and might lead to a greater audibility of wind turbine noise than might normally be expected. This relates to the findings and description of the overall sound pressure level measurements undertaken by van den Berg (2006).

One manufacturer indicated that from 30 turbine installations of their wind turbines, they have one turbine which exhibits high levels of modulation of the aerodynamic noise. This was thought to relate to high inflow turbulence associated with steep sided hills and dense forestry surrounding the turbine.

In summary, from the responses received, it is clear that few wind turbine manufacturers have any practical experience of this phenomenon and even fewer have any potential suggestions as to the cause.

7. Conclusions

1. A comprehensive survey has been conducted of all local authorities with windfarms in their district, or within a closely bordering district. The aim was to ascertain the prevalence of AM. (AM refers to amplitude modulation of aerodynamic noise, i.e. wind turbine noise with a greater than normal degree of fluctuation at about once per second which makes it more noticeable).

2. The survey achieved a 100% response rate. Results indicate that 27 out of the 133 windfarms operational at the time of the survey had received formal complaints about noise at some point in their history.

3. A more detailed survey was conducted among those authorities having received noise complaints. The results revealed that an estimated 230 complaints had been received since 1991, 152 of which were from a single site. The total number of complainants was 81 which is probably a more reliable figure than that for actual complaints.

4. Just under half of the complaints were about mechanical noise and therefore clearly not related to AM. There are four cases where AM appears to be a factor in the complaints, fourteen where it is not, and eight that are marginal.

5. The number of noise complaints about windfarms has been compared with complaint statistics for other types of noise. The total number of complaints about noise generally exceeds those from windfarms by between four and five orders of magnitude indicating that windfarm noise is a small scale problem in absolute terms. In relative terms about 20% of windfarm installations have been subject to complaints, but no data is available to compare this figure with that for other types of noise such as industrial noise.

6. In 16 out of 17 cases for which data is available the windfarm was not considered to be causing a statutory nuisance. In only one case was a statutory nuisance confirmed.

7. A further investigation of the four sites identified by the Local Authority with AM has shown that the conditions associated with AM might occur between about 7% and 15% of the time. It also emerged that for three out of the four sites the complaints have subsided, in one case due to the introduction of a turbine control system.

8. A survey of literature has shown that the causes of windfarm noise have been extensively researched. The general principles are well understood on the whole, although the complexity of turbulent flows means that prediction models are not yet completely reliable.

9. There is little published information on AM, only two peer-reviewed publications are available. The causes of AM are still open to debate, and the theories put forward to date do not apply to some UK sites where the phenomenon has occurred. We conclude that the causes of AM are not fully understood and that AM cannot be fully predicted at current state of the art.

10. A survey of wind turbine manufacturers has showed that some are aware of AM, but that few have practical experience of the issue. It seems unlikely that manufacturers have more advanced knowledge than is available in the literature. This confirms the conclusion in the previous paragraph that AM is not fully understood and cannot be fully predicted at present.

11. Considering the need for further research, the incidence of AM and the number of people affected is probably too small at present to make a compelling case for further research funding in preference to other types of noise which affect many more people. On the other hand, since AM cannot be fully predicted at present, and its causes are not understood we consider that it might be prudent to carry out further research to improve understanding in this area.

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9. Appendix: Detailed survey questionnaire

The following was sent to all LAs who responded 'Yes' to the scoping survey questionnaire. Note that the third question asking about the number of complainants was added to the last 7 questionnaires but not to the first 16. It was added because early responses indicated it would provide useful additional information.

Government Survey into Noise from Wind Turbines
(REF: NANR233)

We are most grateful for your response to Phase I of this survey which is intended to lead to improvements in guidance for assessing planning applications for wind turbines. This is the second phase of the survey. You are receiving this questionnaire because in the first phase you responded that you have had noise complaints about one or more of the wind farms in your area or about a wind farm in a bordering authority.

The aim of this phase is to establish the levels and nature of the reported noise complaints received across the UK relating to noise and vibration issues from wind turbines / wind farms, both historic and current. The Government is hoping for as close to a 100% response as possible in this phase.

You told us that you had received noise complaints about **X** wind farms

We would appreciate you taking the time to complete this questionnaire and emailing it back to us at EMAIL ADDRESS PROVIDED.

Please fill in a questionnaire table for each wind farm for which you have had complaints. We have helped you by listing all the windfarms you mentioned in Phase I of this survey.

Please would you return the questionnaire by email to EMAIL ADDRESS PROVIDED by xxxxxxxx.

Your response will be treated confidentially. The data will only be used for the purposes of this study. We will not identify any individuals. We may quote anonymously from the responses received. If we use the names of Local Authorities and/ or windfarms this will only be to indicate whether or not complaints have been received.

Salford University in conjunction with Hayes McKenzie have been appointed by the UK Government (funded by Defra, DTI, and DCLG) to undertake research into noise from windfarms. For details of why this work was commissioned please see http://www.dti.gov.uk/files/file35043.pdf . The aim of the work is to provide clearer advice to planning authorities about wind turbine planning applications.

Government Survey into Noise from Wind Turbines

(REF: NANR233)

Name of wind farm	
How many complaints were received about this wind farm?	
How many complainants contacted you about this wind farm?	
In what year was each complaint made? (if more than one complaint please list the years)	
Please provide a detailed description of the noise complaint(s): (eg, time of day, wind conditions, description of noise, any other factors that might have contributed to the complaint) THIS INFORMATION IS VERY USEFUL SO PLEASE USE AS MUCH SPACE AS NECESSARY. IF THERE WAS MORE THAN ONE COMPLAINT AND THE COMPLAINTS HAD DIFFERENT CAUSES PLEASE COMPLETE A SEPARATE TABLE FOR THE DIFFERENT TYPES OF COMPLAINT.	

Do any of the following terms describe the noise that was complained about at this wind farm site? (Please delete Yes or No as applies)					
Swish	**YES / NO**	Throbbing	**YES / NO**	'train that never gets there'	**YES / NO**
Swoosh	**YES / NO**	Thudding	**YES / NO**	'like motion sickness'	**YES / NO**
Ghostly Noises	**YES / NO**	Thumping	**YES / NO**	Whistling	**YES / NO**
Wooh Wooh	**YES / NO**	Pulsating	**YES / NO**	Rhythmical Beat	**YES / NO**
Beating	**YES / NO**	Whooshing	**YES / NO**	Other (please list):	**YES / NO**
Lapping	**YES / NO**	Distant Helicopter	**YES / NO**		
Grinding	**YES / NO**	Rumbling	**YES / NO**		

Did you visit the home of the complainant?	**YES / NO**
Did you visit the wind farm site?	**YES / NO**
Did you hear the noise that was being complained about?	**YES / NO**
Briefly describe the investigation that took place.	
Was the wind farm judged to be causing a noise nuisance?	**YES / NO**
What action, if any, was taken?	
This project is about Amplitude Modulation of Aerodynamic Noise (AM) which can be described as 'Wind turbine blade noise which is modulated at blade passage frequency (typically once per second) with a sharper attack and a more clearly defined character than usual blade swoosh. It is sometimes described as being like a distant train or distant piling operations'. **Does the noise from this wind farm conform to this description?**	**YES / NO / DON'T KNOW**

INSTITUTE OF ACOUSTICS

IOA Noise Working Group (Wind Turbine Noise)

Amplitude Modulation Working Group

Final Report

A Method for Rating Amplitude Modulation in Wind Turbine Noise

9 Aug 2016 Version 1

FOREWORD

This report has been produced by the Amplitude Modulation Working Group (AMWG) on behalf of the UK Institute of Acoustics. The group consists of the following members:

Jeremy Bass	RES Ltd
Matthew Cand	Hoare Lea Acoustics
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Robert Davis	RD Associates
Gavin Irvine (Chair)	Ion Acoustics Ltd
Geoff Leventhall	Consultant
Tom Levet	Hayes McKenzie Partnership Ltd
Samuel Miller	
David Sexton	West Devon Borough Council
John Shelton	AcSoft

The group was established in July 2014 and held a series of meetings, usually on a monthly basis with additional conference calls. A discussion document was issued for consultation in April 2015. The group also presented material at conferences and one-day meetings to liaise with other interested parties, to promote discussion and consider options. This report is the culmination of the process and advocates a Reference Method to be used for rating amplitude modulation in wind turbine noise.

This document is based on current knowledge and research available to the authors as of June 2016 and was developed from analyses of data samples from various wind turbine developments and synthesised data from subjective testing. It represents the consensus view of the working group.

The document sets a method to be implemented by suitably competent practitioners familiar with acoustic analysis methods. The level of technical competence required is similar to that required for tonal analysis according to ETSU-R-97 / ISO 1996-2: 2007.

The group would like to thank Malcolm Hayes at Hayes McKenzie, Chair of the IOA's Wind Turbine Noise Working Group, Charles Ellis at the IOA and the peer reviewers: Peter Rogers of Sustainable Acoustics and Ed Clarke at Clarke Saunders Associates and all of those who commented on the discussion document.

TABLE OF CONTENTS

0 EXECUTIVE SUMMARY

0.1 Background

0.1.1 This document has been prepared by the Amplitude Modulation Working Group (AMWG) established by the UK Institute of Acoustics (IOA) to propose a method or methods for measuring and rating amplitude modulation (AM) in wind turbine noise. Amplitude modulation (in this context) is a regular fluctuation in the level of noise, the period of fluctuation being related to the rotational speed of the turbine. This characteristic of the sound might be described by a listener as a regular 'swish', 'whoomph' or 'thump', depending on the cause and the severity of the modulation. Wind turbine AM has been reported in and around dwellings in the UK and elsewhere and, in some cases, its more severe forms have led to specific complaints from residents.

0.1.2 Given public concern over the issue, there is a recognised need to define a robust procedure for measuring and assessing AM, to provide a consistent means of evaluating complaints and to form the basis of appropriate planning conditions that might be applied to regulate AM from new wind turbine developments. Most planning conditions, currently routinely applied to wind turbine installations, have had the effect of limiting overall noise levels and provide a means of controlling tonal noise characteristics, but have not directly addressed AM.

0.1.3 Amplitude modulation has only relatively recently been recognised as an issue for wind turbine developments, perhaps over the last 12 years or so, but has now been the subject of a significant number of research papers and reports in the UK and elsewhere. Some researchers have carried out listening tests to provide information on how people respond to amplitude modulated noise. However, researchers have adopted several different metrics to ascribe a value to the component of AM present in samples of wind turbine noise. The AMWG has reviewed the existing literature on the measurement of AM and carried out further research to enable progress to be made towards defining the most appropriate metric for AM to adopt in the UK.

0.1.4 The AMWG has not addressed the question of what level of AM in wind turbine noise (when measured by a specific metric) is likely to result in adverse community response or how that response should be evaluated. The psycho-acoustic aspects of AM are not within the scope of this study, but the proposed metric is intended to assist with such further research.

0.1.5 The background to the study, information on the composition of the AMWG, its Terms of Reference and key requirements for a metric are set out in the main body of the report.

0.1.6 This report presents the conclusions of the AMWG and recommends a metric to define the extent to which a sample of wind turbine noise exhibits AM. It sets out a procedure for obtaining input noise data and analysing this data to quantify the magnitude of AM.

0.2 Definition of AM

0.2.1 In the context of the objectives of the working group, AM is defined as:

"periodic fluctuations in the level of audible noise from a wind turbine (or wind turbines), the frequency of the fluctuations being related to the blade passing frequency[1] of the turbine rotor(s)."

0.3 Application of the metric

0.3.1 The method applies to the measurement and assessment of the AM characteristics presented by current large upwind turbines with three-bladed rotors rotating at speeds up to approximately 32 rpm. It could also be applied with care to other turbines. Also, the metric is intended to be applied to external measurements of noise experienced at 'residential distances'; separation distances between large wind turbines and dwellings in the UK being typically 500 metres or more. The measurements are made outdoors, primarily because of the practical difficulties associated with making repeatable noise measurements indoors. Reliance on external measurements is consistent with established standards and procedures for assessing environmental noise.

0.4 Consultation documents and responses

0.4.1 The AMWG published a Discussion Document in April 2015 (IOA AMWG, 2015). This document presented the group's preliminary observations and conclusions on methods of measurement and rating AM based on a review of the literature and the combined experience of the group. Three different approaches to developing an AM metric were presented. These were based on, or derived from, methods described in the literature and were evaluated by processing audio recordings and time series records of real and simulated wind turbine noise exhibiting varying levels of AM and with varying degrees of contamination by noise from other sources.

0.4.2 Following publication, comments, observations and criticisms were received from interested parties. A summary of the key points raised by consultees and the AMWG's comments on these points is provided in the main report. The individual consultation responses, for those who agreed to publication, are available on the IOA website.

0.5 Reference Method

0.5.1 As a result of this analysis, and taking input from the responses to the Discussion Document (IOA AMWG, 2015), the AMWG has now identified a method (the 'Reference Method') for adoption in reliably identifying the presence of amplitude modulated wind turbine noise within a sample of data, and of deriving a metric that, in the AMWG's view, best represents the degree of amplitude modulation present. The method is described in detail in Section 4. It is essentially a development of the Hybrid Reconstruction

[1] Blade Passing Frequency (BPF, in Hz) = (Rotor RPM) x (No. of Blades) / 60

method (i.e. Method 3) previously described in the Discussion Document. It also draws on elements of the proposed Methods 1 and 2 and incorporates a newly developed 'prominence' criterion which has been found to be very effective in discriminating wind turbine AM from other sources, thereby reducing (but not eliminating) the need for detailed scrutiny of the data.

0.5.2 In outline, a Fourier transform is taken of band-limited time series data to determine the fundamental modulation frequency (which should be related to the turbine BPF) and the second and third harmonics. These components are then used to reconstruct a time series, which should relate only to wind turbine AM, with the influence of background sources minimised. The modulation depth is then calculated following the method of Tachibana *et. al.*, *i.e.* subtracting the L_{95} of the time-series from the L_5.

0.5.3 The Reference Method involves the following stages:

- Noise is measured in short-term, 100-millisecond L_{Aeq} values in 1/3-octave bands. Three frequency ranges or bands are evaluated: 50 - 200 Hz; 100 - 400 Hz and 200 - 800 Hz, and the results which exhibit the highest resulting levels of AM are used
- The fundamental length of input sample to be assessed (the minor time interval) is 10 seconds
- The hybrid reconstruction method is used to determine the AM value for each 10 second value
- The values of AM measured by the metric in each 10-second interval are aggregated over a 10-minute period (the major time interval) to provide a single value which is the AM rating for the 10 minute period.

0.5.4 The application of the Reference Method is illustrated in the main report through the analysis of data samples including those exhibiting wind turbine AM and also background noise with wind turbine noise absent. Measurement of wind turbine noise made for the purpose of evaluating AM using the Method involves specific requirements for instrumentation and these are described in the main report.

0.5.5 Implementation of the recommended Reference Method requires the use of specific bespoke computing routines programmed in Python, MATLAB or similar platforms. Details of the appropriate code for users to programme these routines will be made available through the IOA, with data samples for validation.

0.5.6 Although it is relatively complex, a degree of complexity is considered inevitable in a method that is sufficiently robust for determining compliance or non-compliance with specific thresholds or limits. A simple preliminary assessment method (the Indicative Method) is also described; this may be useful in some situations where wind turbine AM is subjectively apparent and when noise measurements with minimal contamination by other noise sources are available. However, the Indicative Method must be used with caution and is to be considered as secondary to the Reference Method and in no circumstances as a substitute for it.

1 INTRODUCTION

1.1.1 Amplitude modulation (AM) in wind turbine noise has been well documented in recent years in the UK and overseas and various researchers have proposed methods of ascribing a value to the level of AM in a noise sample (an AM metric) and of assessing the significance of that level. However, the application of different metrics yields different AM values, and few of the metrics are supported by research on dose-response relationships. In response to a request from the Institute of Acoustics Noise Working Group (IOA NWG), and IOA Council, the IOA set up a working group to look at amplitude modulation in wind turbine noise – the Amplitude Modulation Working Group (AMWG). The aim of the group is to review the available evidence and to produce independent guidance on the technical aspects of the assessment of AM and to recommend an appropriate metric. The working group includes academics, representatives from wind farm developers and local authorities and acoustic consultants who have worked for developers, local authorities and objector groups (see Foreword).

1.1.2 It is now generally accepted that there are two manifestations of wind turbine AM. An observer close to a wind turbine will experience 'blade swish' because of the directional characteristics of the noise radiated from the trailing edge of the blades as it rotates towards and then away from them[2]. This effect is reduced for an observer on or close to the (horizontal) turbine axis, and therefore would not generally be expected to be significant at typical separation distances, at least on relatively level sites. The RenewableUK AM project (RenewableUK 2013) has coined the term 'normal' AM (NAM) for this inherent characteristic of wind turbine noise, which has long been recognised and was discussed in ETSU-R-97 in 1996 (ETSU, 1996).

1.1.3 In some cases, a form of AM is observed at residential distances from a wind turbine (or turbines). The sound is generally heard as a periodic 'thumping' or 'whoomphing' noise containing relatively low frequencies. This type of noise was identified in 2002 to 2004 by Frits van den Berg (van den Berg 2005) and in a UK study on low frequency noise from wind farms in 2006 (Hayes, M. 2006). The prevalence of this type of modulation is subject to debate. On sites where it has been reported, occurrences appear to be occasional, although they can persist for several hours under some conditions, dependent on atmospheric factors, including wind speed and direction.

1.1.4 It was proposed in the RenewableUK 2013 study that the fundamental cause of this type of AM is transient stall of the airflow over the blades as these experience periodic (blade passing frequency related) changes in the inflow wind speed as they rotate. Transient stall represents a fundamentally different mechanism from blade swish and can be heard at relatively large

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[2] In addition, complex Doppler effects due to the relative blade movement influence the characteristics of the noise.

distances, primarily downwind[3] of the rotor blade. The RenewableUK AM report adopted the term 'Other AM' (OAM) for this characteristic. Elsewhere it might be reported as Excessive Amplitude Modulation (EAM).

1.1.5 All AM source mechanisms result in a periodic fluctuation (modulation) in the amplitude (level) of the turbine noise, the frequency of the modulation being related to the Blade Passing Frequency (BPF) of the wind turbine blades (the rate at which the blades of the turbine pass a fixed point). For a three-bladed turbine rotating at 20 rpm, this equates to a modulation frequency of 1 Hz.

1.1.6 ETSU-R-97 refers to AM on pages 40 and 68. It is stated that AM of up to 3 dB 'peak to trough' is typical close to a wind turbine, and that fluctuations of up to 6 dB could be experienced in situations where there are two reflective surfaces close to the observer. The statements are not specific; there is no reference to distances or hub heights, and no statement of measurement averaging time. It might be reasonable to assume that the 'peak to trough' values are those evident in a root-mean-square (rms) 'fast' response time history (as suggested in Appendix A of the IEC 61400-11 standard). It should be appreciated that these comments refer to observations made on the sizes and types of wind turbines operating in the early 1990s and may or may not be applicable to the larger turbines currently in widespread use.

1.1.7 On the basis of the comments in ETSU-R-97, the value of 3 dB ('level of AM' or 'modulation depth') is sometimes referred to as the 'expected level' of AM. The Den Brook AM condition[4] adopts a 3 dB peak-to-trough value as the threshold above which AM is deemed to be 'greater than expected'.

1.1.8 There is currently no generally agreed rating methodology for wind turbine AM. New Zealand Standard NZS 6808: 2010 provided a penalty mechanism but noted that there was no objective test available. Authorities in Australia and Finland have published some guidance on rating methodologies and associated limits, although these are either unvalidated or in draft form. In the UK, planning conditions intended to address AM have been imposed on a small number of wind farms to develop a scheme of assessment. These conditions have been based either on the time-series method adopted at Den Brook, which has been the subject of much debate and legal challenge, or the frequency-domain method proposed by RenewableUK (RenewableUK, 2013). However, in virtually all cases, planning officers and inspectors, in granting wind farm planning permission, have declined to impose an AM condition; as either they have considered that the need for such a condition had not been demonstrated, or that there was no robust scientific basis for framing such a condition, or both. In a number of cases, a condition requiring a scheme for assessing AM to be agreed with the local planning authority has been imposed; this form of condition relies on the premise that an appropriate method of assessing AM will be available within the development timescale.

[3] The stall source mechanism radiates equally upwind and downwind, but propagation effects reduce noise levels upwind.
[4] see htt p//www .masenv.co.uk/Den Brook AM Condition [last accessed May 2016]

A scheme of this type has been discharged by Maldon District Council in respect of Turncole Wind Farm[5]. The scheme was based on an amended RenewableUK methodology.

1.1.9 Given public concern over the issue, there is a recognised need to define a repeatable and reproducible procedure for measuring and assessing AM, to provide a consistent means of evaluating complaints and to form the basis of a planning condition that might be applied to regulate AM from new wind turbine developments. Most planning conditions, currently routinely applied to wind turbine installations, have had the effect of limiting overall noise levels and provide a means of controlling tonal noise characteristics, but have not directly addressed AM.

1.1.10 The AMWG has undertaken a comprehensive literature review to assess current research and different rating methods for AM, particularly AM in wind turbine noise. Wind turbine AM has been the subject of a number of research papers and reports. Some researchers have carried out listening tests to provide information on how people respond to amplitude-modulated noise. However, researchers have adopted several different metrics to ascribe a 'value' to the 'level' of AM present in any particular sample of wind turbine noise. The AMWG has reviewed the existing literature on the measurement of AM and carried out further research to enable progress to be made towards defining the most appropriate metric for AM.

1.1.11 The AMWG has not addressed the question of what level of AM in wind turbine noise (when measured by a specific metric) is likely to result in adverse community response, or how that response should be evaluated. The psycho-acoustic aspects of AM are not within the scope of this study, but the proposed metric is intended to assist with such further research. However, the reference method developed has been applied to the synthesised stimuli which were used in the RenewableUK and Japanese research studies (see Section 8).

1.1.12 The background to the study, information on the composition of the working group, its Terms of Reference and key definitions are set out in the Appendices A and B.

1.1.13 The IOA AMWG set out the main issues in a Discussion Document (IOA AMWG, 2015) published in April 2015. This draft presented three methods for consideration, one in the time domain, one in the frequency domain and a 'hybrid' method combining time-and-frequency-domain methods.

1.1.14 Based on review of the consultation responses received (see Appendix C) and further discussion and research, this final report documents the Reference Method for rating AM as now proposed by the AMWG. The proposed Reference Method is described in detail in Section 4. In developing

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[5] Turncole Wind Farm Condition 25 Scheme for the Regulation of Amplitude Modulation Maldon District Council Planning Reference FUL/MAL/10/01070

the methodology, the AMWG defined procedures on the basis of professional judgement and experience, representing the best knowledge available at the time of writing. Section 4.7 discusses some of the key decisions made in defining the procedure and provides justification, based on the experience of the AMWG.

1.1.15 The AMWG does not propose any limits for amplitude modulation. The purpose of the group is simply to use existing research to develop a Reference Methodology for the measurement and rating of amplitude modulation. The definition of any limits of acceptability for AM, or consideration of how such limits might be incorporated into a wind farm planning condition, is outside the scope of the AMWG's work and is currently the subject of a separate Government-funded study.

2 AM DEFINITION

2.1.1 For the purposes of the working group, it is not considered to be appropriate to adopt separate definitions for AM dependent on the source mechanism (see Section 1). There is no agreed basis for defining any particular level or character of AM as 'enhanced', or 'excessive', or 'greater than expected'. The objective is to define a measurement protocol and associated metric which is technically robust and has a number of suitable attributes as defined in the Scope of Work (Appendix B).

2.1.2 The following statement therefore defines wind turbine AM in the context of the working group's objectives:

"Wind turbine amplitude modulation is defined as periodic fluctuations in the level of audible noise from a wind turbine (or wind turbines), the frequency of the fluctuations being related to the blade passing frequency[6] *of the turbine rotor(s)."*

Scope of application

2.1.3 For most medium to large-sized three-bladed upwind turbines (typically with a generating capacity of 500 kW and above) the blade passing frequency (BPF) is up to approximately 1.6 Hz. Turbines below 500 kW or older models could have higher BPFs, and some micro-turbines have rattle/flap problems, which might show the characteristics of AM on a time-history plot, but could subjectively be quite distinctive. Similarly, downwind turbines may have different acoustic characteristics that need consideration of lower frequencies. The AMWG study mainly focussed on the measurement and assessment of AM from current large upwind turbines with three-bladed rotors rotating at speeds up to approximately 20 rpm. However, the metric as designed captures all the first three harmonics of the signal for BPFs up to approximately 1.6 Hz. This corresponds to 32 rpm for a three-bladed turbine.

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[6] Blade Passing Frequency (Hz) = (Rotor RPM) x (No. of Blades) / 60

A higher sampling rate (with a period of less than 100 ms) would be required to capture faster fluctuations but this is untested by the AMWG.

2.1.4 The metric described in this document does not reflect any change in subjective response with modulation frequency. However, it does identify the modulation frequency and this could therefore be used in a subjective rating, if appropriate.

2.1.5 The assessment procedure and metric are intended to be applied to external measurements of noise experienced at locations at 'residential distances', separation distances between large wind turbines and dwellings in the UK being typically 500 metres or greater. The procedure is based on outdoor measurements in the vicinity of dwellings, primarily because of the practical difficulties associated with making repeatable noise measurements indoors. Reliance on external measurements is consistent with established standards and procedures for assessing environmental noise.

3 OUTCOME OF CONSULTATION RESPONSES & SELECTION OF METRIC

3.1.1 Responses to the Discussion Document – see Appendix C – demonstrated an overall preference for a frequency-domain method, mainly because of the ability of such a method to discriminate more objectively between fluctuations in noise levels resulting from wind turbine AM (which has a periodic characteristic related to the turbine rotational speed) and fluctuations resulting from other variable environmental noise sources (such as birdsong). This is particularly important for the purposes of analysing large datasets, perhaps involving many weeks or months of data, which would often require extensive subjective assessment to exclude spurious (non-wind turbine) noise if a time domain approach were adopted.

3.1.2 However, it was observed that the frequency-domain method presented in the Discussion Document (Method 2) could lead to an under-rating of AM, compared with a time-domain analysis, because the energy content in the higher harmonics of the modulation spectrum were not taken into account. It can be argued that this 'under-rating' effect would be offset by the ability of the frequency-domain method to reduce the influence of background noise, and also that allowance could be made for this in devising an acceptability-rating scale for AM. However, such an 'allowance' could not be uniquely defined because of the variations in the relative levels of the fundamental and harmonic components observed in the modulation spectra for different AM samples. Furthermore, achieving an increased 'dynamic range' in the output of the metric was considered useful.

3.1.3 Several respondents expressed support for a time-domain method, mainly on the basis of simplicity and the more 'transparent' nature of the signal analysis procedure compared with the frequency-domain method, but also because it was considered that the frequency-domain method resulted in an under-statement of AM.

3.1.4 Several respondents supported the hybrid method (Method 3), or at least considered it 'interesting', although reservations were expressed about its apparent complexity. The method was considered to work well in quantifying amplitude modulation, however, implementing low bandwidth filters in the time domain presented a number of technical drawbacks such as filter ring-up time.

3.1.5 As a result of the consultation responses, and considerable further discussion and research, the AMWG has agreed to recommend a 'hybrid' method, essentially a development of Methods 2 and 3 described in the Discussion Document, although also drawing on aspects of Method 1. The method (the 'Reference Method') utilises a frequency-domain procedure to identify the presence of AM in wind turbine noise data and to extract the time-series of the AM component (although complete exclusion of background noise cannot be achieved). The level of AM is then assessed using a metric applied to the reconstructed time-series data. In the opinion of the AMWG, this hybrid method addresses the deficiencies of stand-alone time-series and frequency-domain methods. Also, because the final assessment is based on a 'reconstructed' time-domain signal, this enables any results to be related to published research into dose-response relationships, which is almost universally based on assessing AM values from time domain data. The Salford and 'Tachibana' test signals have been analysed using the Reference Method.

3.1.6 A degree of complexity is considered inevitable in a method that is sufficiently consistent for determining compliance or non-compliance with specific thresholds or limits. The level of technical competence required is similar to that required for tonal analysis according to ETSU-R-97 or ISO 1996-2: 2007. A simple preliminary assessment method (the Indicative Method - see Section 4.8) - is also described; this may be useful in situations where wind turbine AM is subjectively very apparent and where measurements are available exhibiting clear AM with minimal contamination by other noise sources. However, the Indicative Method must be used with caution and is to be considered as secondary to the Reference Method and in no circumstances as a substitute for it.

3.1.7 The proposed Reference Method has several merits (set out in Section 7) and provides an objective benchmark for rating AM levels. However, it is possible for AM to be evaluated in different ways, including subjectively. It is noted that noise nuisance investigations, for example, need not be limited to any particular method of assessing wind turbine noise, and will often involve many other factors such as the time of day and the character of the neighbourhood. Furthermore, factors such as the duration and frequency of occurrence may be relevant in determining subjective response. Therefore, the availability of the Reference Method need not preclude other assessments being made. Nevertheless, the Reference Method can provide important information on frequency of occurrence and duration which is relevant and can be used to evaluate different operational conditions including mitigation, since a robust and reliable indicator of AM is achieved.

4 REFERENCE METHOD

4.1 Introduction

4.1.1 This section describes a reference assessment method which characterises a sample of amplitude modulated wind turbine noise by means of a single metric uniquely defining the level of AM within it. In the consensus view of the AMWG, and following consultation, this method was developed in order to best address the scope of works and success criteria provided.

4.1.2 Following an overview of the method, the parameters and principles for measurement and data processing are discussed below. Instrumentation for measuring AM is discussed in Section 5.

4.2 Overview of method

4.2.1 The proposed method is a 'hybrid' approach, based on a frequency domain method (using Discrete Fourier Transform or DFT), with its strength in discriminating wind turbine AM, but which retains time domain characteristics of the signal in the final output produced. It is similar to a method proposed elsewhere (Swinbanks, 2013).

4.2.2 The method is considered by the group to be a representative signal analysis technique which is not excessively complex, being comparable to tonal analysis techniques included in ETSU-R-97, whilst being effective on a wide range of signals and used in other applications such as SONAR for detecting propeller noise. The results obtained with this hybrid method are comparable to those obtained by Method 3 presented in the group's previous discussion document, in particular, in terms of the dynamic range obtained. In the same way, three harmonics of the signal are retained (if relevant) in order to represent the non-sinusoidal modulation more accurately.

4.2.3 Frequency analysis of the time signal allows the identification of the pattern of clear modulation which, when it occurs, is typical of wind turbine amplitude modulation and distinguishes it from a myriad of other time-varying sources found in all noise environments. Such a pattern becomes a distinct peak in the resulting power spectrum, which may be related to the Blade Passing Frequency (BPF) of the turbine(s) (particularly if it is consistent in time). As the BPF can vary for modern turbines, the method requires the range of expected blade passing frequencies to be defined. This can be determined from examination of 'waterfall' plots, or from turbine SCADA data, or with reference to published information on the turbines (see Section 4.3). It is not dependent on the availability of SCADA data, as it is acknowledged that this may not be provided.

4.2.4 In addition, following consultation, the AMWG developed a technique for evaluating the 'prominence' of the spectral peaks obtained (see Section 4.6). This represents how much a peak stands out above the noise floor of the power spectrum. In the experience of the group, this is a good indicator of clear modulation of the noise levels for the frequency of interest and an objective indicator of how clear the modulation is. Spectra generated from irregular sources, such as impulses or bird noise, tend to create irregular spectra with low prominence. Although this criterion does not fully exclude all individual spurious periods, the prominence check and the requirement for at least 30 valid 10-second samples to calculate the 10-minute values provides a remarkably effective indicator of the presence of corruption and has been found to perform well in identifying AM associated with wind turbines for a range of sometimes very corrupted signals.

4.2.5 In outline, the method proceeds as follows:

- The input signal (a time series of band-limited, A-weighted, 1/3-octave L_{eq} data in 100 millisecond samples) is split into blocks of 10 seconds;
- It is transformed to the frequency domain using Fourier analysis to obtain a modulation spectrum;
- If a clear (prominent) peak is present at a rate expected from the turbines, a window[7] around that frequency (and the next two harmonics) is selected (subject to some tests);
- An inverse Fourier transform is applied to the filtered spectrum to reconstruct a filtered time-series;
- The modulation depth in the filtered time-series is then determined
- A value for a 10-minute period is calculated from a combination of the 10-second modulation depths within that period.

4.2.6 The modulation depth over 10 seconds is determined directly from the difference between the L_5 and L_{95} values within the filtered time-series (as in the approach of Fukushima, Yamamoto *et. al.*, 2013). It would also be possible to uniquely and objectively identify the peaks and troughs in the reconstructed signal by using modulation at the fundamental rate (also obtained by inverse Fourier transform) as a guide. This would in theory evaluate the variability of the modulation within each 10 second block. However, this adds complexity and the AMWG's investigations showed that this does not tend to provide significant benefit when considering the 10 second time intervals addressed in the analysis, and it is therefore proposed to retain the simpler $L_5 - L_{95}$ method as standard.

4.2.7 The method produces a single value for a 10-minute period. The variations in 10 second AM ratings over 10 minutes are available as one stage of the method, and this may also be of interest to some researchers in further studies; however there is little known at present about the subjective response to transient or variable AM. As noted above, considering valid 10-minute periods using the prominence requirements was found to be very effective at eliminating spurious noise (hence achieving a more repeatable measure). Therefore a metric based on determining a 10-minute value as recommended herein will be more robust.

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[7] The width of this window was chosen based on experience of typical modulation and allows the variation of modulation depth in the input signal to be represented.

4.2.8 The method is described in six steps as follows:

Step A Survey requirements and find appropriate acoustic frequency range – see Fig 4.2.1

Step B Calculate 10-minute average using methodologies C1, C2, C3 – see Fig 4.2.2

Step C1 Determine modulation in a 10-second block – see Fig 4.2.3

Step C2 Prominence Check – see Fig 4.2.4

Step C3 Include Harmonics – see Fig 4.2.5.

4.2.9 These steps are shown in the following Figures 4.2.1 to 4.2.5 below.

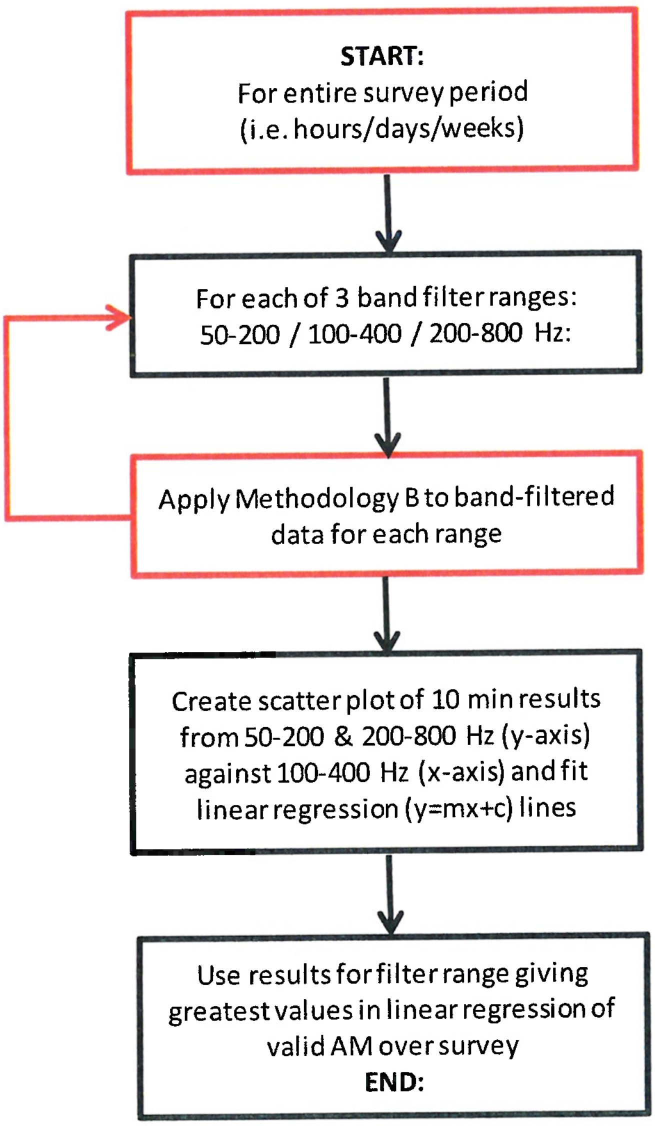

Figure 4.2.1 - 'Overall' Methodology

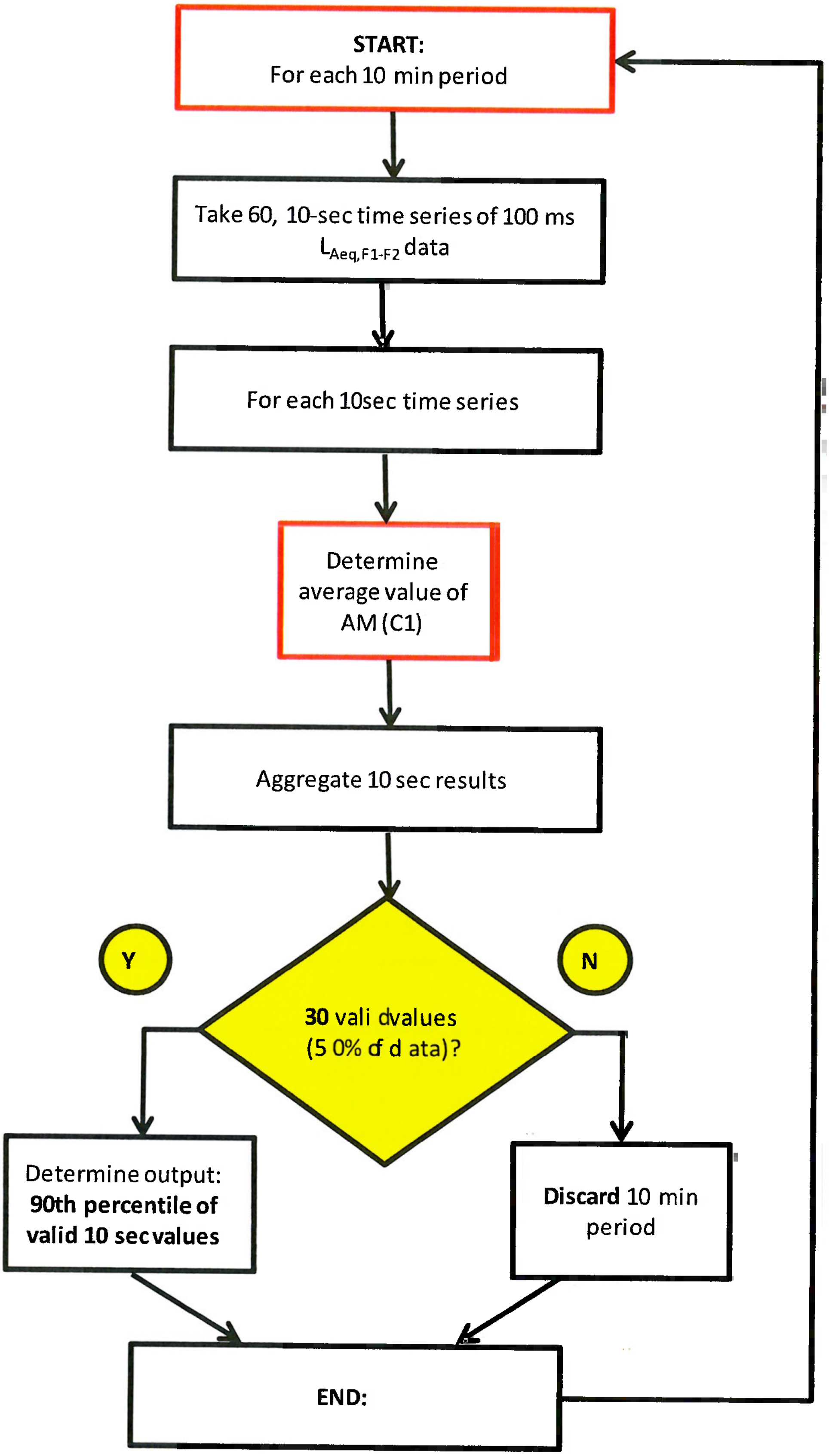

Figure 4.2.2 - B: 10 Minute Methodology

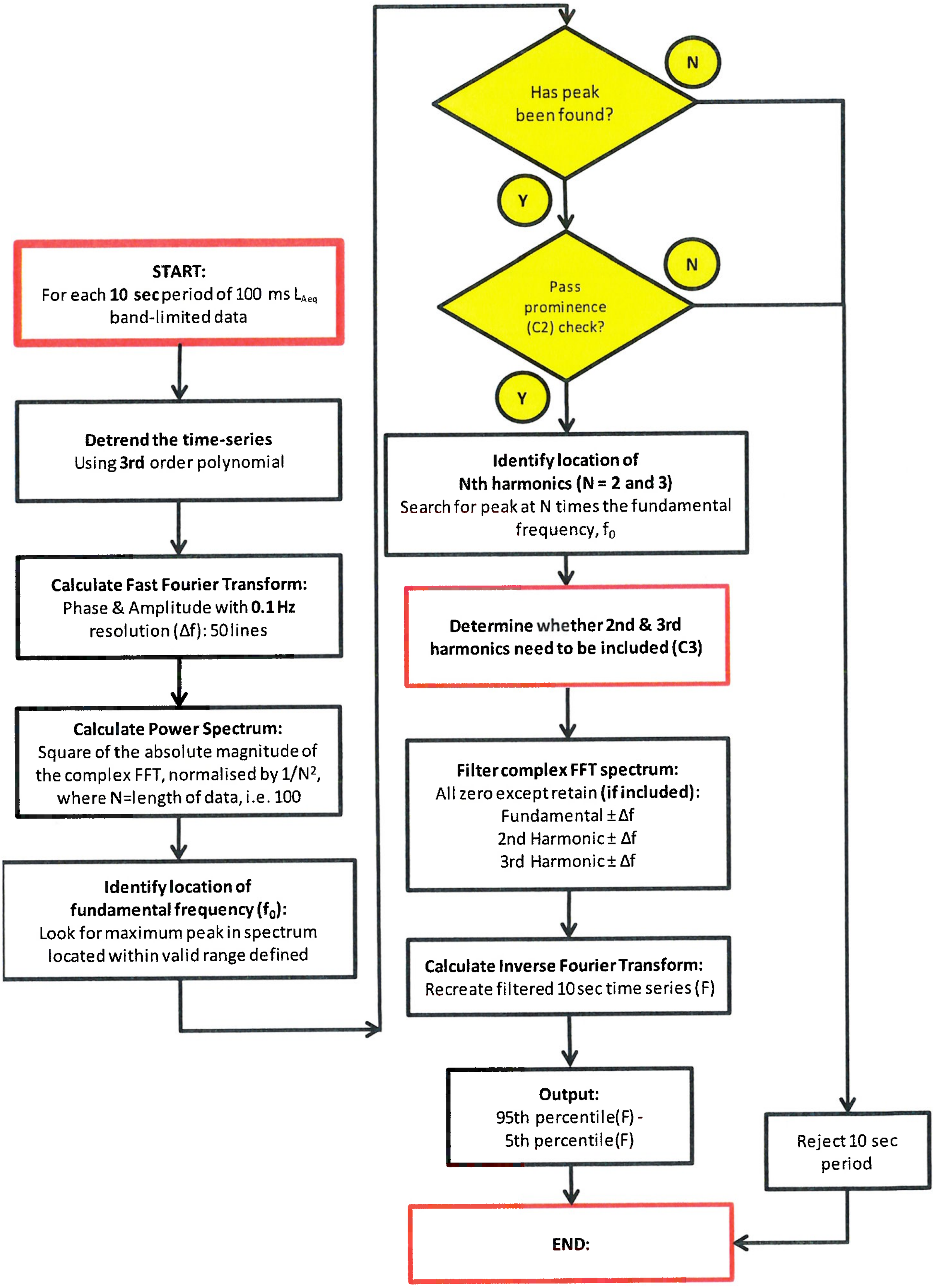

Figure 4.2.3 - C1: 10 Second Methodology

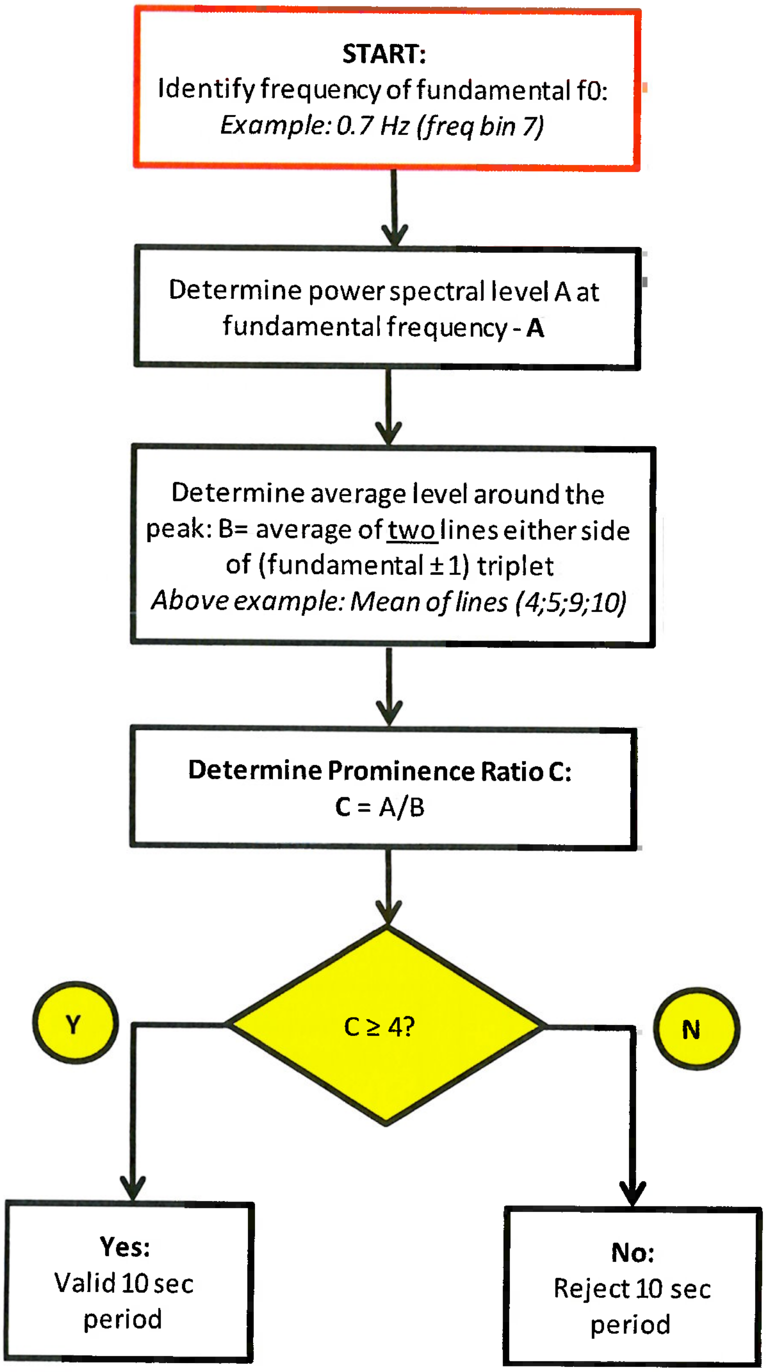

Figure 4.2.4 - C2: Prominence Check Methodology

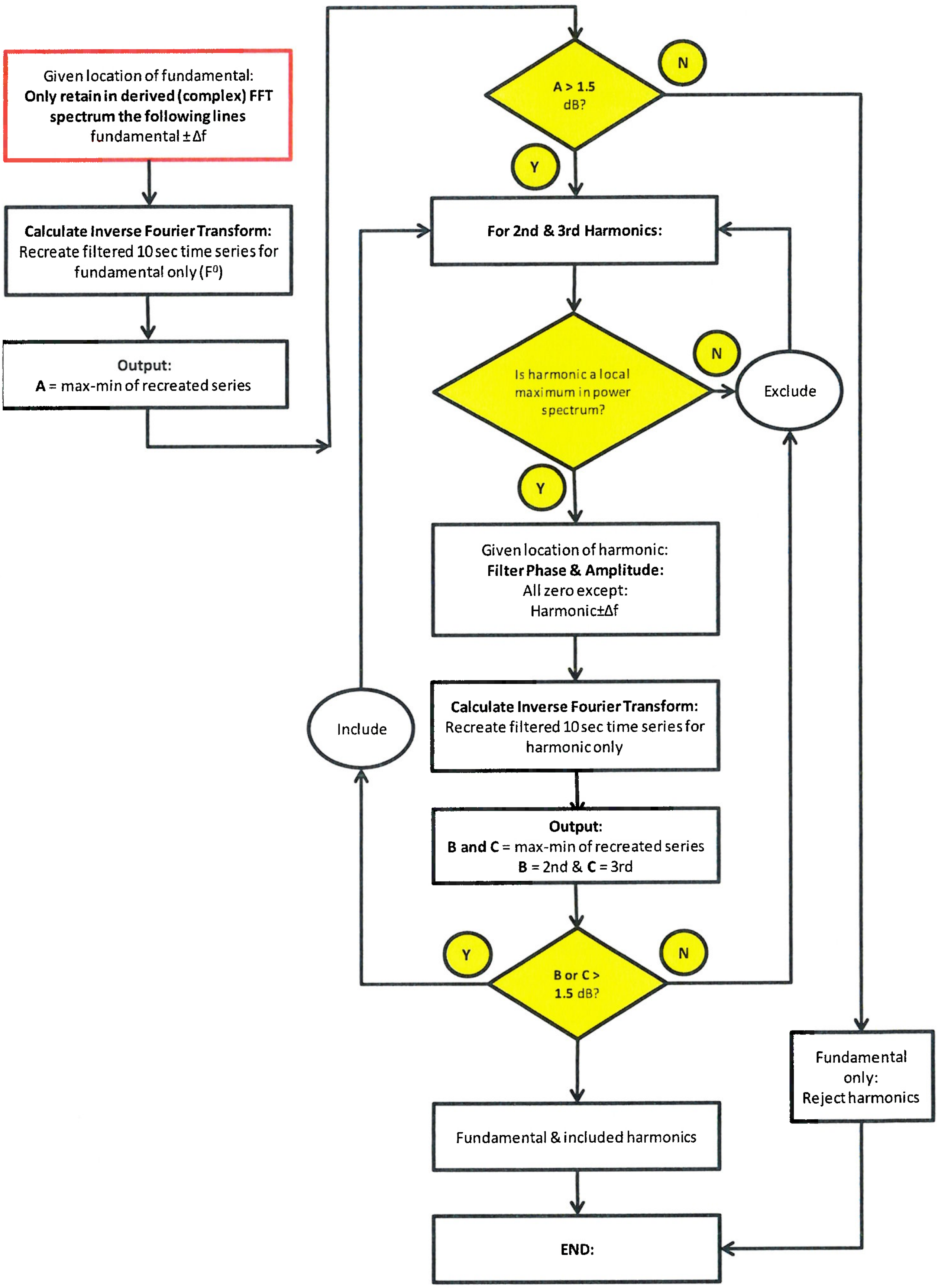

Figure 4.2.5 - C3: Decision Methodology for Including Harmonics

4.3 Input data

4.3.1 The input data to the analysis should be A-weighted, band-filtered 100-millisecond L_{eq} values. The analysis should be done for the following three frequency ranges:

- 50 to 200 Hz
- 100 to 400 Hz (reference)
- 200 to 800 Hz.

4.3.2 The range encompasses seven 1/3-octave bands. The specific range chosen is the one which tends to give the highest modulation values over a representative range of *valid* data measured. This can be evaluated by plotting the analysed, valid data as a scatter plot (x-y graph) with the reference 100 to 400 Hz range values as the x-axis – see Fig 4.3.1.

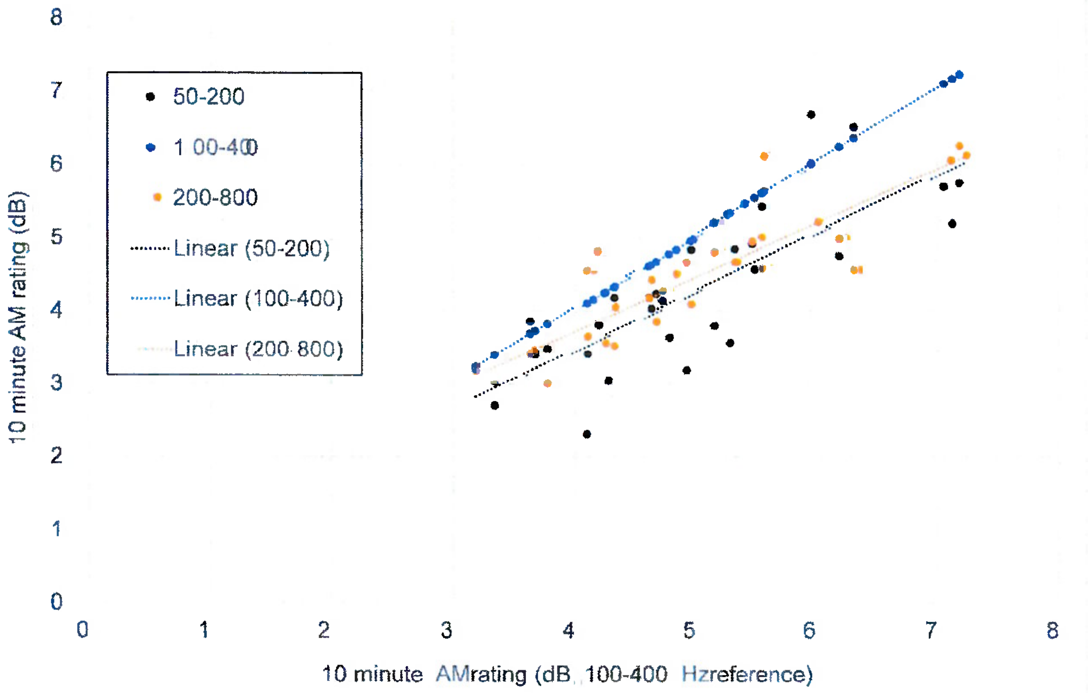

Fig 4.3.1 Comparison of ratings obtained with different frequency bands. This example shows that the 100-400Hz range should be used

4.3.3 It should be borne in mind that for the higher frequency range, data may be more prone to corruption from other sources, such as bird calls, and the resulting spectra should be scrutinised more carefully. Similarly, the lower frequency range might be more affected by wind noise.

Discussion

4.3.4 Focussing on a limited frequency range dominated by modulation assists in both the identification of AM and in excluding spurious data. It also results in higher levels of AM compared to those obtained from broadband (A-weighted) analysis. In fact, the band-limited data can detect AM which might have been masked using a broadband analysis based on overall L_{Aeq} values.

4.3.5 A range comprising seven 1/3-octave bands has been found to offer a good compromise between reduction of variability and discrimination. Compared with the choice of the single 1/3-octave band, there is a reduced sensitivity to the choice made, and it results in a cleaner and clearer analysis result.

4.3.6 In the experience of the AMWG, based on a number of cases of modulation measured at typical residential separation distances, the range of 100 – 400 Hz has been found to be representative of frequencies dominating the modulation for the majority of cases. In other specific cases, in which separation distances were reduced, or the turbines were of relatively smaller scale, a range of higher frequencies was found to be more suitable. It is therefore not possible to determine a single range that would best represent different situations and the method, based on analysis of three ranges, represents a prescriptive way to account for the different spectral characteristics encountered.

4.3.7 Frequencies higher than 800 Hz were found to generally not include much AM signal, but did feature corrupting sources such as bird or insect noise. For frequencies less than 50 Hz, there was, in the experience of the group and in available literature, little evidence of substantial audible modulation present, and in addition, the clear possibility of corruption from other sources. Downwind turbines may require analysis of lower frequencies (if audible); this would need to be considered on a case-by-case basis.

Deriving band-limited input data in practice

4.3.8 Many modern sound level meters offer the possibility to log 1/3-octave band spectra in 100 millisecond periods to obtain the required information directly. The 1/3-octaves should be either measured A-weighted, or have the A-weighting corrections applied to each band as a post-processing step. The resulting A-weighted bands should then be summed (logarithmically) within each of the above frequency ranges of interest in order to obtain a band-pass filtered $L_{Aeq,100ms\ (BP)}$ signal.

4.3.9 While it is possible to post-process audio recordings to A-weight them and filter them over the frequency band of interest, this entails significant practical difficulties: high resolution audio recordings would be required, which have large storage requirements; post-processing requires specialist software and is generally not straightforward. Therefore, the preferred approach is to use directly logged 1/3-octave band L_{eq} values, between 50 and 800 Hz, in 100 millisecond resolution, either A-weighted or with the A-weighting corrections applied in post-processing. L_{eq} 1/3-octave bands were chosen in preference to fast time-weighted 1/3-octave bands as the former are more precisely defined and allow summing up in the manner prescribed. They also lead to a higher result as they result in more pronounced peaks and troughs[8].

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[8] A comparative study for turbines modulating at around 0.7 Hz indicated that AM ratings obtained with the L_{eq} bands could be around 0.5 to 1dB higher than those obtained with fast time-weighted analysis on the same signal, depending on the characteristics of the signal.

Input parameters – modulation frequency range

4.3.10 The method requires, as input, a range of modulation frequencies in which the main (or fundamental) modulation frequency is expected to be found. This assists in excluding apparent 'modulation' which is not related to the turbines.

4.3.11 Knowledge of the turbine type and its possible rotational rates, or turbine operational (SCADA) data, can assist in defining this range. For example, for a three-bladed turbine rotating at 20 rpm, the BPF modulation frequency would be 1 Hz. In practice, the rotational rate can vary between turbines on a particular site and it may not possible or practical (except maybe in the simplest cases) to define a single expected BPF for each 10 minute analysis period based on operational data. This is why it was found effective to specify a range and determine the highest modulation peak found within this range.

4.3.12 It may be necessary, for example if the BPF is unknown, to proceed iteratively and first define a wider range (in a preliminary analysis) which is then refined based on the results of the modulation spectrum analysis, in order to minimise the influence of other sources.

4.3.13 If a consistent fundamental modulation frequency is apparent over a period of time, which also coincides with a potential blade passing frequency, this is a strong indication that the modulation results are related to the wind turbine operation. This is in these cases clearly apparent as a trend on a plot of the modulation spectrum with time[9]; this is known as a waterfall plot. The use of such waterfall visualisation (see Fig 4.3.2) is in practice very effective in assisting with defining the valid range to use.

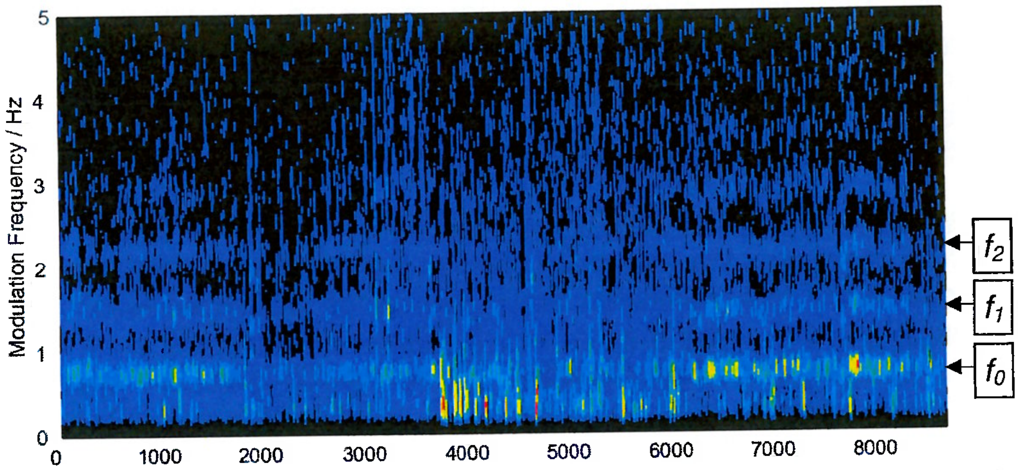

Figure 4.3.2 Typical waterfall plot (showing evolution of the modulation frequency (vertical axis) with time (horizontal axis, 10 s blocks) with a clear trend of modulation apparent at times just below 1 Hz – see the horizontal lines. The harmonics are also visible. Spurious non-modulating events tend to be represented by vertical lines.

[9] Waterfall plots are a representation of the magnitude of the power spectrum *S*, as defined in section 4.5, changing as a function of time. Trends appear more clearly if the square root of *S* is plotted as in the example of Figure 4.3.2.

4.4 Assessment time periods

4.4.1 The main aim in analysing data is to characterise the short-term fluctuations in the modulation, whilst relating these to standard longer time intervals used in the analysis of wind turbine noise. Sometimes this will be related to complaint investigations. It is also necessary to analyse data as a function of wind speed in 10-minute periods. It is necessary that the noise input data has an agreed format and length. The AMWG therefore considers that the analysis period should be separated into 'major' and 'minor' time intervals.

Minor time interval

4.4.2 The 100 millisecond samples should be separated into consecutive, non-overlapping 10-second blocks (the 'minor' time interval). There are 60 such minor time intervals in each major interval.

4.4.3 A 10-second block will only be considered valid if not excluded for the following reasons:

- The 'prominence' ratio is less than four (automatic processing) (see Section 4.6)
- There are no local maxima within the expected modulation frequency range in the power spectrum
- Manually excluded for other reasons (according to the practitioner).

Major time interval

4.4.4 The 'major' time interval for analysis is 10 minutes. It is proposed that a representative rating for AM is derived using the 90th percentile[10] of the distribution calculated within each 10 minute period. This value is only calculated over the distribution of valid 10 second samples, and only if the 10 minute period contains at least 50 % (*i.e.* 30) valid samples. The main test for a 10 second block being valid is whether there is a local peak within the expected modulation frequency range and whether this spectral peak is sufficiently prominent (see Section 4.6).

4.4.5 The criterion of requiring 50 % valid 10-second blocks (or 30 minor periods in a 10 minute period with sufficiently high prominence) has been found, on a range of sample data available to the AMWG, to be a very effective indicator to exclude spurious data where little continuous AM attributable to wind turbines could be detected – see, for example, Fig 4.4.1 below. In other words, this was, in the majority of cases, an objective indicator of the presence of sustained wind turbine AM with varying magnitude. This criterion was chosen to be conservative, to minimise the risk of false exclusion of valid data, and so it is possible that some samples, i.e. 10-minute major periods with more than 50 % valid 10-second blocks still represent erroneous data (or false positives). Conversely the 50 % criterion will exclude isolated periods of sporadic AM.

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[10] The highest 10% of the 10-second values analysed, which is the equivalent of the L_{10} for noise levels.

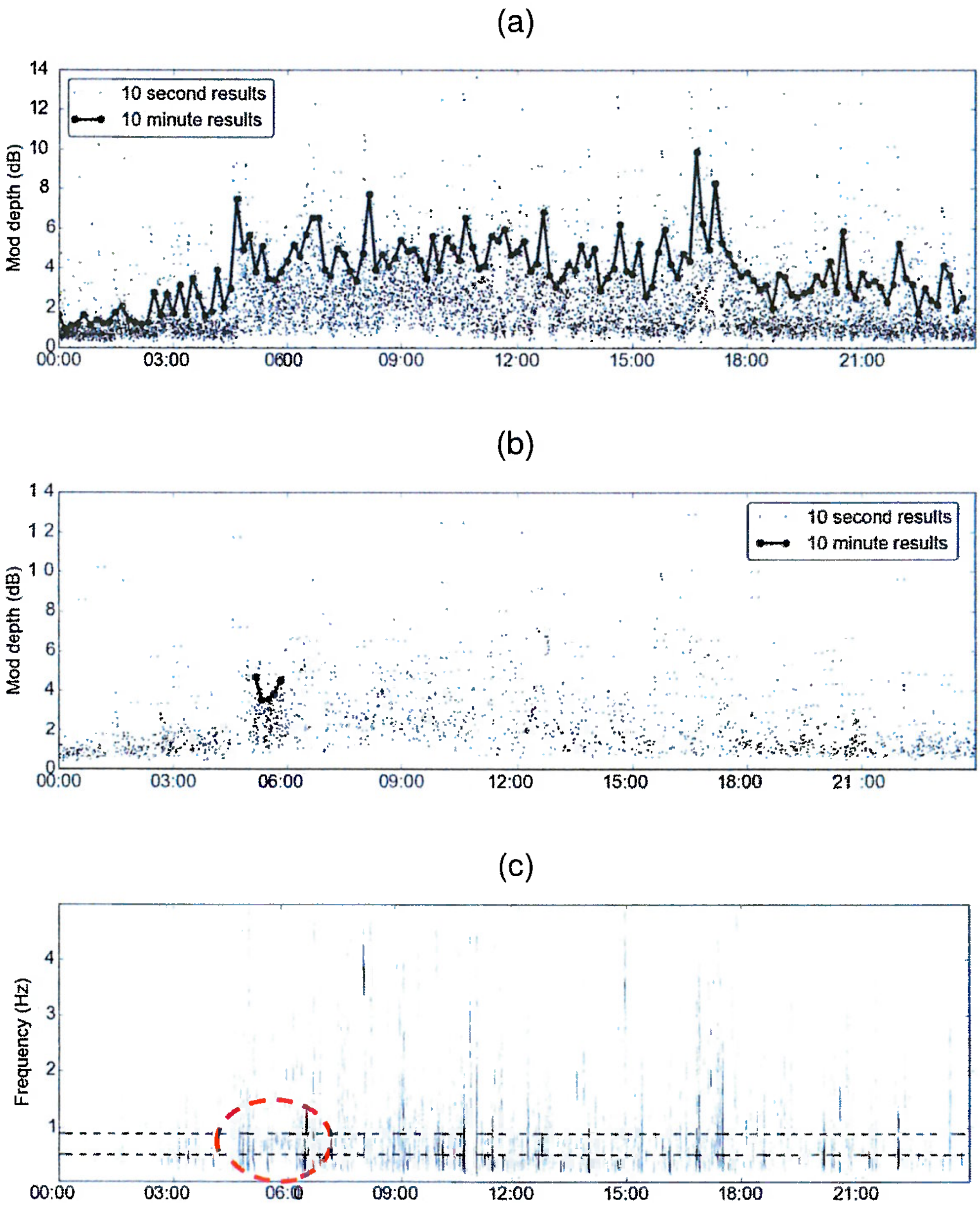

Fig. 4.4.1 Results of the analysis using the reference method over one day at a site with a relatively large amount of corruption from non-turbine sources (birds, trees etc.) The 10-minute results are shown both without (a) and with (b) the above criteria of sufficient valid data with high prominence, and no manual input. It was verified in this case that the only valid period in which 10-minute results are retained in (b) corresponds to the only period in which the turbines operated on that day. Panel (c) shows a waterfall plot, which shows that there is only a consistent trend of modulation apparent in the expected modulation frequency range (shown by dashed lines) for the valid period for which 10-minute results are obtained in panel (b).

4.4.6 As for any acoustic data analysis, the practitioner will retain the ultimate responsibility for selecting valid periods of data if there is any doubt as to their suitability. This can be done in practice by a combination of the following:

- **Review of 'waterfall' plots**: a graph of the calculated modulation spectrum over longer periods of time (at least one hour or 30 minutes) clearly shows trends of consistent AM over these periods, which are characteristic of wind turbine AM. This provides an objective indicator of AM occurring at a certain frequency. Conversely, periods with apparent 'modulation' occurring at all or wrong frequencies indicate spurious sources. For example in Fig 4.3.2 or 4.4.1 above, horizontal lines represent periods of clear turbine modulation at the rate indicated, whereas spurious periods are characterised by vertical lines.

- **Review of spectrogram plots:** a figure showing the acoustic frequency content of the raw noise data (e.g. third octave content on a 100ms basis) is helpful in identifying the main sources of noise and clarifying whether it is wind turbine related, although it may not be practical to undertake this for the entire measured period.

- **Reviewing operational data for the turbines**: this may show that turbines were, or were not operational, and whether they were operational at a rate consistent with the modulation frequency detected.

- **Listening to audio recordings if available:** this can assist in identifying/confirming the sources of noise analysed by listening to sample periods. It is considered useful in any case to form a subjective view of the character of the noise which is being evaluated; it should however be borne in mind that amplification of the audio signal, to make it audible, inherently changes its character and perception.

4.4.7 In the experience of the AMWG, the use of the prominence test and other processing to determine the AM rating in a 10-minute period in the reference method acts as a very effective pre-selection filter, meaning that the exclusion of spurious data is practicable even on large datasets, negating the need for a subjective review of the entire data set. There should be sufficient valid data remaining to undertake a meaningful analysis of the valid periods, particularly at night when spurious sources tend to decrease.

Discussion

4.4.8 AM, and indeed wind turbine noise in general, is variable. It is recognised that the choice of a 10 second block as the minor time interval may appear arbitrary, but on the basis of comparative analysis, the AMWG considers 10 seconds to be a representative minimum period for analysis. This describes approximately 10 cycles of AM at 1 Hz. It was observed on typical data that the 90th percentile value (of the 10 second values)[11], determined over a 10 minute period, provided a broad to good representation of the upper range of the individual peak-to-trough variability over the same 10-minute period (Levet, 2015).

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[11] As defined in statistics, i.e. 90% of the samples are at or below this value.

4.4.9 Comments from the discussion document suggested the use of a wider minor time interval (such as 30 seconds or one minute). This would increase the frequency resolution of the analysis and therefore the potential discrimination of wind-turbine related AM, but at the cost of further averaging of the variability observed. Investigations made by the AMWG using a minor interval of 30 seconds, but considering in further detail the variability observed in each interval showed that similar results could be obtained as with the method proposed. Therefore, it was considered that increasing the minor interval to 30 seconds offered no significant benefits.

4.4.10 The major time interval of 10 minutes is clearly desirable for any method to obtain an indicative AM rating for each such interval, using a data reduction method. This is because of the standard use of 10 minute periods to analyse wind turbine noise, for example in ETSU-R-97. Wind data and SCADA data from the wind turbine are also generally available in 10-minute periods, as is meteorological data. Furthermore, an AM rating applied to each 10 minute period can be used to collect statistics on the frequency of occurrence and, if appropriate, could be related to a penalty which could then be added to the measured noise levels to determine a rating level for comparison with planning conditions. Other penalty mechanisms and planning conditions could be formulated, but clearly, in the context of UK practice, it is useful to determine an AM metric in 10 minute intervals.

4.5 Signal analysis

Reference Method

4.5.1 Having discussed input data and assessment time periods, this section provides specific details of the signal processing required to calculate modulation depth (and frequency) for each 10-second block of 100 ms data. Before describing the details (which should be read with care), it is useful to describe an overview of the analysis of a 10-second block of data. This highlights the simple principle upon which the method is based. The analysis, which in essence is based on a time-series, comprises the following:

1. De-trending the time-series to reduce the influence of variations in noise levels below the modulation frequency
2. Using Fourier analysis to assess the power spectrum and remove energy not associated with fundamental (and harmonic) modulation frequency (which itself should be related to the wind turbine(s))
3. Performing an inverse Fourier transform to provide a 'clean' time-series containing energy only at the fundamental modulation frequency (and associated harmonics)
4. Calculating the modulation depth by subtracting the L_{95} from the L_5 of the reconstructed time-series.

4.5.2 The full procedure, detailing all specifics of the signal processing, is described below (and outlined in Figure 4.2.3):

1. The time-series is de-trended using a 3rd order polynomial 'best fit'.

2. The Discrete Fourier Transform (DFT) is calculated and both the real and imaginary parts of the output are retained. No window function should be used in the transform (*i.e.* rectangular window). Furthermore, no padding should be applied to the input; therefore the output will have a frequency resolution of 0.1 Hz. This also restricts the maximum modulation frequency that can be assessed to 5/3 or just below 1.7 Hz.

3. The power spectrum is calculated from the DFT output using the following equation:

$$S = \frac{|F\{x\}|^2}{n^2},$$

   - where $F\{x\}$ is the output of the DFT and n is the number of samples in the time-series (100 in this case).

   - Care should be taken to ensure correct handling of the indices referring to the positive and negative frequencies in the DFT output. Given that the input to the DFT is real, the indices corresponding to the negative frequencies may be excluded in the calculation of the power spectrum. This will result in a power spectrum with half the magnitude, however this is of no great consequence as only relative levels are considered in the analysis of the power spectrum. However, indices corresponding to the negative frequencies will be required later when performing the inverse Fourier transform.

4. The highest peak (local maximum) is identified within the user-defined allowable range of fundamental modulation frequencies (e.g. between 0.4 and 0.8 Hz, for example, see Figure 4.5.1). The frequency at which the peak is found is considered the fundamental frequency of modulation for the 10-second block. If there are no local maxima within the defined range, the 10-second block should be excluded from the wider analysis as it is considered that there is either no AM, or the block is corrupted.

5. The prominence of the peak at the fundamental frequency is calculated (following the procedure described in Section 4.6). If the prominence ratio is less than **4**, the 10-second block is excluded from the wider analysis as this indicates that AM at the BPF could not be readily identified.

6. For each harmonic (2nd and 3rd), determine whether or not to include the harmonic energy in the inverse Fourier transform using the following method:

   a) Estimate the harmonic frequencies by multiplying the fundamental frequency by 2 or 3 (for 2nd and 3rd harmonics respectively).

b) If the line at this frequency is not a local maximum in the power spectrum, check *N* lines either side for a local maximum (where *N* is one for 2nd harmonic and two for the 3rd harmonic). If no local maximum is found, do not include this harmonic in the inverse transform (Step 7). If more than one local maximum is found, the largest is chosen.

c) Assuming a local maximum is found for the harmonic frequency, two additional conditions must be met for the harmonic to be included in the inverse transform, namely:

i. The peak to peak amplitude[12] of the time-series generated by performing an inverse transform[13] with only the energy at the fundamental frequency must be greater than 1.5 dB.

ii. The peak to peak amplitude of the time-series generated by performing an inverse transform with only the energy at that specific harmonic must be greater than 1.5 dB.

d) If any of the aforementioned conditions are not met, the energy at that harmonic should not be included in the inverse transform.

7. The inverse Fourier transform is performed in the following manner:

a) An array of zeros is created, the same size as the output from the DFT.

b) Take the index of the fundamental frequency identified in the power spectrum, along with one index either side (totalling three lines), and insert the corresponding indices from the original DFT output (including real and imaginary components) into the corresponding indices of the newly created array of zeros. Repeat this for the indices of the corresponding negative frequencies.

c) Do the same for each harmonic identified for inclusion in the inverse transform (each time taking three lines centred on the harmonic frequency and also including the corresponding negative frequencies).

d) Perform an inverse Fourier transform on the newly created array, which should include components (from the original DFT output, complex numbers) only at the fundamental frequency and identified harmonics (three lines at each). The output of this transform should be real, without any imaginary part.

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[12] Defined here as the maximum of the entire 10-second time-series minus the minimum of the same.

[13] The inverse transform should be performed in a manner similar to that described in Point 7, i.e. with three lines – the line of the peak and one either side.

8. The output of the inverse Fourier transform will be a time-series resembling[14] the original time-series, but containing only energy relating to the identified frequencies.

9. The modulation depth for the 10-second block is calculated by subtracting the 5th percentile (L_{95}) of the reconstructed time-series from the 95th percentile (L_5) in the manner of Fukushima and Yamamoto (2013). This will tend to represent the highest typical modulation in the 10-second block.

4.5.3 Figures highlighting key parts of the method are shown below.

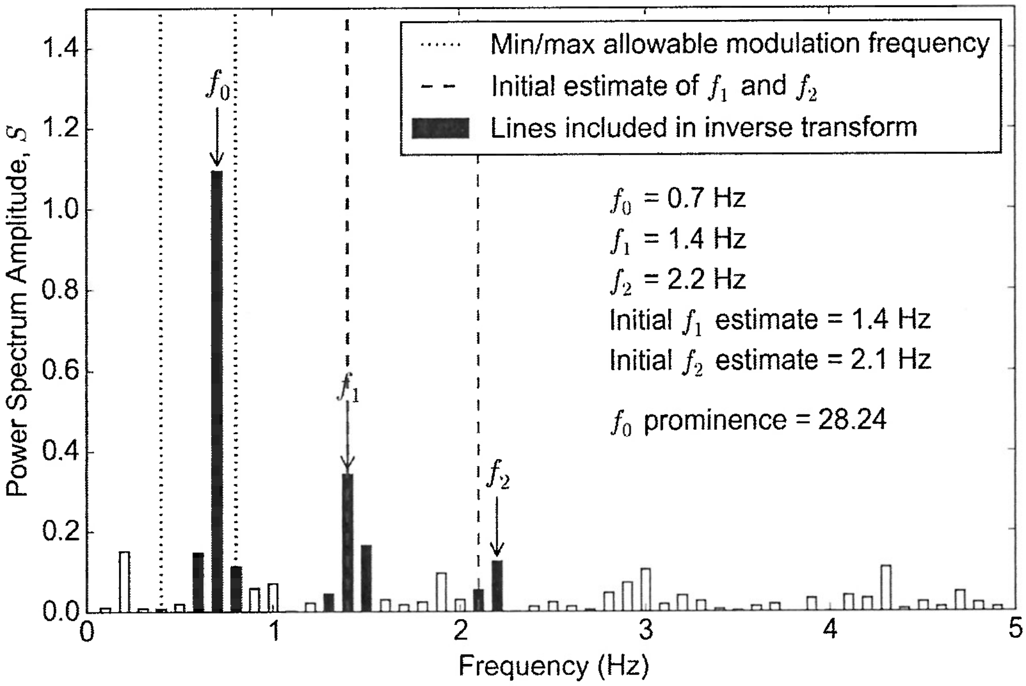

Figure 4.5.1: The power spectrum for a 10-second block. The fundamental frequency, f_0, has been identified within the range of allowable modulation frequencies (marked as dotted lines). Initial estimates of the frequencies of the second and third harmonics are shown as dashed green lines. The estimated frequency of the second harmonic, f_1, is a local maximum. The estimated frequency of the third harmonic is not a local maximum and the highest peak within two lines of the estimated frequency is identified as the true frequency of the third harmonic, f_2. Lines to be included in the inverse Fourier transform are marked (showing, in each case, the central line plus one line either side, i.e. three lines).

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[14] A useful verification check for any user implementing the procedure is to first include all lines in the spectrum and check that the result of the inverse Fourier transform is the same as the original (de-trended) time series.

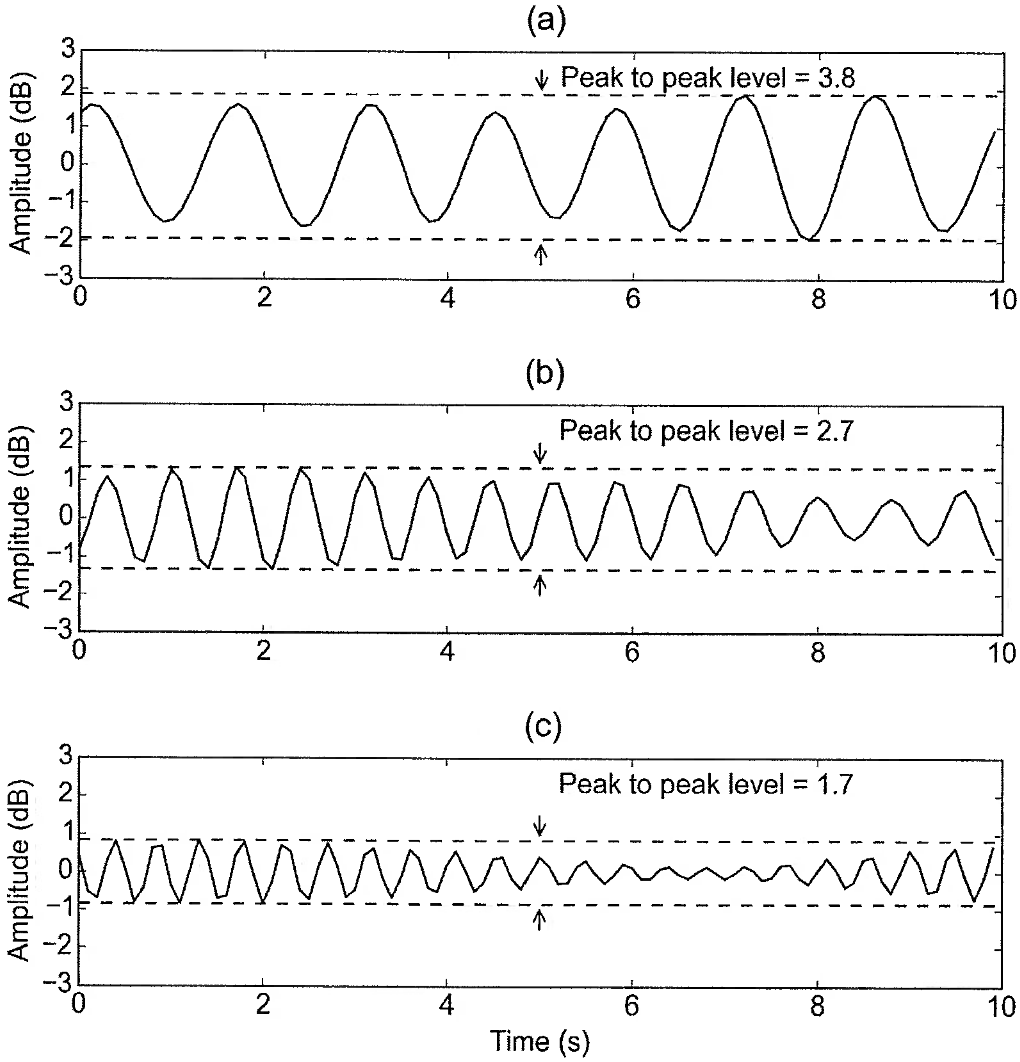


Figure 4.5.2: The inverse Fourier transform of energy at the fundamental frequency and the second and third harmonics, shown in panels (a), (b) and (c) respectively. The figure shows that the peak to peak levels for all harmonics exceeds the criterion specified in Step 6c(ii) of the method description and therefore energy at all harmonics should be included in the final inverse Fourier transform.

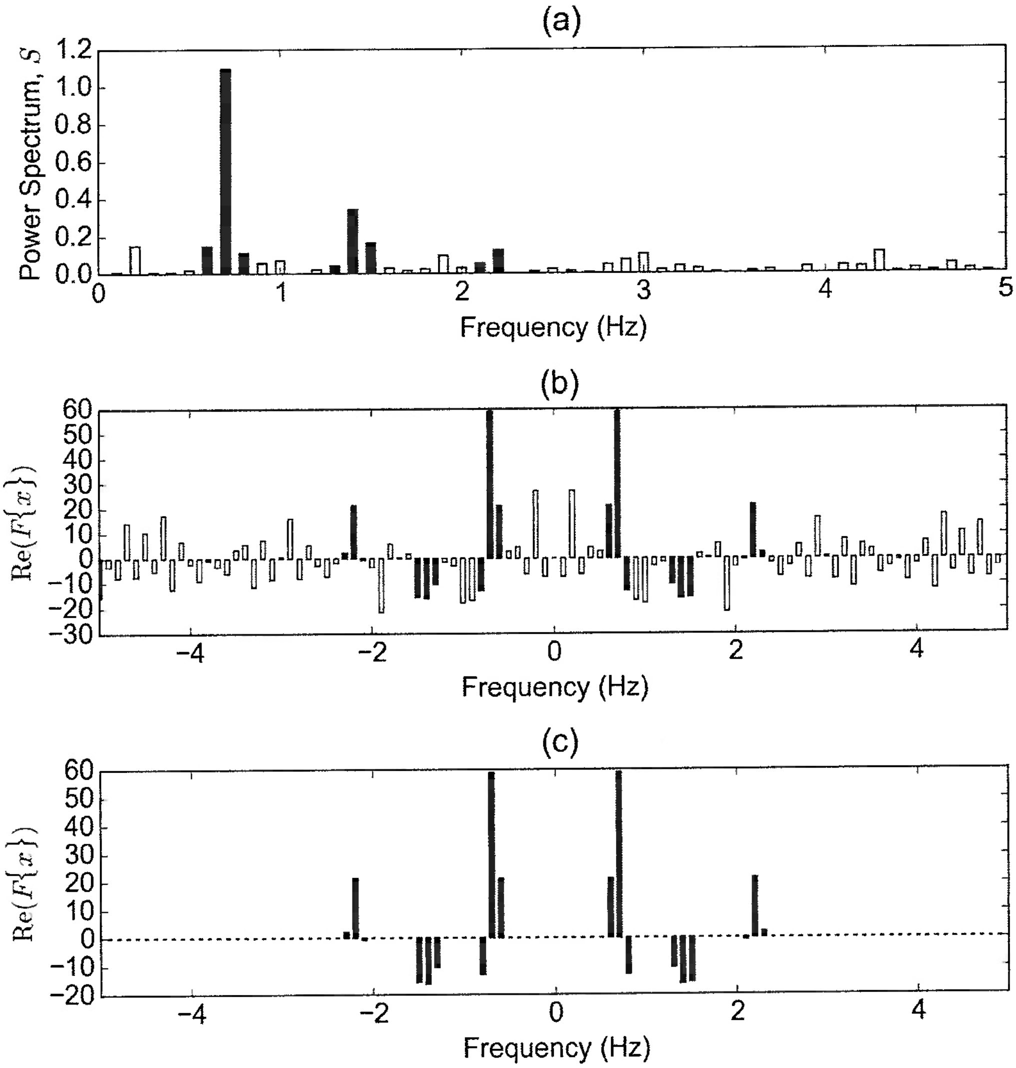


Figure 4.5.3: A clarification on indices to include in the inverse Fourier transform. Panel (a) shows the power spectrum and the identification of indices to include. Panel (b) shows the original output from the DFT (only the real part is shown here) with the identified indices shown as black lines. Note that the complex conjugates are also shown as black lines (the negative frequency components). Panel (c) shows the array with the identified indices included, and zeros at all other values. The inverse Fourier transform is performed on this array.

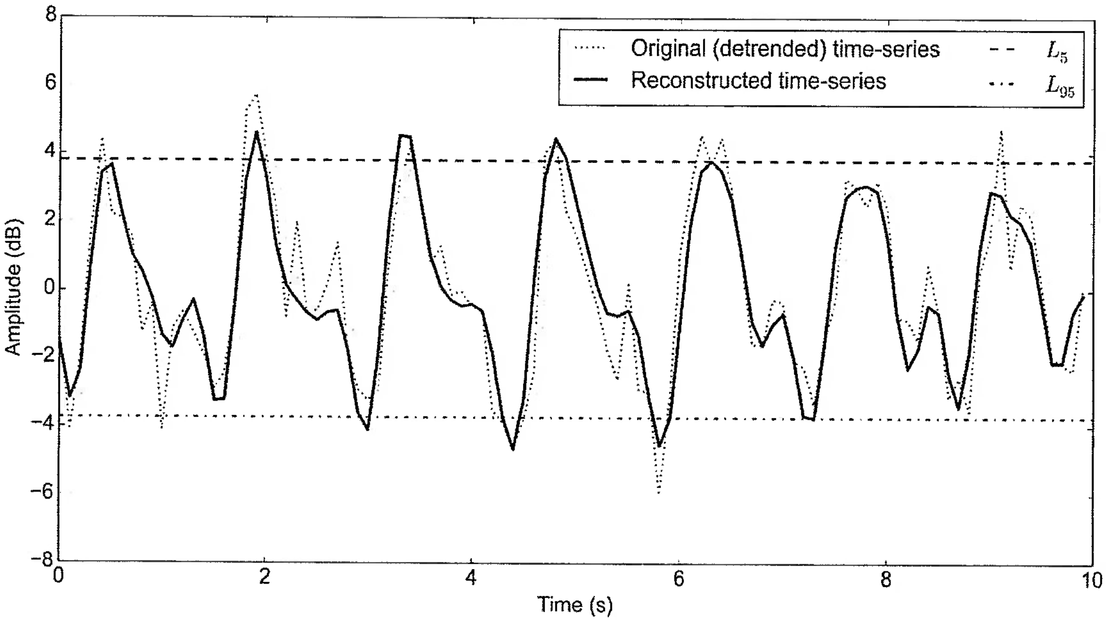


Figure 4.5.4: The original time-series (detrended with a 3rd order polynomial) and the reconstructed time-series. The modulation depth is calculated by subtracting the L_{95} from the L_5.

Possible output – individual peaks and troughs

4.5.4 A reconstituted time series is generated as part of the reference method. This could be used as the basis for identifying individual peaks and troughs. The reconstructed fundamental signal can provide a guide for locating the peaks and troughs using a search window equal to half of the fundamental period.

4.5.5 Note that this is not part of the proposed Reference Method, but this level of detail is achievable if deemed beneficial to the analysis. It is however more difficult to ensure, for an individual 10 second period, that all peaks relate to wind turbine AM, as the longer-term 10 minute analysis described above is more robust in this respect. It was also determined, following investigations by the AMWG, that despite the additional complexity introduced, the additional information acquired did not have significant benefits compared with the L_5 – L_{95} approach of the Reference Method.

4.6 Prominence noise exclusions

4.6.1 The method described in Section 4.5 provides a reasonable level of noise suppression, i.e. the reported level of modulation is low when there is no wind turbine AM present in the signal. However, extraneous noise can often incorrectly manifest as high levels of AM. It is possible to greatly reduce the number of false positives by assessing the prominence of the peaks in the power spectrum. This exploits the fact that genuine wind turbine AM produces very pronounced peaks in the power spectrum of the modulation envelope. Excluding samples with indistinct peaks greatly reduces the number of false positives whilst introducing a negligible number of false negatives.

4.6.2 The proposed method for assessing the prominence of the fundamental is described below:

1. The magnitude of the fundamental peak, L_{pk}, is taken as the amplitude of a single line in the power spectrum at the frequency of the peak.
2. The two lines either side of the peak are ignored.
3. The masking level, L_m, is taken as the linear average of two lines each side of the peak (beyond those lines immediately adjacent to the peak).
4. The prominence, p, of the peak is calculated using:

$$p = \frac{L_{pk}}{L_m}$$

4.6.3 An example clarifying the classification of masking lines in the power spectrum is shown below. The lines adjacent to the peak are ignored. The masking lines are the two lines beyond the adjacent lines either side of the peak.

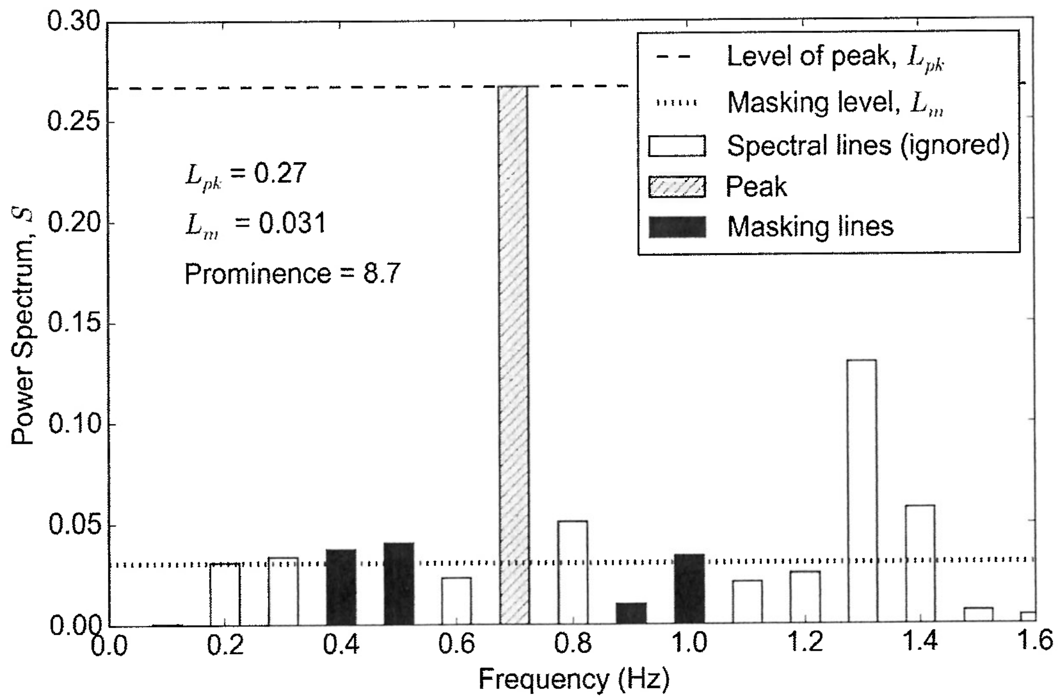
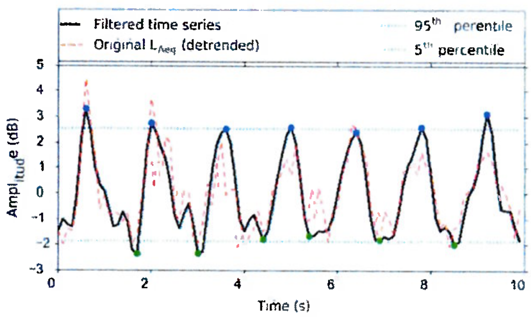


Figure 4.6.1: An example calculation of the peak prominence

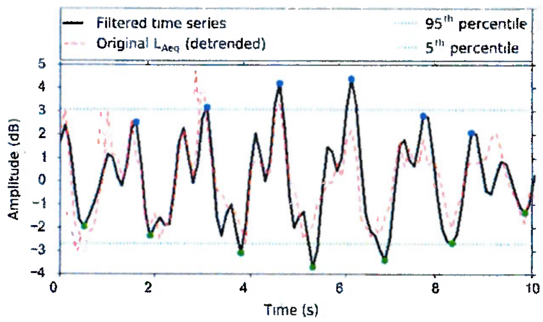
4.7 Discussion

4.7.1 The examples of Figure 4.7.1 below show that a complex modulating time-series can be accurately reconstructed using the first three harmonics. A balance has to be made when deciding how many harmonics to include – using too many will increase the noise floor while including too few will result in missing the true amplitudes of the peaks and troughs when harmonic energy is present. The use of the first three harmonics has been found to provide a good representation of the original time-series in the large majority of cases, whilst maintaining a reasonably low noise floor.

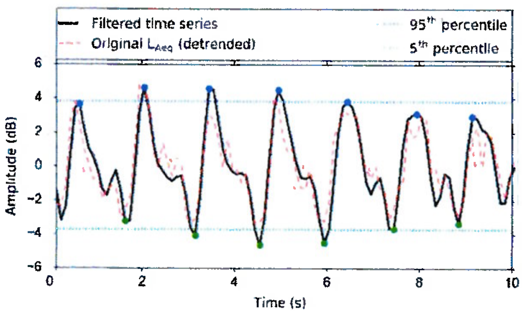
4.7.2 Notwithstanding the above, it can be seen in some of these examples that short small peaks (and less often troughs) are occasionally not fully represented in the reconstructed series. This could be a consequence of the spectral windowing undertaken, which means these very short variations cannot be represented. The peak could also be extraneous noise in a frequency band outside that of the bands considered, in which case it would be right to reject it. Despite these occasional discrepancies, the average peak-to-trough level is well represented by the reconstruction method in most cases. There is also limited evidence that turbine-related short impulses occur outside of periods of sustained modulation, which would be in any case adequately detected and rated by the proposed method.



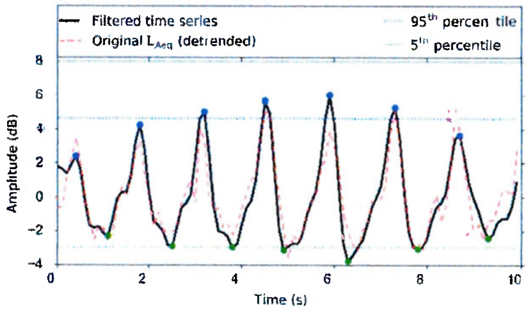
a)



b)



c)



d)

Figure 4.7.1 Examples (a to d) of 10-second blocks of AM time-series reconstructed using the reference method compared with the (unfiltered) $L_{Aeq,\,100ms}$ signal

4.7.3 Figure 4.7.2 below provides an example of a six hour period of persistent and mainly clear AM analysed using the Reference Method. The chart shows both the individual 10-second results (grey dots) and the 10-minute derived values (black line) when valid, using the prominence test. The second half of the chart shows a waterfall plot of the modulation frequency changing with time. Dotted lines represent the valid range of modulation frequency used; as the modulation remains within these bounds, the method continues to work well despite the relatively variable modulation frequency associated with changes in the turbine rotational speed. It can be seen that the AM ratings obtained vary in accordance with the magnitude apparent in the waterfall plot and the valid 10-minute values obtained are consistently typical of the highest 10-second results. Furthermore, a period corrupted by bird song from just after 5am (visible as vertical bars on the waterfall plot) was excluded using the prominence criterion, with the exception of one 10-minute sample (with a similar rating obtained as for the previous valid period).

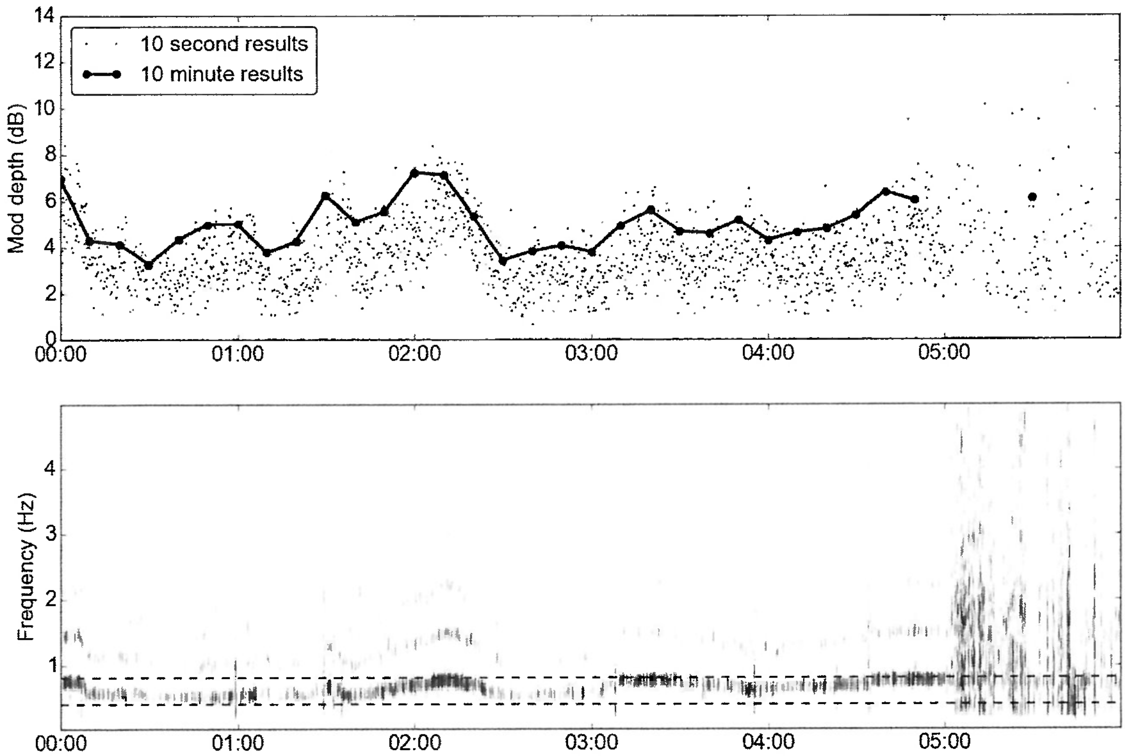


Figure 4.7.2 – Example of AM analysis results for a six-hour period

4.7.4 In the development of the methodology, it was necessary to reach a number of decisions on the most appropriate form of the input data and analysis parameters. Those finally agreed are set out below with the associated rationale for their adoption:

Input data:

- A sample rate of 0.1 Hz (100 ms data) – this is a pragmatic choice which is short enough to resolve the variation in sound pressure level resulting from AM but long enough to avoid the capture of unnecessarily high resolution data. Also it is the shortest period commonly available on many modern sound level meters. This means that for high modulation rates of 1.6 Hz or more, it may not be possible to resolve the signal or its harmonics.

- Recording in 1/3-octave bands from at least 50 to 800 Hz – this range is a pragmatic choice based on the collective experience of the authors and captures the range of frequencies within which audible AM is expected to occur. It is also a range which is possible to capture with many modern SLMs without considerable measurement challenges.

- Use of L_{eq} 100 ms data (rather than L_{max} or L_f[15]) – this allows the 1/3-octave band levels to be easily combined and reduces noise corruption. The use of $L_{Aeq,\ 100ms}$ rather than $L_{pAF,\ 100ms}$ in 1/3-octave frequency bands also results in a peakier signal and is therefore more conservative.

- The use of A-weighting – this gives consideration to the response of the human ear and hence the human response to AM, is consistent with ETSU-R-97 and reduces wind noise influence. Comparative testing indicated more robust results with the A-weighting applied.

- Measurements made according to the IOA GPG recommendations – this underpins the measurement methodology i.e. where to measure, when not to measure, wind speeds etc.

Analysis parameters:

- A major time interval of 10 minutes – this choice is consistent with the typical averaging times used for meteorological and SCADA data and so allows a straightforward correlation between the two;

- A minor time interval of 10 seconds – this is a pragmatic choice which is short enough that the evolution in level of AM over a 10 minute period can be captured but long enough to capture periodicity and for a meaningful AM level to be uniquely determined;

- Use of $L_5 - L_{95}$ over 10 seconds: this will weigh the result towards the higher peaks in the 10-second block without being too sensitive to extremes (which increase noise), whilst also providing a simple approach;

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[15] *i.e.* time-weighted sound pressure level data.

- Use of the 90th percentile of 10-second ratings distribution – this was a pragmatic choice, considered to represent the typical worst-case instances of AM within a 10-minute interval, based on the observed variability of AM in the field, without being excessively sensitive to possibly spurious extreme values (which increase noise);

- The requirement for a minimum of 30, 10-second values of AM per 10 min before a valid AM result can be determined – this is a pragmatic choice which accepts that there may be some data loss due to external noise sources, whilst still allowing a meaningful rating to be determined from partial data. It was found to be very effective in practice on a range of data;

- Use of a prominence ratio of ≥ 4 for accepting/rejecting a 10-second block; this corresponds to a peak which is 6 dB (10log(4)) above the spectral noise floor. This value is a pragmatic (and conservative) choice, based on data analysis for the available sites, which is considered to represent a balance between rejecting extraneous samples and retaining samples featuring AM;

- Use of DFT analysis as a key element of the methodology – this allows the identification of patterns of noise occurring at the BPF (modulation frequency) and harmonics;

- Use of a frequency resolution of 0.1 Hz in the FFT – this is the maximum resolution possible from 10 seconds of 100 ms data without padding the data;

- Use of an amplitude level of 1.5 dB as a threshold for the fundamental and harmonics. Excluding energy which is not associated with wind turbine noise is beneficial in reducing the noise floor of the metric, but obviously must not exclude wind turbine AM. A value of 1.5 dB was determined as a threshold based on the typical peak-to-peak variations in the background / extraneous noise on the sample data available. Variations in background noise are often greater than 1.5 dB but this was chosen as a conservative threshold to minimise false negatives;

- Use of the first three harmonics of AM to capture and reconstruct the time series – this is a pragmatic choice, based on the experimental observation that, for the majority of data samples most of the modulation energy is associated with the first three harmonics. Higher harmonics were poorly resolved and their use increased noise;

- Use of a rectangular windowing function within the DFT process (i.e. no window) – this allows the average level of AM over the entire period to be determined.

4.8 Indicative Method (After 'Tachibana' et. al.)

4.8.1 It is accepted that some people may want to measure wind farm noise on an ad-hoc basis, perhaps with attended measurements with a sound level meter. The method devised by a group of Japanese researchers led by Pr. Tachibana (Fukushima, Yamamoto et al, 2013) would be suitable in this context although, it is subject to corruption by extraneous noise and therefore is only suitable where there is clean data and the values obtained are not directly comparable with the reference method. It is therefore not suitable for use in planning conditions, but can be used to describe short uncorrupted samples of amplitude modulation. Note that the method requires the sound level meter to measure the fast and slow time-weighted sound pressure level simultaneously. Not all sound level meters can do this; an estimation method is therefore provided as an alternative. A brief description of the method is provided here.

4.8.2 The A-weighted short-term sound pressure level values with fast and slow time weightings are measured. Data should be measured as the sound pressure level, $L_{p(A)}$ fast and slow in 100 millisecond samples. The time varying difference in the two parameters is calculated.

$$\Delta L_A(t) = L_{A,F}(t) - L_{A,S}(t)$$

Where:

$\Delta L_A(t)$ is the difference in A-weighted sound pressure levels, between the two time weightings

$L_{A,F}(t)$ is the A-weighted sound pressure level, with Fast time weighting (i.e. time constant = 125 ms)

$L_{A,S}(t)$ is the A-weighted sound pressure level, with Slow time weighting (i.e. time constant = 1 s)

4.8.3 The above subtraction step is analogous to the de-trending step in the reference method. See Figure 4.8.1 below.

4.8.4 The Japanese researchers chose a 3-minute period for their analyses. However, the longer the sample, the greater the risk of corruption from extraneous noise. In fact, it can be used on shorter samples including 10-second periods as shown in Figure 4.8.1. Note however that some form of averaging or other processing of the individual samples must be used to obtain a representative value. For example, the 90th percentile could be used to calculate a 10-minute value providing that all samples are uncorrupted.

4.8.5 The slow weighted time response can either be measured directly by the sound level meter (if possible) or derived by post-processing audio files (if available), or calculated using the following equation from Section 6.1 of the Nordtest 112 standard (2002):

$$L_{AS}(t) = 10 \cdot \log\left[\frac{\left(\left(\frac{\tau}{\Delta t} - 1\right) \cdot 10^{\frac{L_{AS,t-1}}{10}} + 10^{\frac{L_{Af,t}}{10}}\right)}{\left(\frac{\tau}{\Delta t}\right)}\right]$$

4.8.6 In this case, the first ~3 seconds of data may need to be excluded from the final analysis, as the approximated measure will need a certain amount of data before it is correctly representative of the general level of the previous 1 second.

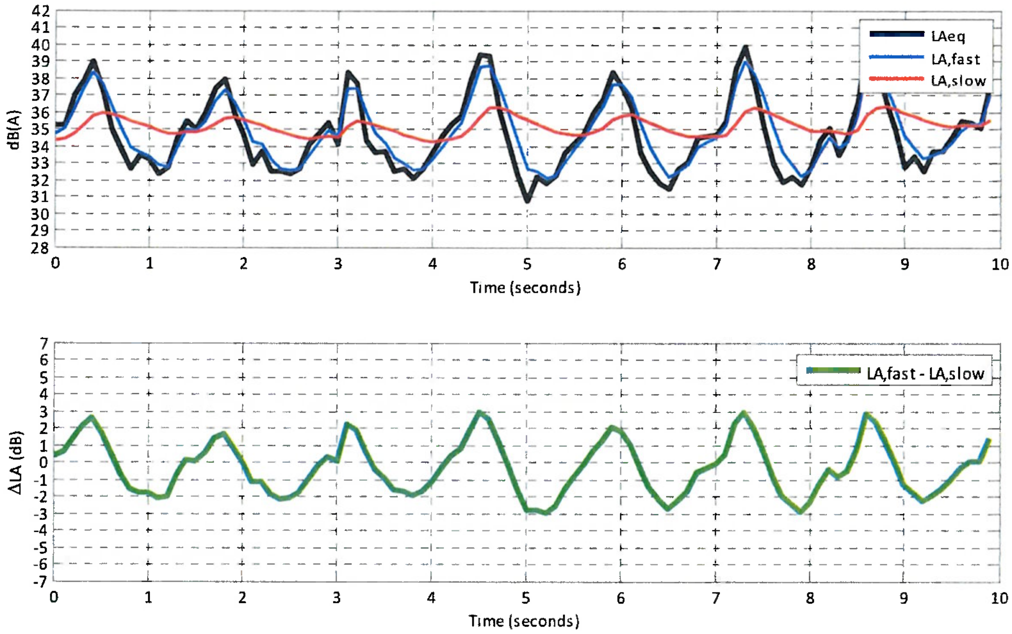

Figure 4.8.1 Derivation of ΔL$_A$(t)

4.8.7 The magnitude of modulation is then examined on a statistical basis, where a cumulative distribution is calculated on the $\Delta L_A(t)$ values within the sample. On the cumulative distribution of $\Delta L_A(t)$ values, the modulation depth parameter D_{AM}, is defined from the 90% range.

$$D_{AM} = \Delta L_{A,5} - \Delta L_{A,95}$$

Where:

D_{AM} is the depth of modulation (dB)

$\Delta L_{A,5}$ is the 5% point on the cumulative distribution of $\Delta L_A(t)$, within the period

$\Delta L_{A,95}$ is the 95% point on the cumulative distribution of $\Delta L_A(t)$, within the period

4.8.8 Figure 4.8.2 shows an example cumulative distribution of the period shown in Figure 4.8.1, and the derivation of the D_{AM} value.

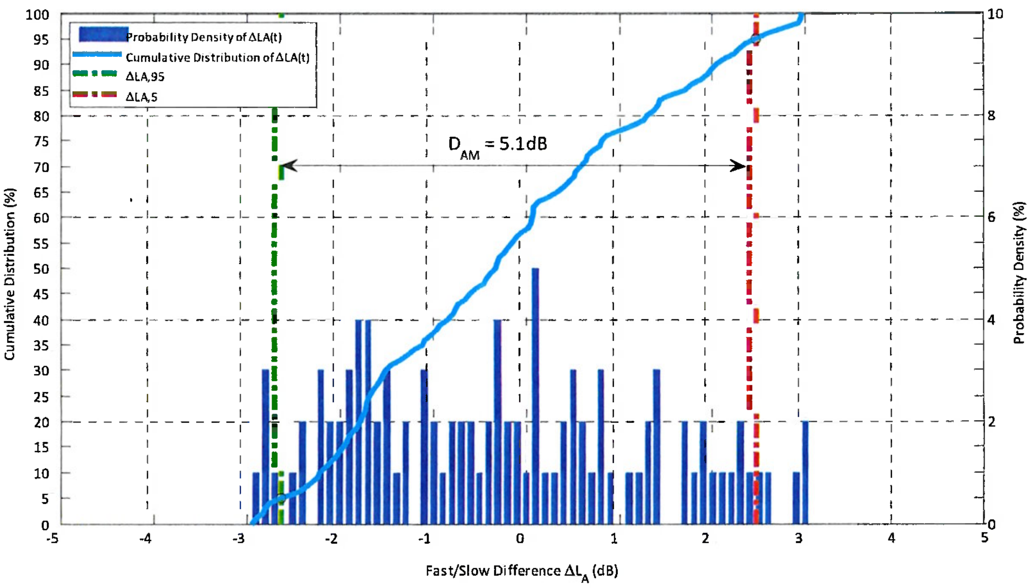

Figure 4.8.2 Cumulative distribution of $\Delta L_A(t)$ and derivation of DAM

Limitations of the Indicative Method

4.8.9 The indicative method for measuring AM is based only on analysis of the differences between two statistical measures of an A-weighted time-varying noise. It does not specifically provide a measure of modulation occurring at the blade passing frequency (or frequencies) of the wind turbines concerned. Rather, it provides a measure of variation, at whatever modulation frequency is occurring. With 'clean' signals that are dominated by wind farm noise, the method will be a reasonable measure of modulation at blade passage frequencies. However, as the method is based upon short-term A-weighted sound pressure levels, there is a high probability that some periods will be contaminated by extraneous noise sources. Steps can be taken to reduce that probability, e.g. by focussing on night-time or evening periods, when the level of other ambient noise is generally at its lowest. However, the influence of spurious noise sources is unavoidable if long-term monitoring is carried out. Consequently, there is a need for rigorous visual and/or aural examination of the data to ensure that the resulting modulation depth values are related to the actual wind turbine noise under assessment.

4.8.10 The auto-correlation function of the $\Delta L_A(t)$ values proposed by the Japanese researchers is also a useful tool in identifying periods that are not related to wind farm modulation. If the resulting modulation frequency is significantly different to the expected wind farm blade passage frequencies, then that period can be excluded from the overall analysis. However the converse is not always true, in that a modulation frequency indicated by the auto-correlation function that is similar to the expected blade passage frequency may not always be due to wind farm noise. There may be other noise sources in the environment such as bird song that give rise to similar modulation frequencies.

4.8.11 For instances of significant variation in underlying overall level, a sound pressure level with slow time weighting may not always fairly represent the mid-point between the 'peaks' and 'troughs' i.e. at times, the slow time-weighted sound pressure level may not react quickly enough to reflect the drift in underlying level. This results in a relatively large D_{AM} value, as the cumulative distribution of the $\Delta L_A(t)$ values picks up several instances of large differences between the two channels, partly due to the slow channel not reflecting the large drift. This effect is mostly seen when extraneous noise sources corrupt the measurements. When this effect occurs with wind farm noise, the D_{AM} parameter may revert from a measure of modulation to a measure of a variation. This is why this method is only suitable for the rapid evaluation of short samples.

4.8.12 Extracting the 90% range from the cumulative distribution function means the resulting D_{AM} value tends towards the two extremes of the time series. Taking the 95th percentile point, essentially finds one of the largest positive differences in the two channels, i.e. one of the largest 'peaks'. Taking the 5th percentile point essentially finds one of the largest negative differences in the two channels, i.e. one of the largest 'troughs'. Therefore if there is significant intermittency in modulation within the analysis subsection, the method tends to be representative of the larger modulation depths.

4.8.13 The Indicative Method must be used with caution and is to be considered as secondary to the reference method and in no circumstances as a substitute for it when the level of AM is being assessed against a specific criterion or limit (such as might be specified in a planning condition).

5 INSTRUMENTATION

5.1 General requirements

5.1.1 In principle, the instrumentation requirements are little different to those specified in the existing IOA Good Practice Guide and Supplementary Guidance Note 1: Data Collection (IOA 2013) (IOA 2014). However, the main requirements will be re-iterated here, along with specific considerations relating to amplitude modulation only.

5.1.2 In order that the AM measurements are resistant to the effects of wind turbulence, the existing guidance regarding windshields is recommended.

5.1.3 Similarly, any correction required for microphone orientation should be used. For example, if a free field microphone is used at grazing incidence (i.e. mounted vertically) with an outdoor enclosure (e.g. rain cover, birdspikes, windshield, etc.), the response should be corrected back to free field.

5.1.4 However, these corrections may not be significant in the frequency range proposed for AM metrics.

5.1.5 The main difference with normal wind turbine noise measurements is the requirement to log data at sufficient resolution in order to capture the variations in levels associated with AM. A resolution of 100 milliseconds is required rather than the 10-minute averaging used in ETSU-R-97. Furthermore 1/3-octave band measurements are required.

5.2 Noise measuring equipment

5.2.1 As the focus of this document is metrics for AM, it is outside the scope to specify a mandatory length of time for AM surveys; it is likely, in any case, that this will be defined elsewhere in separate guidance.

5.2.2 Having said that, as a general principle, it is likely that the best description of AM will be obtained if data is collected over as broad a range of conditions as are typical for the site in question, or related to specific conditions highlighted for example as part of complaints. This may involve specification of the range of wind speeds, directions, times of day, atmospheric stabilities etc.

5.2.3 Noise measuring equipment for AM can be divided into three types:

1) Equipment which can measure amplitude modulation directly

2) Equipment which can measure and log sound levels, from which amplitude modulation may be subsequently derived by post-processing

3) Equipment which simply records the audio signal, for subsequent post-processing.

5.3 On-line AM measurement

5.3.1 Although no such equipment is currently available, there may be sufficient demand to may make it worthwhile for a manufacturer to develop an instrument which calculates and logs an AM-related parameter.

5.3.2 In such a case, the instrument shall meet the relevant performance requirements of the second type, although it may not be necessary to display or store all the same measurement parameters.

5.4 Sound level logging equipment

5.4.1 To ensure a common, or at least a minimum level of fidelity, the minimum requirements for the sound level meters are those specified in the IOA's Good Practice Guide. This includes the specification of the wind shield and, in general, the same equipment used for noise compliance measurements can be used to capture suitable data for AM analysis (IOA 2013) (IOA 2014).

5.4.2 Instruments for storing sound level with time shall meet the requirements of BS EN 61672-1: 2013 to Class 1 accuracy.

5.4.3 Older equipment may also be used which is designed to BS EN 60651: 1994 and BS EN 60804 : 2001 to Type 1 accuracy.

5.4.4 The 1/3-octave filters shall meet the requirements of BS EN 61260-1: 2014 to Class 1 accuracy.

5.4.5 The instrument shall be capable of measuring and storing the $L_{Aeq,\ 100ms}$, and optionally the L_{pAF} and L_{pAS} simultaneously with the same time resolution.

5.4.6 The instrument shall be able to measure and store the $L_{eq,100ms}$ 1/3-octave spectra at least over the range 50 Hz to 800 Hz.

5.4.7 In order to minimise the influence of instrument noise on AM depth, the lower limit of the instrument linearity range shall be no higher than 25 dB(A).

5.5 Audio recording equipment

5.5.1 Audio recordings, if necessary, shall preferably be done by using one of the instruments above, thus ensuring a minimum level of accuracy.

5.5.2 Recordings should be made with a bit depth of 24 bit, although 16 bit recordings may be made, as long as care is taken to optimise the dynamic range due to instrument noise, and high level fluctuations due to wind turbulence.

5.5.3 Recordings shall be uncompressed, with a minimum sample rate of 12 kHz.

5.5.4 'Lossy' audio compression such as MP3 is not acceptable for post-processing purposes. Lossless compression such as to ALAC or FLAC formats may be used. However, if the only purpose of the audio is to play back audio to subjectively identify samples with wind turbine AM, as opposed to other noises, then compression to minimise data storage would be acceptable.

5.5.5 The recording front end (including the microphone/preamplifier/windshield), if not one of the instruments above, shall meet the requirements of the relevant parts of BS EN 61672-1 Class 1 (or BS EN 60651 Type 1), including frequency response, linearity and dynamic range. The onus is on the user to verify these requirements are met.

5.5.6 If available, calibration information shall be readable from the file header, otherwise, a calibration signal shall be recorded using the same settings as those for the measurement. This subsequently allows the recording to be scaled correctly for sound levels.

5.5.7 Alternatively, where it is possible to record audio for the entire period of interest, it is also possible to calculate the band-limited 100-millisecond L_{Aeq} values from the audio data using suitable software, the performance of which can be suitably verified (see 5.4.1 to 5.4.4). In this event, high quality recordings are required and careful consideration should be given to obtaining calibration recordings so that all data can be converted into absolute units.

6 MEASUREMENT PROCEDURE

6.1.1 Measurements of the noise data required to fulfil the requirements of this methodology, as defined in Section 4, should be made in accordance with the requirements of the IOA's Good Practice Guide to the Assessment and Rating of Wind Turbine Noise (IOA NWG, 2013).

6.1.2 The length of survey required in order to obtain sufficient data for a comprehensive description of the variation in AM with external factors, for example wind speed, direction, time of day etc. will depend on both the climatology of the site and the underlying reason for which measurements have been made. This may be related to complaint investigations or may simply be used to demonstrate compliance with pre-agreed limits on acceptable levels of AM.

6.1.3 Attention is drawn to the fact that, as for any measurement, critically reviewing the data and analysis, through for example listening to audio recordings, remains a fundamental part of the analysis methodology. The automated process described here will enable the elimination of a portion of the measured data which does not contain sustained wind turbine derived AM, identifying those periods which do, to enable the analyst to focus their listening efforts on the key samples of audio data.

7 EVALUATION OF METHOD AGAINST ADOPTED SUCCESS CRITERIA

7.1.1 The following presents an assessment of the reference method against the success criteria adopted by the AMWG, as set out in Appendix B.

7.1.2 **Achievability**: The proposed reference method has already been implemented and trialled by different members of the AMWG, using input data measured by different modern sound level meters, and consistent results have been obtained. The provision of software code will assist other practitioners in readily applying the method.

7.1.3 **Reality**: The method was extensively trialled on real wind turbine noise data measured at a variety of sites exhibiting varying levels of AM, including data with significant contributions from other noise sources ('corruption') and data with no AM evident. The results from this method produce a value of AM when wind turbine AM is present and a low or no value when AM is absent.

7.1.4 **Robustness**: This method is relatively robust; in particular, the proposed prominence criterion works very effectively in minimising the influence of non-turbine sources and the requirement for 30 valid results in a 10-minute period further identifies persistent AM. The thresholds used were set conservatively to also minimise the risk of 'false negatives' (i.e. failure to detect AM when it is present). Whilst false positives (i.e. generating a value for AM when no AM is present) cannot be fully eliminated, this is the case for any numerical method. The selected approach was the most robust of all the methods evaluated by the AMWG.

7.1.5 **Location**: As described in Appendix C, it is proposed that this method applies to free-field external measurements as is standard practice for wind farm noise measurements.

7.1.6 **Objectivity**: The proposed method applies a metric to provide a numerical value which characterises the peak-to-trough variations in that component of measured overall noise that can be attributed to a wind turbine or turbines.

7.1.7 **Repeatability and reproducibility**: The AMWG undertook an internal 'round robin' test which demonstrated that different members independently were able to implement and test the method and obtain effectively identical values of the AM metric across a range of test data. The production of software code will enable other practitioners to achieve consistent and repeatable results.

7.1.8 **Specificity**: The method includes the application of frequency-band-limiting to the input data, selection of relevant modulation frequencies and use of a 'prominence test' to help to discriminate between wind turbine noise and other noise sources. The Reference Method and resulting metric are specific to the detection and rating of AM in wind turbine noise.

7.1.9 **Automation**: The method has been proven to rapidly process large amounts of data, which is essential for this application because AM, if it occurs, is generally only evident in some conditions and may occur very infrequently. There is a recognised need for a practitioner to review the analysis to reduce the risk of 'false positive' results, but the need for subjective examination of data is much reduced, compared with other methods, by the incorporation of objective indicators and tests to allow spurious data to be identified and rejected.

7.1.10 **Relativity**: The method assigns a specific value, in dB, to the level of AM within a sample of wind turbine noise. The range of values generated provides discrimination of different levels of AM and an effective dynamic range, and can be related to the results of studies of the subjective response to noise exhibiting amplitude modulation.

7.1.11 It can be seen from the example of Figure 4.7.2 above that the Reference Method determines an AM rating which varies in accordance with the visual waterfall plot and consistently picks out values which are typical of the highest 10-second periods. This therefore meets the above requirements for objectivity and relativity. Furthermore, a period corresponding to bird song is excluded, apart from one 10-minute sample, thus demonstrating specificity, and the suitability of the Reference Method for automation.

8 APPLICATION OF THE REFERENCE METHOD TO TEST STUDY STIMULI

8.1 Background

8.1.1 The AMWG obtained the synthesised test samples (as .wav files) used in the subjective studies undertaken both by Salford University for the RenewableUK project and the large Japanese research team (Tachibana *et. al.*). The results have been processed using the Reference Method to determine the AM rating. These could be used to translate the results of subject studies with the AM rated with the Reference Method. Such studies are outside the scope of the AMWG but are provided for information. As the files were of synthesised constant AM with no temporal variation, the analysis has been based on the 10-second methodology only. The results are shown below.

8.2 RenewableUK Salford Stimuli

8.2.1 The stimuli used by Salford University in Work Package B2 (WPB2) of the RenewableUK research were classified in terms of modulation depth and overall L_{Aeq} levels. To obtain the results with the Reference Method, the audio samples were A-weighted and band-pass filtered in the time domain. The results are shown in Figure 8.2.1 below for the 30, 35 and 40 dB(A) samples in the three frequency ranges.

8.2.2 The AM ratings obtained with the Reference Method generally produced higher results than the Salford design modulation depth. For these samples, the 50 – 200 Hz frequency range produces the greatest AM ratings.

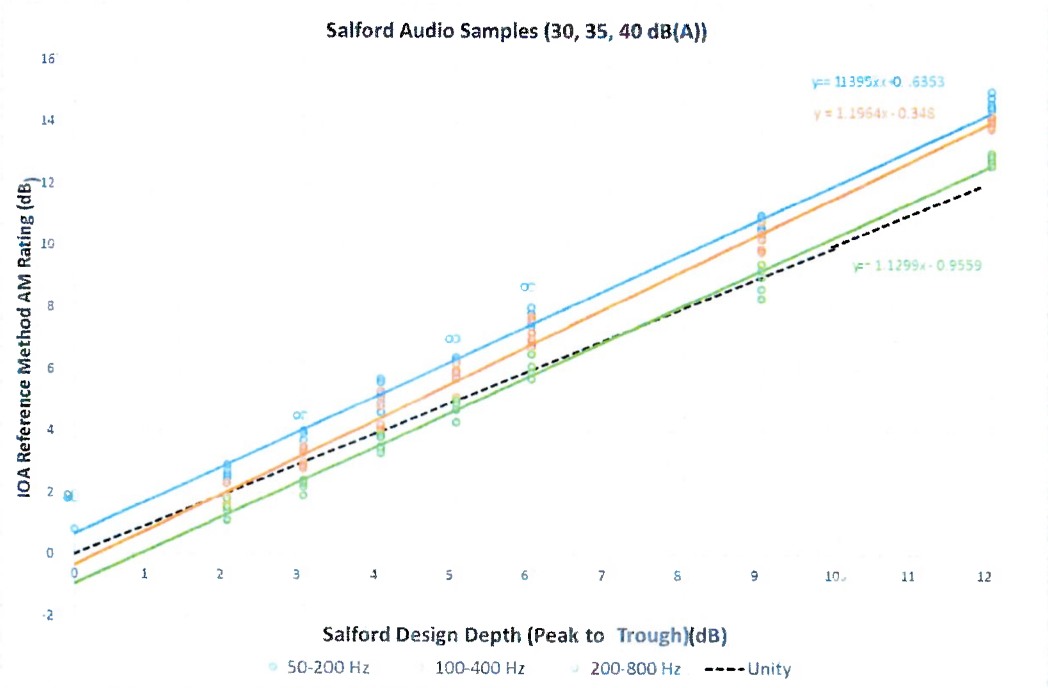

Figure 8.2.1 Analysis of Salford Stimuli with the IOA Reference Method

8.2.3 In the Salford study, results of additional tests are presented (in Figure 9.5 of the Work Package B2 report) in which the participants were asked to adjust the level of an unmodulated broadband signal (an Adaptive BroadBand Signal (ABBS)) to the level at which it was found to be equally annoying as the modulated test stimulus. The results with the Salford modulation depth can be replaced with the results of the IOA Reference Method: see Figure 8.2.2.

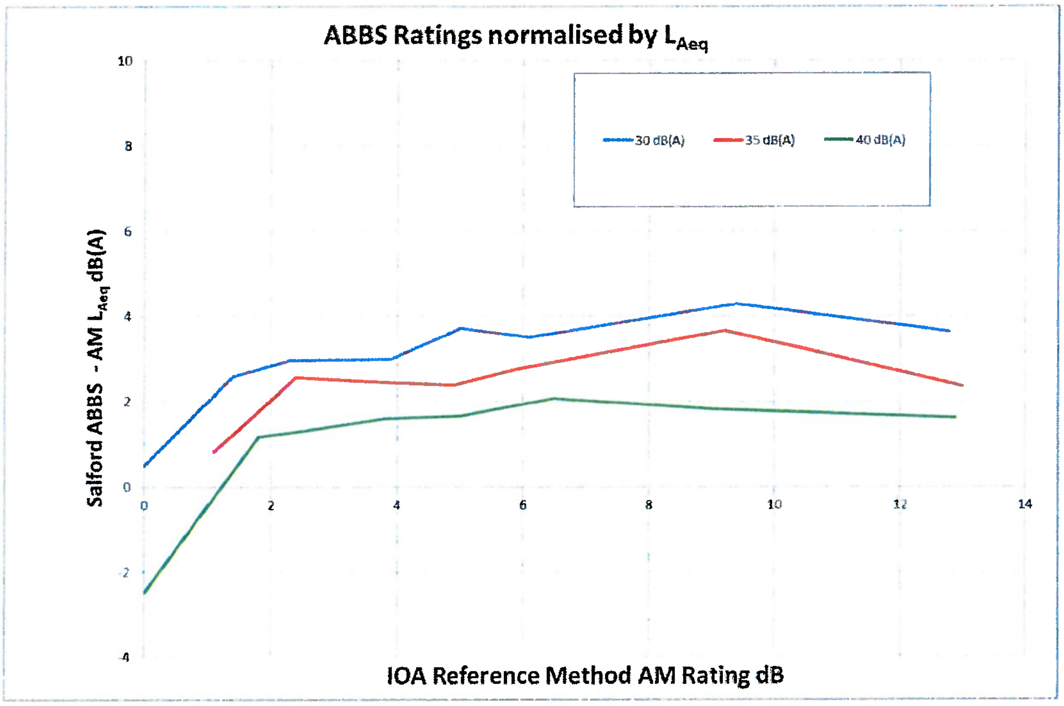

Figure 8.2.2 Comparison of Salford ABBS – AM L_{Aeq} results for IOA AM Rating (average values only 30, 35 & 40 dB(A), error bars omitted)

8.2.4 The WPB2 report also presented an alternative analysis, in Section 9.6 and 22, showing the adjustment relative to the L_{A90} levels of the samples. It noted the potential relevance of such an approach and recommend further investigation using this parameter in future studies. Figure 8.2.3 below reproduces Figure 22.2b of the report using the Reference Method ratings.

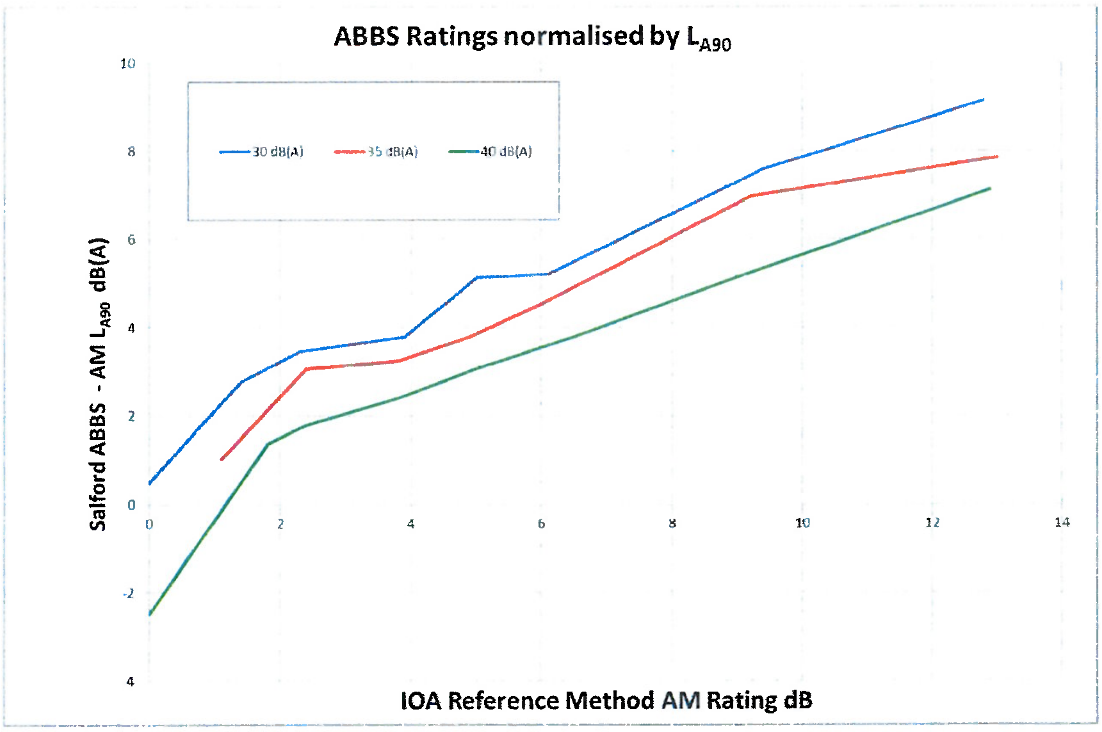

Figure 8.2.3 Comparison of Salford ABBS – AM L_{A90} results for IOA AM Rating (average values only 30, 35 & 40 dB(A), error bars omitted)

8.2.5 The Salford study noted that the difference between the L_{Aeq} and L_{A90} results could be partially explained by the difference between the L_{Aeq} and L_{A90} values for the test samples. Caution should however be used when interpreting these last results as this may not relate to the $L_{A90,10min}$ values used in ETSU-R-97 measurements. The differences between L_{A90} and L_{Aeq} of more than 3 dB (WPB2 Table 22.1) obtained for some of the 20 s artificial stimuli (9 and 12 dB design modulation) have not been observed in practice over 10 minutes even for clean samples of strong modulation.

8.3 Tachibana Stimuli

8.3.1 A similar analysis has been carried out for the stimuli used by Japanese researchers (Yokoyama, S., et al. (2013)) led by Professor Tachibana. The results are shown below in Figure 8.3.1. Please note that this is shown with reference to the AM Index values used to design the stimuli rather than the D_{AM} metric defined in the research or in Section 4.8, which is different.

8.3.2 Again, the results show a good correspondence with the design depth used in the study and this could th en allow a translation to the Tachibana AM results based on the IOA Reference Method.

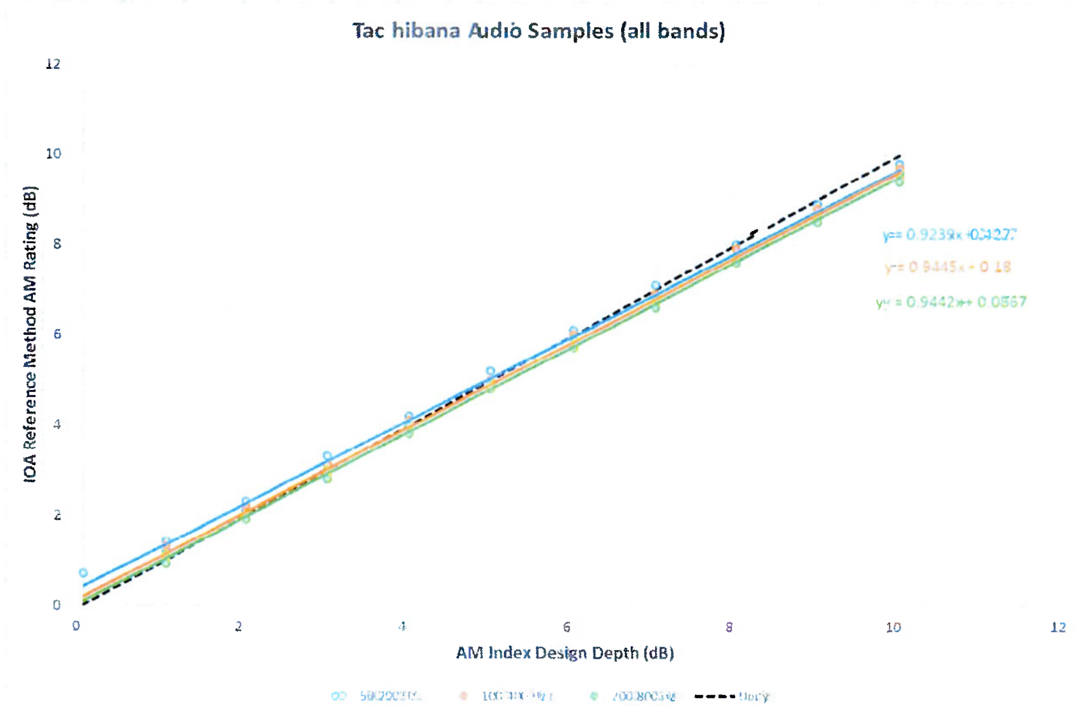

Figure 8.3.1 Analysis of Tachibana audio samples with the IOA Reference Method

9 SOFTWARE

9.1.1 Software will be provided when available, with data samples for validation purposes.

10 REFERENCES[16]

van den Berg, F. (2005). "The Beat is Getting Stronger: The Effect of Atmospheric Stability on Low Frequency Modulated Sound of Wind Turbines." Journal of Low Frequency Noise, Vibration and Active Control **24**(1): 1-24

ETSU-R-97 (1996), "the Assessment and Rating of Noise from Wind Farms", Final Report for the Department of Trade & Industry, The Working Group on Noise from Wind Turbines, September 1996

Fukushima, A., Yamamoto et al. (2013). "Study on the amplitude modulation of wind turbine noise: Part 1 – Physical investigation" Proc Internoise 2013

Hayes, M. (2006). "The measurement of low frequency noise at three UK wind farms. DTI Report 06/1412"

IOA (2013). "A good practice guide to the application of ETSU-R-97 for the assessment and rating of wind turbine noise"

IOA (2014). "Good Practice Guide - Supplementary Guidance Note 5 - Post Completion Measurements"

IOA AMWG (2015), "Discussion Document, Methods for Rating Amplitude Modulation in Wind Turbine Noise", April 2015

Levet, T (2015), "Application of the AM metrics – case studies", IOA Acoustics 2015 conference, Harrogate, UK, 15 October 2015

NordTest 112 (2002) "Prominence Of Impulsive Sounds And For Adjustment Of L_{Aeq}"

RenewableUK (2013). "Wind Turbine Amplitude Modulation: Research to Improve Understanding as to its Cause and Effect"

Swinbanks, M.A. (MAS Research Ltd), (2013), "Assessment of RES Revised Condition 20 for Evaluating Excessive Amplitude Modulation", May 2013

Yokoyama, S., et al. (2013). "Study on the amplitude modulation of wind turbine noise: part 2- Auditory experiments " Proc Internoise 2013, Innsbruck.

[16] Note that this section lists solely the documents explicitly referenced in this final report. For a complete list of documents considered in the entire process this list need to be combined with the references presented in Section 12 of the AMWG 'Discussion Document' published in April 2015.

APPENDICES

Appendix A Terms of Reference

INSTITUTE OF ACOUSTICS

IOA Noise Working Group (Wind Turbine Noise)

Amplitude Modulation Working Group

Terms of Reference

INTRODUCTION

In response to a request from the Institute of Acoustics Noise Working Group (IOA NWG), and approved by IOA Council, the IOA has agreed to set up a working group to look at the issue known as 'amplitude modulation'. The aim of the group will be to review the available evidence, and to produce guidance on the technical aspects for the assessment of AM in wind turbine noise.

The membership of the AM Working Group (AMWG) is drawn from the membership of the IOA and the CIEH, and seeks to include different representatives of the consultancy, academic, development and local authority sectors.

The AMWG will report to the IOA NWG, who in turn report to IOA Council.

ROLES AND RESPONSIBILITIES

The role of the AMWG is to provide advice to the IOA NWG on current good practice in the assessment of AM within wind turbine noise assessment.

The working group should:

- Undertake a literature review of available research and evidence on amplitude modulation and current methods in use, as appropriate; and on psycho-acoustic effects of AM
- Consider the design parameters for an AM metric and assessment method to be used in the UK
- Consider the various metrics and methodologies available to describe AM, and develop a preferred option if possible, or identify alternatives for the IOA membership to consider
- Produce a first draft of a consultation document with explanatory notes / justifications for consultation
- Consult the IOA membership and where appropriate other relevant technical experts on the draft guidance document
- Consider the consultation responses and if appropriate, produce a final Supplementary Guidance Note and / or consider the need for further research
- Provide software, if possible, to allow the analysis of AM data.

It is expected that the Supplementary Guidance Note will report on the metrics and methods considered, propose a preferred metric and assessment methodology and illustrate how it might work in practice. The primary goal is to develop a methodology which could be used within the planning regime; consideration must be given to use within the statutory nuisance regime as well.

If a consensus view on a particular issue cannot be reached between members of the working group, the various options should be listed out, with the pros and cons of each option discussed. Specific consultation questions to be put to the IOA NWG / peer review group should be aimed firstly at resolving these issues.

It is expected that the working group's activities will be of relevance to:

i. Acoustic consultants
ii. Local authorities;
iii. Developers
iv. Academics carrying out research on wind turbine noise
v. Turbine manufacturers
vi. The general public living close to wind turbines.

The activities of the working group initially relate to technical acoustic issues only, and therefore the initial membership will be drawn from groups i) to iv).

There may be occasions when the subject matter under discussion could benefit from input from other specialist representatives. When such occasions arise the working group may agree additional representation. If this results in additional costs these should be referred to the IOA Executive for approval.

WORKING ARRANGEMENTS

Meeting frequency

The working group will meet as often as necessary; at least four times provided a quorum is present.

Meeting quorum and leadership

A quorum is defined as five members of the working group. The working group meetings should be chaired by the chairperson, who will also act as the group's liaison to the IOA NWG. In the absence of the appointed chairperson, those present shall elect a temporary chairperson.

Administration

The other arrangements for the AMWG are:-

- Secretariat duties will be performed by a member of the AMWG appointed by the chairperson
- An agenda for each meeting will be drawn up and circulated to the working group (copied to the steering group for information) no less than two working days in advance of each meeting
- AOB can be tabled at the discretion of the chairperson
- Notes and summary action points of each meeting will be produced and sent to AMWG members (copied to the IOA NWG for information) within 10 working days of each meeting
- The AMWG will conduct most of its business via teleconference calls and email, but will meet at least once prior to the publication of the draft guidance for consultation with the IOA NWG and then as often as necessary. Meeting notes listing key actions will be made available to the IOA Council via the IOA Executive and published on the IOA website
- The AMWG will report formally to the IOA NWG chairperson, and shall provide ongoing reports as required
- The Terms of Reference for the AMWG, and any subsequent amendments, will be approved by the IOA NWG.

AMWG members will be entitled to claim travel expenses to meetings, at a rate to be set by the IOA Executive. No other payments will be made.

Proposed Timescales

The AMWG will agree a work programme, which is expected to cover a period of five months from the Inception meeting to the publication of a consultation draft and software. A six week consultation is envisaged, followed by a further four-week period during which the working group will consider the responses and produce a final version of the document and software for approval by IOA Council.

Ownership

Editorial ownership of the output document(s) will be retained by IOA Council.

Version 5 – 30 09 2014

Appendix B Scope of Work

INSTITUTE OF ACOUSTICS

IOA Noise Working Group (Wind Turbine Noise)

Amplitude Modulation Working Group

Outline Scope of Work

INTRODUCTION

In response to a request from the Institute of Acoustics Noise Working Group (IOA NWG), and approved by IOA Council, the IOA has agreed to set up a working group to look at the issue known as 'amplitude modulation' (AM). The aim of this 'AM Working Group' will be to review the available evidence, and to produce guidance on the technical elements for the assessment of AM in wind turbine noise.

This document defines:

- The membership of the AMWG
- The schedule of meetings that the AM WG will hold
- The aim of the AM WG
- The criteria by which the different options available for analysis of AM will be assessed
- The work packages necessary to achieve these aims.

The Terms of Reference of the AMWG are defined separately, and should be read in conjunction with this document.

MEMBERSHIP

The IOA NWG reports to IOA Council and comprises the following members:

- Richard Perkins, Parsons Brinckerhoff (Chair)
- Matthew Cand, Hoare Lea Acoustics
- Bob Davis, R Davis Associates
- Chris Jordan, Northern Group Systems (Environmental Health)
- Malcolm Hayes, Hayes McKenzie Partnership

The AM WG reports to the IOA NWG and comprises the following individuals:

- Gavin Irvine, Ion Acoustics (Chair)
- Matthew Cand, Hoare Lea Acoustics

- Bob Davis, Robert Davis Associates
- Dave Coles, 24 Acoustics
- Samuel Miller
- Tom Levet, Hayes McKenzie Partnership
- John Shelton, AcSoft
- Jeremy Bass, RES
- David Sexton, West Devon Borough Council
- Geoff Leventhall, Acoustical Consultant

The membership of the AM Working Group (AM WG) is drawn from the membership of the IOA and CIEH and seeks to include different representatives of the consultancy, academic, development and local authority sectors.

It is anticipated that the IOA NWG will provide oversight to the AM WG and participate in meetings and discussions at their discretion.

SCHEDULE OF MEETINGS

It is planned that the AM WG will hold face-to-face meetings of all members on the following dates:

- Wed 10 Sep — Kick-off meeting
- Wed 8 Oct 2014 — Update #1
- Wed 12 Nov 2014 — Update #2
- Wed 3 Dec 2014. — Update #3

Between meetings, conference calls between AM WG members will be held at fortnightly intervals.

The timescale for the work of the group is set out in the Terms of Reference.

GOALS

The overarching aim of the group is to develop the technical elements of an assessment method for amplitude modulated noise from wind turbines and wind farms. This will be:

- Based on best available science
- based on the most up-to-date psycho-acoustic and technical information on modulation available

- Provided in the format to allow straightforward inclusion in 'standard' forms of planning conditions for wind turbines [subject to thresholds or penalties set by others]

- Accompanied by software where necessary to allow the condition to be implemented by all parties.

To achieve this, the assessment method will need to contain a means of characterising a sample of amplitude modulated wind turbine noise data, with an agreed format and length, by means of a single metric uniquely defining the level of AM within it.

The results of the work of the AM WG will be communicated to the acoustics community via a Supplementary Guidance Note (SGN) or other document, thus providing additional information to that provided in the original IOA Good Practice Guide to 'The Assessment and Rating of Noise from Wind Farms' – ETSU-R-97.

WORK PLANS

To achieve the goals of the WG, it is anticipated that there will be a number of work packages.

WP1 AM definition and target audience

To provide clarity surrounding the issue of wind turbine AM, current definitions of AM will be reviewed and/or combined.

The WP will also consider the respective needs for the target audience, and ensure the final guidance document is appropriate where possible.

WP2 Data collation

The aim of this WP is to compile as much measured AM data as possible from as wide a range of wind turbine sites, in terms of terrain and meteorological complexity, and turbine types, hub height, as possible. Such data will be essential for identifying and testing the preferred AM metric.

WP3 Literature review

A literature review will be performed of all known literature relevant to the assessment and rating of wind turbine AM. The aim of the task is to compile a list of the different 'rating' methods currently available for AM, this to include the following:

- the 'Den Brook' method – see Condition 20 in the planning conditions and the scheme proposed by RES to satisfy a planning requirement to implement the above condition

- Work by MAS Environmental

- The RenewableUK method, published in December 2013 and recent modifications to the RenewableUK method which would correct some of the shortcomings – see Tom Levet (metric) and Jeremy Bass (penalty scheme)
- The method published by Tachibana et al of Japan
- The German Impulsiveness Rating
- Australian research by Evans and Cooper, Acoustics 2013
- Lee et al, 2009 + 2012
- McCabe, WTN11, 2011
- McLaughlin, WTN11, 2011
- Gunnar Lundmark, WTN11, 2011
- Larsson & Öhlund, Internoise 2011 and WTN2013
- Gabriel, WTN2013
- Carlo di Napoli, WTN2009 & WTN2011.
- Any national standards such as those of South Australia and New Zealand
- Other AM information (non-wind turbine) e.g. psycho-acoustic effects, Zwicker Fastl

WP4 Critical comparison of available methods

The intention is that the outcome of WP3 is an evidence basis on which to determine the preferred AM metric. This will comprise three elements:

- A review of the evidence of WP3 identifying common, desirable elements of the different methods available. This could include:
    - Methods based in the time domain
    - Methods based in the frequency domain or
    - A combination of the two.
- The review would also consider other hybrid methods to be developed from the above if appropriate
- The most promising method(s) will be implemented in software to allow a direct comparison of them based on the assessment of real-world data samples from WP2.

The content of subsequent work packages will be dependent on the outcome of WP3 and WP4

These could include the following potential work packages:

WP5 data requirements

To ensure a common, or at least a minimum level of fidelity, the minimum requirements for data loggers will be defined.

Parameters to be considered for data loggers could include:

- Instrument and windshield specifications
- The measurement index, L_{eq}, L_p, L_F etc.
- Short-term logging in 100 millisecond or 125 millisecond periods
- The maximum noise floor permitted
- frequency weighting network, e.g. A, C or none
- 1/3 octave band or octave band logging
- Audio recording ability.

For audio-recordings the following parameters could be considered

- Minimum length, in seconds/minutes
- Sample rate, in Hertz
- Bit rate
- Stereo or mono
- File format, e.g. WAV or MPG.

WP6 Data reduction definition

Given a suitable metric, the aim of this WP is to characterise an AM sample in terms of the following:

- The major time interval for analysis, e.g. 10 min
- The minor time interval for analysis
- Averaging or statistical analysis of AM samples.

WP7 Develop software

So that all parties involved in the assessment of wind turbine AM noise can do so with equal facility, a software package will be developed for implementing the preferred AM methodology.

This could be provided as a stand-alone executable program running on PCs with the Windows operating system, but other options will be considered.

WP8 Batch processing

It would be desirable that any AM methodology can be implemented in software which allows the 'bulk' processing of suitable data. This is because AM is typically only present in certain specific meteorological conditions, so that it may be necessary to screen large amounts of data to identify those periods which contain AM.

Ideally the software should discriminate wind turbine AM from other modulated noise sources, although it may be necessary for samples to be checked by listening where there is some doubt about their validity. The extent to which the software should do this must be defined. Where the software can only provide limited reliability, such that additional checks are required, then the process for checking and verifying data must be determined.

WP9 Psycho-acoustic significance

To be able to create a meaningful planning control for wind turbine AM noise, two elements are necessary: a metric, i.e. a number, which represents the level of AM present within a sample of wind turbine noise, and a scheme for providing a context for interpreting that number which encapsulates the typical psycho-acoustic response to AM.

This context might take a number of different forms, for example a stand-alone scheme, a penalty scheme or a hybrid of the two. For example, it might be:

- A stand-alone condition, which applies irrespective of overall wind turbine noise levels
- Integrated into the overall compliance process for wind turbine noise via a penalty added to wind turbine noise levels
- A hybrid of the two. For example, a penalty scheme for low to moderate levels of AM and an automatic fail, irrespective of overall noise levels, for higher levels of AM.

The aim of this WP will be to collate papers relating to the psycho-acoustic response to AM, with a view to identifying possible ways forward. This may involve re-analysis, using the new metric, of the audio data used in the RenewableUK funded listening tests, at the University of Salford. The AM

WG can make recommendations about the form, and nature, of the psycho-acoustic consequences of a given level of AM, if the available evidence supports a view, which might include:

- The nature of the test, i.e. stand-alone, a penalty or hybrid scheme
- If a penalty scheme is recommended, how this might be defined.

It should be stressed that the intention of this work package is to collate the information needed to help decision makers make an informed decision on how an appropriate threshold or penalty might be applied, if the available evidence supports this, or to recommend further work which would assist.

SUCCESS CRITERIA

A number of criteria will be considered by the group when assessing the output of each work package as follows:

Achievability – using the equipment and software typically available to acoustic professionals

Reality – work with samples of 'noisy', real-world data, not just, artificial simulated data created for testing purposes

Robustness – minimising the influence of 'noise' in test data, which can make signal detection difficult, to ensure low rates of false positives and negatives

Location – the chosen methodology will be applicable to measurements in free-field conditions, external to affected premises, so that it can be used in conjunction with current good practice in wind turbine compliance measurements

Objectivity – providing a unique number which characterises the level of AM in each case

Repeatability and reproducibility – returning the same unique number for a given sample of test data irrespective of who runs the test, where or when or how

Specificity – as AM is currently defined as 'the modulation of the broadband noise emission of a wind turbine at the blade passing frequency (BPF)', it is essential that the methodology is specific to the BPF and not sensitive to variation at any other frequencies

Automation – the ability to process large data sets. This is necessary because AM is typically only present in certain specific conditions, so that it is necessary to screen large amounts of data to identify those periods which contain AM

Relativity – relatable to the psycho-acoustic, or subjective, response of individuals to AM noise.

Appendix C IOA AMWG responses to Consultation Document

Summary of responses and working group comments

The IOA Discussion Document on Methods for Rating Amplitude Modulation was issued on 23 April 2015. This section summarises the responses and provides the AMWG's considered comments on the points raised.

Responses - general

Twenty individuals (some presumably representing the views of their companies or organisations) responded to the Discussion Document by providing replies to specific questions and, in some cases, providing additional comments. Two responses were received from non-UK sources. Most responses will be published in un-edited form except that some details will be redacted to preserve anonymity where this has been requested. It is recognised that the significance of comments made by individuals is likely to be influenced by their professional and commercial affiliations (if any) as well as the experience of the person concerned. In reviewing responses, the AMWG has attempted to take these factors into account, in an objective way, when considering the weight to be given to any particular response, suggestion or criticism.

In addition to the formal consultation, since the date of the Discussion Document further input on signal processing has been provided by Professor Paul White of the Institute of Sound and Vibration Research, University of Southampton. The AMWG gratefully acknowledges the contributions made by the respondents to the Discussion Document, and to Professor White.

Respondents were asked to address 20 specific questions and to make further comments as they thought necessary. The following commentary summarises the main points raised in answer to the questions. Some responses were comprehensive and complex. Every effort has been made to take account of all issues raised, including issues not referred to in the summary below.

Q1 Definition – wind turbine amplitude modulation (AM)

The definition of AM in the consultation document was as follows:

In the context of the objectives of the working group, wind turbine AM is defined as periodic fluctuations in the level of broadband noise from a wind turbine (or wind turbines), the frequency of the fluctuations being the blade passing frequency of the turbine rotor, as observed outdoors at residential distances in free-field conditions.

The majority of respondents agreed with the definition but some proposed additions or amendments as follows:

- The definition should specify 'audible' noise rather than 'broadband' noise.
- The reference to the measurement location and free-field conditions should be omitted since this is not relevant to the definition of AM but only to the application of a metric.
- The definition should distinguish between 'normal' and 'other' AM.

AMWG comments

The AMWG accepted the first two points and the definition has been amended as follows:

"Wind turbine amplitude modulation is defined as periodic fluctuations in the level of audible noise from a wind turbine (or wind turbines), the frequency of the fluctuations being related to the blade passing frequency[1] *of the turbine rotor(s)."*

The third point was discussed, but the AMWG considers that the source mechanism is not relevant to the experience of AM.

Q2 Is the AM definition applicable to small turbines?

This question produced a mixed response. Some respondents did not make any comment or said that they had no experience of small turbines. The question of 'what is a small turbine?' was raised. There was wide agreement that smaller turbines would exhibit different characteristics – different dominant blade noise frequencies, higher modulation frequencies, with the possibility that some fluctuations in levels resulting from mechanical sources ('rattling' or 'flapping' noises have been observed from some micro turbines, for example) rather than aerodynamic sources. The majority view was that although the definition of AM applied, in principle, to any wind turbine, the assessment of AM from smaller turbines would require different measurement and analysis parameters, and even if a common metric could be devised, its application to small turbines was likely to require different acceptability criteria to be developed.

AMWG comments

This question would perhaps have been better framed if directed towards the *application of an AM metric* rather than the definition of AM. Most of the measured data of wind turbine noise exhibiting AM relates to turbines with outputs in excess of 500kW; experience of AM from smaller turbines is limited. Therefore the AMWG has focused its study of AM metrics on data from wind turbines of 500kW capacity upwards.

Q3 Is it appropriate to measure AM outdoors in free-field?

This question generated considerable discussion. Most respondents observed that complaints regarding AM often concerned indoor noise, particularly at night. It could therefore be thought logical to measure noise inside dwellings. Furthermore experience suggests that there is a variable 'transfer function' between indoor and outdoor perception of AM and in some cases, higher levels of AM may be detected indoors than outdoors. However, most respondents accepted the difficulties in

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[1] The blade passing frequency (Hz) = rotor rpm times No. of Blades / 60

measuring noise inside, including the influence of room modes and the resulting spatial variations in noise level, as well as to the influence of domestic noise sources. An analysis of a domestic source was provided by one respondent who noted the similarity with wind turbine AM, albeit at a non-typical modulation frequency. This is shown below in Figure C1. The source in this case is snoring. This also represents an example of the limitations of the sole review of time-series data.

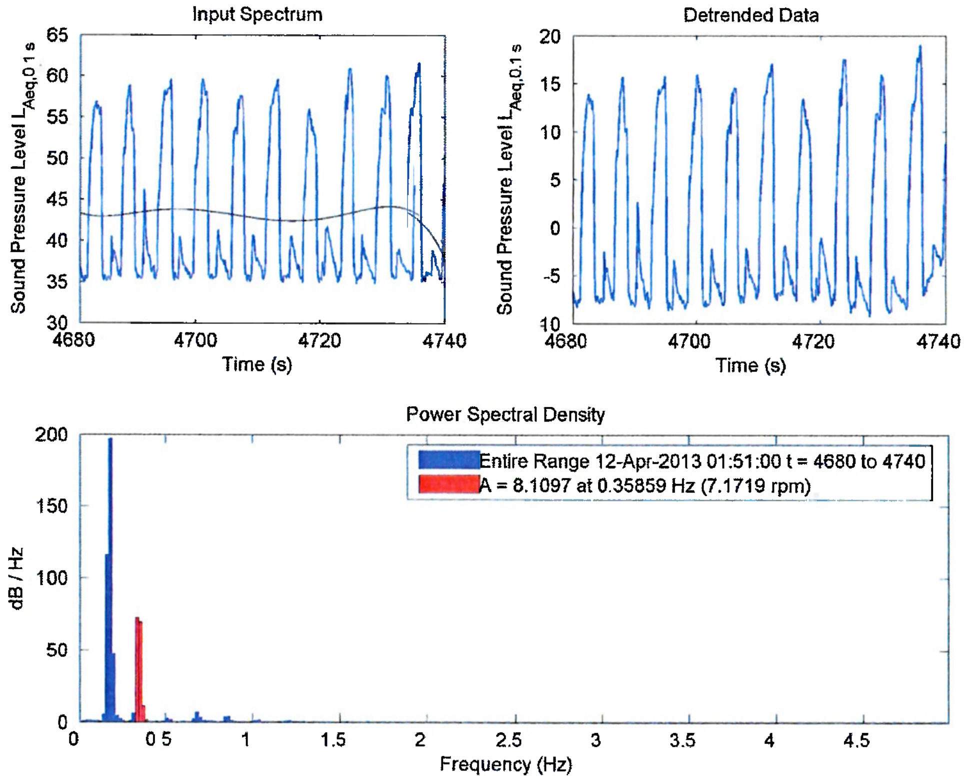

Figure C1 – 'AM' in noise from snoring

For the purposes of defining and applying a method for rating AM, most thought that measuring indoors presented too many practical difficulties and outdoor measurements were strongly preferred. Measuring outside is also consistent with most other environmental noise assessment procedures. It was suggested by some that additional indoor measurements would be appropriate if complaints related specifically to noise indoors.

AMWG comments

The working group's objective is to define a metric that can be used reliably within the planning system, and external measurements are the only practicable option. For specific complaint or nuisance measurements, Investigators are of course free to make internal measurements and assessments in connection with the specific issues. Indoor measurements are problematic for a variety of reasons including, access difficulties, corruption by other sources, and room modes which could result in different responses in different positions in the room. These factors can cause a large variation in noise levels which can affect reproducibility. It is considered unnecessary to account for all of these factors when wind turbine AM can be measured reliably outdoors. Furthermore the noise data input to the recommended metric is band-limited to reduce the influence of high- and low-frequency background noise. To some (although indeterminate) extent, this reflects the sound attenuation characteristics of building facades and windows in preferentially reducing higher frequencies rather than low, which may mean that the outdoor metric better reflects the perception of AM indoors, compared with a metric based on broadband A-weighted noise data where other sources may mask the AM. This is a possible incidental benefit of band-limiting which is incorporated into the recommended method for other reasons.

Q4 Are there any other rating methods or important references that the AMWG should consider?

There was only limited feedback on this question. One respondent suggested that standards such as BS 4142:2014 could be used, or guidance for assessing music noise, since both are suited to the assessment of sound with 'character'. The same respondent referred to the 'hybrid' method adopted by Evans and Cooper (already referenced in the Discussion Document). No other relevant references were identified. One respondent gave the opinion that there were no robust dose-response relationship studies (because of small test subject numbers in all published studies) and in any event that none of the proposed forms of metric could be related to the results of those studies.

AMWG comments

The AMWG considered, but rejected, adoption of the BS 4142 method for rating impulsive characteristics as not sufficiently discriminating wind turbine AM. Other criteria in the standard (apart from tonality) were partly subjective, or would depend on user-judgment and were subject 'to context'. It was concluded that it was not suitable for evaluating AM. The question of the robustness of the available research into dose-response relationships for AM is a matter for others and outside the scope of the WG.

More generally, the AMWG recognises that the response of any individual to AM noise is complex and subject to a wide range of factors in addition to its level, including: the characteristics of the noise (in spectrum and time), the context in which it is heard, the health, attitude and experiences of the person hearing the noise etc. But this is also the case for any other noise, and yet, in the interest of providing objective quantifications of noise levels, all standards used in the UK are based on metrics such as L_{90} and L_{eq} which provide some form of averaging or processing but represent a reasonable and practicable representation of the noise levels and their variation. This is therefore the approach retained by the AMWG.

Q5 In principle, which is the best domain for rating and describing amplitude modulation: the time domain; the frequency domain; or is a hybrid method preferred?

Overall there was a clear preference for the frequency-domain method (Method 2 in the Discussion Document), although of those preferring this method, a second or equal preference was generally given to the hybrid method (Method 3). It is noted however that this was overwhelmingly the case for a group of respondents which included wind farm developers. Another group of responses generally preferred the time-domain method (Method 1) on the basis of its intuitive nature and technical simplicity. The Northern Ireland Environmental Protection Group also adopted this view, although their preferred metric of the three presented was the hybrid method (See Question 14). A few respondents recommended that the domain/method chosen should be that which is shown to be the most robust and best correlates with subjective response.

AMWG comments

The AMWG strongly believes that frequency analysis is an essential tool in identifying the presence of AM. Using Fourier analysis to detect amplitude modulation is widely used by wind farm researchers in the literature, and in other fields, for example in detecting propeller noise using Sonar. This provides an objective indicator of the fluctuation rate which can allow excluding the majority of the contamination by other sources. The AMWG also considers that a time-domain method, used alone, is too susceptible to corruption by ambient noise sources and cannot be reliably applied, particularly to large datasets, and relies substantially on subjective judgment.

However, using time series data does provide a more easily-grasped and intuitive presentation of level and variation of AM within a noise sample. As a result of further research, the AMWG has decided to adopt a hybrid method, which utilises a frequency-domain analysis to identify the presence of AM in background noise and to 'reconstruct' a time-series plot of the modulated wind turbine noise, with background noise (to a large extent) removed.

The method retains the energy in the first three harmonics of the modulation spectrum. The AMWG believes that the adoption of this method, and the use of the prominence criteria developed, addresses many of the issues put forward in response the Discussion Document (see also Q8, Q9 and Q10 below).

Q6 Do you agree with time intervals proposed, that is: 100 millisecond samples, 10-second blocks, 10-minute periods?

Differing views were expressed about the suggested time intervals proposed and also about the way in which levels within each time 'block' were analysed to produce 'average' or 'typical' values, and what criterion should be applied to label data as 'spurious' and to be discarded.

There was general agreement on the acquisition of data in terms of $L_{eq,100ms}$. Similarly, a metric that defines a level of AM within a 10-minute period, by aggregating the levels in successive shorter sampling intervals, was considered by most to be a pragmatic choice. The adoption of a 10-minute reference interval is consistent with ETSU-R-97 and reflects averaging periods for anemometry and SCADA data. However, some respondents gave the opinion that any form of 'averaging' over 10 minutes could understate the impact of varying levels of AM with short periods of high level.

The case for adopting 10-second sampling intervals was less clear. It was noted that longer intervals (say 30 seconds) would provide longer averaging times and therefore improved frequency resolution.

AMWG comments

There was considerable debate within the AMWG over whether to adopt longer sampling intervals (perhaps 30 seconds) to obtain better frequency resolution. This would also allow the harmonics of the modulation frequency to be better defined. However, if a longer sampling interval were used, there would need to be a method for accounting for the variability within the longer interval, whereas the variation within a 10-second interval is relatively small such that the level of AM can be reasonably represented, for example by averaging the peak and trough values in the time-series. It is therefore recommended that the method characterises the varying AM by outputting the individual 10-second values. If appropriate, in terms of the subjective response, it would be possible to devise an AM rating based on individual 10-second values, rather than a 10-minute period, although the method as formulated provides a 10-minute value.

Q7 Do you agree with the band-limiting filtering approach for rating AM?

Most respondents were in favour of band-limiting the measured data as an initial stage of the analysis (typically using pass bands corresponding to some combinations of the 100-800Hz one-third octave filters), on the basis that it has the effect of reducing the influence of high-frequency background noise. One response was forthright: "*Yes, excellent method. Focusses on the frequencies imported for OAM, and also ditches the extraneous noise*". There were some concerns: filtering may exclude noise at some frequencies which exhibit amplitude modulation, thereby understating the level of AM present and there were some comments that low frequency noise was not being addressed. Conversely, reduction of background noise could result in an overstatement of AM, compared with an assessment based on broadband A-weighted levels, because in some cases background noise has the effect of 'filling in the troughs' and therefore reducing the measured modulation.

AMWG comments

The band-limited frequency range have been tested on data from several sites and has shown a clear ability to provide useful discrimination between noise level fluctuations caused by wind turbine AM and those resulting from other ambient sources. Band-limiting may also address (at least to some extent) the issue of whether external measurements can adequately be used to assess AM in situations where complaints relate to internal noise (see Q3).

Q8 Is the default frequency range (*for band-limiting*) appropriate? What other frequency ranges could be considered, taking into account the desirability to characterize the frequency range in which AM occurs?

Several respondents noted the difficulty in selecting the appropriate frequency range for band-limiting the input data. Some suggested that this must be done on a case-by-case basis. One observed that the same model of turbine could exhibit significant AM in the 80 Hz band and the 500 Hz band at different times. It was agreed that frequencies above 800 Hz were often corrupted by extraneous noise. Some respondents expressed concerns regarding what was perceived as the exclusion of modulation occurring at frequencies lower than 100 Hz.

AMWG comments

The band-limited approach is of great benefit for detecting AM in noise, and minimising influence of other sources. Band filtering is also a pragmatic way of addressing concerns of indoor impact from evidence of previous reports of apparent increased modulation internally. The adoption of different frequency ranges can yield different results and no single 'default' range can be specified. Although the frequency content of modulation can vary due to a range of effects, the aim is to provide a consistent, reasonable and pragmatic representation of the modulation which is not excessively sensitive to spurious variations.

Concerning lower frequencies, the remit of the group, based on the definition agreed, is to consider modulation which is audible. The experience of the group and all evidence available shows that noise produced by modern upwind turbines at low frequencies below 20Hz is at low and inaudible levels in the far-field. The AMWG was not convinced by the thoroughness or relevance of studies in other countries cited to show effects of very low frequencies (<20Hz), as these often do not consider the effects of audible noise. It should also be noted that low-frequency tonal emissions from turbines are already covered by the method set out in ETSU-R-97.

Varying the band-filtering region around the reference 100-400Hz, to higher or lower frequencies, has been actively considered by the group based on the available data. On the basis of these investigations, the AMWG has agreed to provide three ranges: 50 Hz to 200 Hz, 100 Hz to 400 Hz and 200 Hz to 800 Hz. The data is processed for each of these ranges and then the range yielding the highest results chosen.

Q9 Do you think the time series method proposed is suitable for rating AM? If not, can you explain why?

Most respondents agreed that a time-domain method, based on examination of a time-series plot to determine the typical, average, or maximum peak-to-trough values, is very suitable for the assessment of short-term 'clean' wind turbine noise data with minimal corruption by other ambient noise. The method has the benefit of relative simplicity. However, the strong majority view was that it was not suitable for rigorous assessment of AM, especially when there was significant noise from other sources, because it was unable to discriminate between fluctuations in noise levels resulting from wind turbine AM and those resulting from variations in other ambient noise. Significant subjective (visual or aural) screening is required to overcome this fundamental deficiency, which is considered to be impracticable for the analysis of long-term data (perhaps covering periods of weeks or months) One respondent strongly supported a simple time-series method, stating that long-term measurements were not required and that data corrupted by other noise could be readily detected by inspection.

AMWG comments

There is some benefit in having a simple method of assessing AM, for example for the purpose of forming an initial conclusion about the validity of a noise complaint. A method of the form proposed by Japanese researchers (Fukushima, Yamamoto et al. 2013) provides such a method, which was more precisely defined than some of the other methods proposed, but is still subject to corruption from extraneous noise (as its authors recognised). Any output from such a method would be open to question unless accompanied by time histories which demonstrated (on subjective judgement) the presence of clear AM with no significant contribution from other ambient noise, or using tools such as autocorrelation spectra. However the AMWG does not consider that the method is a robust basis for an assessment metric which may be adopted in a planning condition.

Wind turbine AM, where it occurs, is an intermittent occurrence. The assessment of AM on a particular site would generally involve long-term measurements to establish the frequency and duration of occurrence and the particular wind conditions. Reliance on a time-domain method only, which may appear more direct to non-specialists, is not considered to be practicable or robust, because unlike a frequency-domain method, it is unable to detect WTAM on the basis of its distinctive periodicity and therefore requires significant subjective 'filtering'.

Q10 Do you think the frequency domain method proposed is suitable for rating AM? If not, can you explain why?

As in Q5, most respondents considered the frequency-domain method (Method 2) appropriate and more robust and reliable than time-domain methods. Difficulties in choosing the appropriate range for the blade passing frequency were highlighted, as this can be variable. Some stated that the methodology was difficult to explain to lay persons. An error in the methodology relating to the number of FFT lines was pointed out by several respondents. The exclusion of energy in the higher harmonics of the modulation spectrum was criticised by several respondents on the grounds that this can lead to levels of AM being understated (compared with a time-series analysis).

AMWG comments

With regards to the 'under-estimation' concerns, there were indications that some respondents may have applied the methodology erroneously. It should in any case be noted that the aim of the method was not necessarily to match the peak-to-trough variations but to provide a meaningful and robust *representation* of the magnitude of modulation in a signal, which would *scale* with the level of the modulation present. The question of the threshold of acceptance or of different effects is separate, and must be adapted to each method ('accounted for in the establishment of any assessment method that should be used' as one response notes). It is however true that obtaining higher values for higher levels of AM provides a higher "dynamic range" in the output of the metric which is valuable and provides better discrimination and difference with the noise 'floor 'inherent in any numerical method.

Overall, the comments and criticisms were accepted and/or taken into account. The recommended hybrid method is designed to overcome the criticisms of the original Method 2; in particular, the contribution of higher harmonics is included.

Q11 Should other parameters be used in the application of this (FFT) method and why?

There were few responses to this question, and perhaps its intention was not clear. Some responses repeated points which arose in answer to other questions – inclusion of harmonics, sample intervals etc. One raised the issue that the method is only assessing modulation depth (peak to trough values) whereas this is only one of the factors influencing response to AM, although the other potential factors were not identified. Some responses considered the technical parameters used in detail.

AMWG comments

The FFT method is no longer being pursued and therefore this question is not now directly relevant. The point made about the possible relevance of other factors, in addition to modulation depth, is applicable to all the methods considered. The AMWG accepts that there may be other factors influencing response to AM (variability, intermittency, event duration, suddenness of onset etc.) but in the absence of any dose-response data relating to these factors it is not possible to ascribe any significance to them or to incorporate descriptive parameters for them in the AM metric. As noted above (see Q4), the proposed method provides a reasonable and objective representation of the level of modulation.

Some of the detailed responses represented useful feedback which prompted further studies and investigations, for example of different frequency resolution and sampling approaches as described elsewhere. A-weighting of the input signal was questioned but seen by the AMWG as beneficial in reducing corruption from wind noise (a concern for other respondents). One respondent outlined an approach in which a model was fitted to the derived spectra in order to assist rejecting periods where the spectrum did not exhibit a clear peak at a certain frequency and its harmonics; this has been actively considered by the AMWG and is a basis for the 'prominence' approach used in the reference method.

Q12 Do you think the hybrid method proposed is suitable for rating AM? If not, can you explain why?

This method (Method 3) attracted favourable comments. Some used the term 'best of both worlds'. Reservations were expressed on the grounds of complexity and it being difficult to understand. Respondents who did not favour the frequency-domain method (Method 2) and preferred the time-domain method (Method 1) also objected to this method, although judged it to be slightly preferable to Method 2.

AMWG comments

The AMWG has now proposed a hybrid method which represents a development from the methods described in the consultation document. It is accepted that the method is relatively complex, although less than the Method 3 previously described, but the degree of complexity is considered inevitable in a method that is sufficiently robust for determining compliance or non-compliance with specific thresholds or limits. One benefit is that the interim output is a reconstructed time series that can be compared with the original unprocessed time series, which is a significant aid to validating the method and rendering it more 'transparent'. Furthermore, the AMWG aims to provide a software code which will assist several stakeholders in implementing the method.

Q13 Should other parameters be used in the application of this (hybrid) method and why?

Most respondents did not answer this question; again, the point of the question was perhaps not clear (as one respondent noted). There were some comments about correcting for the 'continuum' (or masking level) in the spectrum and providing criteria for uncertainty, and for the need to compare the reconstructed time series with the 'original'. It was also noted that multiple descriptors could be used to characterise the resulting time series including the L_{50} and L_{max} values.

AMWG comments

The AMWG has decided that it is reasonable to characterise the level of AM in each 10-minute interval by a single value. However, since the time series is reconstructed, with knowledge that allows the peaks and troughs to be identified, they could be characterised by any combination of statistical parameters. There is no robust basis for adopting any specific parameters, but in the judgement of the AMWG the adopted parameters are reasonable. They can readily be modified if further dose-response data becomes available which indicates that other parameters provide better correlation with subjective response.

Q14 Of the three methods proposed, which is your preferred method?

When asked this specific question, rather than the 'in principle' question (Q5), most respondents preferred the frequency-domain method (Method 2) although some favoured the hybrid method (Method 3). For both methods, some reservations were expressed about complexity. Again the response was split between groups which preferred a Fourier-based approach and those who preferred a time method. Some also stated again that the preferred method is the one which best represents subjective response. Others stated that more refinements were required to all methods and therefore qualified their response.

AMWG comments

For similar reasons to those set out in response to Q5 above, the AMWG considers that the hybrid method should help to address the clear difference in views between those favouring a time-domain method and the majority who favour a frequency-domain method. The assessment stage in the hybrid method is performed on the (reconstructed) time series but a frequency-domain technique is used to identify AM components and minimise the effect of other ambient noise. The hybrid method has been significantly enhanced since the issue of the Discussion Document and comments to that document have been taken into account.

Q15 Is there another alternative method not recommended by the AMWG which would be preferable? Explain why

Most respondents did not comment. No substantially different method was proposed. Time series methods using subjective filtering, rather than 'automated' methods, were (again) identified by a small number as being preferred. One respondent raised the possibility of using BS 4142:2014. Two respondents suggested improvements to the proposed methods: improving the frequency-domain method (Method 2) to include the harmonics in the modulation spectrum and improving the frequency resolution, and modifying the 'Tachibana' (time series) method (Method 1) by using band-limited data to reduce the influence of background noise.

AMWG comments

The AMWG members are guided by the adopted success criteria (Appendix B) which (amongst other requirements) specify that any adopted assessment method/metric is specific to wind turbine noise, objective, and is applicable to long-term noise monitoring. Furthermore, the scope of the AMWG was to specifically rate modulation in wind turbine noise rather than characterise wind turbine noise more generally. For this reason it has rejected a time-series approach and methods such as BS 4142:2014 primarily on the grounds that their application requires significant subjective intervention. The impulsive rating in BS 4142 was rejected at an early stage because it does not characterise AM very well as it is better suited to noises with a more rapid rise time. A hybrid method is now recommended by the AMWG.

Q16 Are the proposed requirements for instrumentation appropriate?

Most respondents were satisfied that application of any of the methods would not incur additional instrumentation requirements, although it was suggested that 100ms averaging intervals might be too long for assessment of AM from small turbines. One respondent suggested that reliance only on 100ms L_{eq} data is inadequate – audio recording was also required and some processing technique to reduce spurious noise generated by wind at the microphone was desirable. The question of whether the noise floor of Class 1 instrumentation was low enough to adequately measure the full range of AM in all cases was raised, as was the question of the specification of microphone windscreens. Some of the references to instrumentation standards were incorrect in the consultation document.

AMWG comments

The noise floor of Class 1 instrumentation is not a concern for outdoor noise measurements. It is agreed that the specification of microphone windscreens for use in high wind speeds requires further research, but such research is outside the scope of the AMWG's brief. Nonetheless, the use of correct band-filtering can assist in minimising wind noise corruption. The AMWG recommends that audio recordings are obtained.

Q17 Would you like instrument manufacturers to make available an 'AM rating' option for sound level meters

Generally it was considered unlikely that instrumentation manufacturers would provide such an analysis option, since the demand and therefore the market would be limited. Also provision of such a facility would risk AM being over-stated: the need for visual and/or aural scrutiny of data was still necessary for all methods, to identify and discard noise samples influenced by extraneous noise. An instrument which produced an 'instant' rating might discourage users from carrying out this essential filtering exercise.

AMWG comments

The AMWG agree that the market for instrument manufacturers would be small and there is no specific requirement for such a development. For the recommended method the AMWG, through the IOA, will make available software to perform the necessary analysis (see Q18). However, it would be very desirable for the 'front end' instrumentation to provide 100ms L_{eq} data in one-third octave bands for direct input into the analysis software; not all current Class 1 sound level meters can provide this output. The desirability of obtaining audio data is accepted.

Q18 Should the IOA make available software for rating AM?

Most respondents stated that software (required for Methods 2 and 3) was necessary or desirable and it should be 'open-source' and therefore 'transparent' and allow individuals to modify it. There was no particular consensus view on whether the software should be made available through the IOA.

AMWG comments

It is intended that software will be made available through to IOA to implement the recommended hybrid method. The means of supply has not been determined. The software code will be made available, open source with appropriate disclaimers.

Q19 Do you have any comments on the software released?

Trial software for applying the methods proposed in the Discussion Document had been released although few respondents had tested this. Various comments were received including requests for the source code. Some refinements were requested including file naming, additional outputs in terms of graphs etc. and a request for the software to work with audio files as an input.

AMWG comments

The output software provided to date was necessarily basic in nature, but the software for applying the recommended hybrid method has been greatly refined; the source code for implementing the recommended method will be released so it can be implemented by a wide range of users and can be further developed and refined by experienced users.

Q20 Recommendations for further study and any other comments

There were a few responses. The Northern Ireland Group suggested further work should be done on single turbines, while others required more research on subjective aspects and on the mechanisms causing AM. The issue of the design and performance of microphone windscreens was also raised.

AMWG comments

Further research is very desirable in a number of areas relating to the measurement and assessment of wind turbine noise, including those identified by respondents. However, it considers that the existing information base is adequate to support the recommended AM metric.

WIND TURBINE AM REVIEW

PHASE 2 REPORT

CONFIDENTIAL

AUGUST 2016

WSP | PARSONS BRINCKERHOFF

WIND TURBINE AM REVIEW

PHASE 2 REPORT

Department of Energy & Climate Change

Issue 3 – Issued

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QUALITY MANAGEMENT

ISSUE/REVISION	DRAFT ISSUE	FIRST ISSUE	SECOND ISSUE	THIRD ISSUE
Remarks	Issued for external peer review	Issued for DECC review	Second Issue	Third Issue
Date	27.01.16	14.03.16	31.03.16	10.08.16
Prepared by	M. Lotinga	M. Lotinga	M. Lotinga	M. Lotinga
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PRODUCTION TEAM

DEPARTMENT OF ENERGY AND CLIMATE CHANGE (DECC)

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INDEPENDE NTEXTERNAL REVIEWERS

Reviewer	Bernard Berry
Reviewer	Colin Grimwood
Reviewer	Stephen Stansfeld

PREAMBLE

The project has been undertaken by a research team lead by WSP | Parsons Brinckerhoff (the Internal Research Team), who are responsible for the overall editorial content of the report. During the project, help was sought from three Independent External Reviewers (IER), who undertook a number of paper reviews, providing commentary on the robustness and conclusions for those papers. They also provided a review of the entire document. Comments attributed to the IER are clearly signposted in the report.

An OAM Review Steering Group, chaired by DECC, was set up to agree the detail of the proposed approach to this work and to monitor progress. The Group provided a scrutiny and challenge function but it did not seek to influence the conclusions or recommendations, in order to maintain the independence of the research. The other Steering Group members were Public Health England (PHE); Department for Environment, Food and Rural Affairs (Defra); Department for Communities and Local Government (DCLG); Welsh Government; Scottish Government and Northern Ireland Executive. The [WSP | Parsons Brinckerhoff] project team were also invited to attend the Steering Group meetings.

A draft report was provided to three peer reviewers commissioned separately by DECC. This final report addresses the comments raised by the peer reviewers, and a spreadsheet detailing their comments and how they have been addressed in the report has been produced.

The authors would like to take this opportunity to thank all those who have assisted in gathering data, making papers available, and raising awareness with Stakeholders of this research.

TABLE OF CONTENTS

APPENDICES

ANNEXES

NON TECHNICAL SUMMARY

BACKGROUND

Current planning policy for the assessment and rating of wind turbine noise in England, Scotland, Wales and Northern Ireland refers to the ETSU-R-97[1] document. Wind turbines are known for their distinctive acoustic character often described as a 'swish', which is also referred to as amplitude modulation (AM). Recent evidence suggests that at times this 'swish' can become more of a pronounced 'thump', leading to complaints from wind farm neighbours.

In response to growing concerns about the impact of excessive AM on residents, WSP | Parsons Brinckerhoff was commissioned by the Department of Energy and Climate Change to undertake a review of research into the effects of and response to AM and, if considered necessary, to recommend a control method suitable for use as part of the planning regime.

AIMS

The aims of the study are to review the evidence on the effects of AM in relation to wind turbines, the robustness of relevant research into AM, and to recommend how excessive AM might be controlled through the use of a planning condition, taking into account the current policy context of wind turbine noise. The work included working closely with the Institute of Acoustics' AM Working Group, who have proposed a robust metric and methodology for quantifying and assessing the level of AM in a sample of wind turbine noise data.

METHOD

The study has involved the collation and critical review of relevant literature on the subject of AM, which included published papers on dose response studies, case studies, existing planning conditions, and current planning guidance. Key points from the reviewed evidence have been extracted and summarised upon which to draw the reports' conclusions.

CONCLUSIONS

The review has concluded that there is sufficient robust evidence that excessive AM leads to increased annoyance from wind turbine noise, and that it should be controlled using suitable planning conditions. Key elements required to formulate such a condition have been recommended.

RECOMMENDATION

It is recommended that excessive AM is controlled through a suitably worded planning condition which will control it during periods of complaint. Those periods should be identified by measurement using the metric proposed by work undertaken by the Institute of Acoustics, and enforcement action judged by Local Authority Environmental Health Officers based on the duration and frequency of occurrence.

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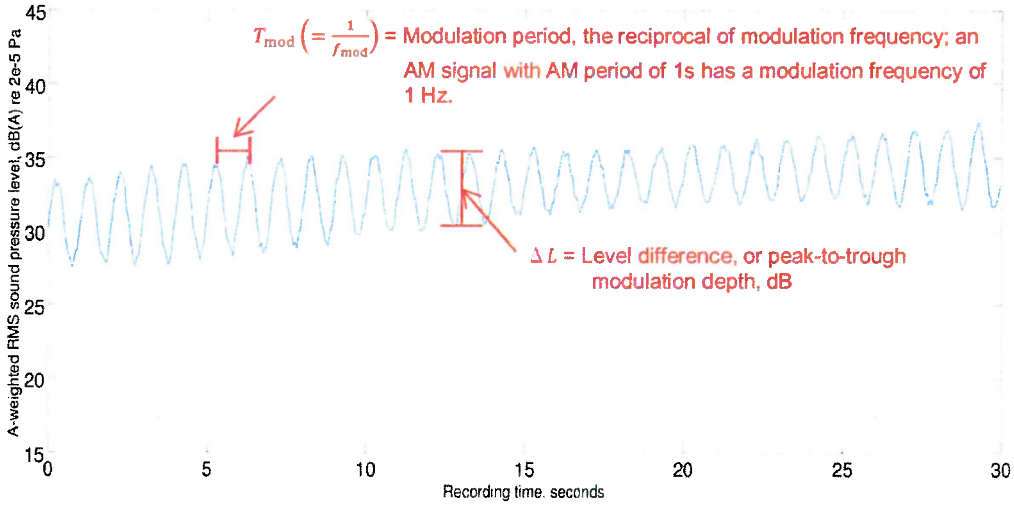
[1] *ETSU-R-97 The assessment and rating of noise from wind farms,* The Working Group on Noise from Wind Turbines Final Report September 1996

EXECUTIVE SUMMARY

WSP | Parsons Brinckerhoff has been commissioned by the Department of Energy and Climate Change (DECC) to undertake a review of research into the effects of and response to the acoustic character of wind turbine noise (WTN) known as Amplitude Modulation (AM).

The diagram below illustrates an example of a signal exhibiting amplitude modulation, and how the terms of modulation frequency and depth are defined.



In WTN, these fluctuating AM characteristics are commonly perceived as sounds that could be described as 'swish', or less frequently as 'thump'. Further definitions of amplitude modulation, fluctuation sensation and relevant acoustical concepts are described in an Appendix to this report.

At the time of writing, planning policy in England, Scotland, Wales and Northern Ireland refers to the ETSU-R-97[2] document for the assessment and rating of wind turbine noise. This planning guidance document is supplemented by a Good Practice Guide[3] (GPG) which is currently endorsed by all four Governments.

The ETSU-R-97 and GPG documents set out how noise assessments should be undertaken at the planning stage in the United Kingdom. It should be noted that the acoustic descriptor $L_{A90,\ 10min}$ is used for both the background noise and the wind turbine noise, and that the noise levels recommended in ETSU-R-97 *"take into account the character of noise described as blade swish."* That is to say that a certain level of amplitude modulation is included within the recommended noise limits.

The objective of this project has been to review the current evidence on the human response to WTN AM, evaluate the factors that contribute to human response (such as level, intermittency, frequency of occurrence, time of day, etc.), and recommend how excessive AM might be controlled through the use of a planning condition. The work has been undertaken in two Phases. This report relates to Phase 2, and should be read in conjunction with the Phase 1 report.

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[2] *ETSU-R-97 The assessment and rating of noise from wind farms,* The Working Group on Noise from Wind Turbines Final Report September 1996

[3] *A good practice guide to the application of ETSU-R-97 for the assessment and rating of wind turbine noise*, Institute of Acoustics, May 2013

The project work for Phase 2 has involved the collation and critical review of relevant papers, existing planning conditions, and existing planning policies where they relate to AM from wind turbines. Based on a combination of the evidence found and professional experience, a recommendation has been made on the potential make up of a planning condition to control AM. It should be noted that the condition has been designed only for new planning applications, and applicability for use in Statutory Nuisance investigations (where methodologies and acceptability criteria are different to those used for planning enforcement) on existing wind turbine sites has not been considered as part of this review.

The collated research was split into two categories. 'Category 1' papers comprised only those studies specifically investigating a scaled response to quantified AM WTN exposure, while 'Category 2' papers covered any other papers considered relevant to AM, such as complaints-triggered case-studies, broader epidemiological studies, and research into the psychoacoustics of WTN sound characteristics.

The main conclusions from the Category 1 studies reviewed in Section 3.2 can be summarised as follows:

- Within both laboratory and field test environments there is a strong association between increasing overall time-average levels of AM WTN-like sounds with increasing ratings of annoyance.
- Within a laboratory test environment:
  - subjects rated noticeable modulating WTN-like sounds as more annoying than similar noise without significant modulation;
  - the onset of fluctuation sensation for a modulating WTN-like sound appeared to be in the region of around 2 dB modulation depth;
  - increasing modulation depth above the onset of fluctuation sensation showed a broadly increasing trend in mean ratings of annoyance, but changes in mean annoyance rating tended to be relatively small and in some cases inconsistent;
  - equivalent annoyance ratings of AM and steady WTN-like sounds derived by level adjustment did not show a strong increasing trend with increasing depth of modulation; and
  - equivalent 'noisiness perception' of WTN-like AM sounds compared with a steady sound showed a gradually increasing trend with modulation depth.

It was also concluded that the results from both the laboratory and field studies should be approached with caution, since they may not readily translate to how people respond to WTN exposure in their homes[4].

The Category 2 papers reviewed in section 3.3 provide supporting evidence that:

- Perception of amplitude modulation in WTN and other environmental sounds affects subjective annoyance;
- There is a potential association between WTN-related annoyance and increased risks of sleep disturbance and stress;
- There are non-acoustic factors that play an important role in influencing the subjective annoyance attributed to noise from wind turbines, including sensitivity, attitude, situation,

[4] The field studies typically quantify noise exposure externally to the properties, but exposure (especially at night) could often be indoors.

aesthetic perception and economic benefits (this is common to many other industrial noise sources as well); and

- Annoyance due to AM WTN seems to be increased during normal resting periods, i.e. late evening / night-time / early morning. This could be due to increased sensitivity, greater AM prevalence or magnitude (e.g. due to diurnal variations in atmospheric conditions) or a combination of these factors.

It is noted that none of the Category 1 or 2 papers have been designed to answer the main aim of the current review in its entirety. The Category 1 studies have limited representativeness due to sample constraints and the artificiality of laboratory environments, whereas the Category 2 studies generally do not directly address the issue of AM WTN exposure-response. A meta-analysis of the identified studies was not possible due to the incompatibility of the various methodologies employed. Notwithstanding the limitations in the evidence, it was agreed with DECC that the factors to be included in a planning condition should be recommended based on the available evidence, and supplemented with professional experience.

The prevalence of unacceptable AM has not been evaluated as part of this study, and current state of the art is that the likely occurrence cannot be predicted at the planning stage. That does not preclude future research to determine the likelihood of AM occurring coming forward, and the development of a risk based evaluation, or similar. Due to the lack of ability to predict AM occurring on a site, and the reported difficulties in applying Statutory Nuisance provisions to control AM on existing sites, it is likely that the default position for a decision maker would be to apply the condition on all sites unless evidence is presented to the contrary.

The review concludes that where there are high levels of AM[5], the adverse effects could be significant. On this basis a control for AM is required, and this could be achieved via a suitably-worded planning condition imposing action on the operator of the turbine(s) to reduce the impacts identified. The condition must accord with existing planning guidance, and should be subject to legal advice on a case by case basis.

The few existing planning conditions or suggested methods in existence to control AM have been reviewed as part of the project. The methods include the well documented condition for the Den Brook[6] wind farm, a sample condition from Renewable UK[7] and proposals to use the method in British Standard BS 4142:2014.

Following the review, the elements required for a suitable planning condition to control AM have been recommended. It is noted that the AM control has only been designed for use with new planning applications; applicability for use in Statutory Nuisance investigations on existing wind turbine sites, where the legal regime is different (and outside the project scope), has not been considered as part of this review.

Any condition developed using the elements proposed in this study should be subject to a period of testing and review. The period should cover a number of sites where the condition has been implemented, and would be typically in the order of 2-5 years from planning approval being granted.

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[5] At present it is not possible to predict whether AM will or will not be prevalent on a site.
[6] http://www.den-brook.co.uk/
[7] http://www.renewableuk.com/en/publications/index.cfm/template-planning-condition-am-guidance-notes

PROPOSAL FOR PENALTY SCHEME

The review found that the planning condition should include the following elements:

- ✓ The AM condition should cover periods of complaints (due to unacceptable AM);
- ✓ The IOA-recommended metric[8] should be used to quantify AM (being the most robust available objective metric);
- ✓ Analysis should be made using individual 10-minute periods, applying the appropriate decibel 'penalty' to each period (using Figure 12), with subsequent bin- analysis;
- ✓ The AM decibel penalty should be additional to any decibel penalty for tonality;
- ✓ An additional decibel penalty is proposed during the night time period to account for the current difference between the night and day limits on many sites to ensure the control method works during the most sensitive period of the day, i.e. the night-time period (this addition would not apply to situations in which other planning conditions dictate the limits to be set as lower for night-time than for daytime).;
- ✓ Professional judgement should be used for planning enforcement of the AM condition in terms of frequency and duration of breaches identified; and
- ✓ The condition is only designed for upwind, 3-bladed turbines with rotational speeds up to approximately 32 RPM[9]. Further research is needed for turbines with higher rotational speeds or greater numbers of blades[10].

Further research has been recommended to supplement the limitations of the available research which underpins the above recommendation, although if the proposed penalty system, when implemented in a suitable planning condition, achieves the aim of reducing the impact from AM, then this research may not be required.

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[8] *A Method Rating Amplitude Modulation in Wind Turbine Noise,* Institute of Acoustics Noise Working Group (Wind Turbine Noise), 2016

[9] Specifically, the IOA metric is limited to a working upper modulation frequency of around 1.6 Hz, and the exposure-response research underpinning the proposed penalty system addresses modulation frequencies within the 0-1.5 Hz range.

[10] Both of these factors affect the AM character due to the 'blade passing frequency', as explained in Appendix A Glossary & Concepts.

1 INTRODUCTION

1.1 GENERAL

1.1.1 WSP | Parsons Brinckerhoff has been commissioned by the Department of Energy and Climate Change (DECC) to undertake a review of research into the effects of and response to the acoustic character of wind turbine noise (WTN) known as Amplitude Modulation (AM), or more specifically an increased level of modulation of aerodynamic noise as perceived at neighbouring residential dwellings. A glossary of acoustical terminology and concepts relevant to WTN and AM is included in Appendix A.

1.1.2 At the time of writing, planning policy in England, Scotland, Wales and Northern Ireland refers to the ETSU-R-97 (Energy Technology Support Unit Working Group on Noise from Wind Turbines, 1996) document for the assessment and rating of wind turbine noise. This planning guidance document is supplemented by a Good Practice Guide (GPG) which is currently endorsed by all four Governments, published by the Institute of Acoustics (IOA, 2013).

1.1.3 The ETSU-R-97 and GPG documents set out how noise assessments should be undertaken at the planning stage in the United Kingdom, The following aspects of the assessment process are particularly drawn out for later reference:

- The acoustic descriptor $L_{A90,\ 10min}$ is used for both the background noise and the wind turbine noise. In the case of wind turbine noise, the $L_{A90,\ 10min}$ is expected to be about 1.5-2.5dB(A) less than the L_{Aeq} measured over the same period. The reason stated for the use of the $L_{A90,\ 10min}$ descriptor for wind turbine noise is *"to allow reliable measurements to be made without corruption from relatively loud, transitory noise events from other sources."*
- The noise levels recommended in ETSU-R-97 *"take into account the character of noise described as blade swish."* That is to say that amplitude modulation is included within the recommended noise limits.
- ETSU-R-97 contains a separate assessment method for the identification of tonality in wind turbine noise, and a prescribed 'penalty'[11] system is stated which adds a decibel penalty to the overall noise level to be compared to the noise limits.

1.1.4 Concern about AM has been growing over recent years. The issue is routinely brought up at planning meetings and Public Inquiries for new wind turbine schemes, and it is alleged that complaints to Local Authorities relating to AM from wind turbines are increasing[12]. The extent of the problem is unclear, due in part to a lack of agreement on the definition of the type and degree of AM in wind turbine noise that could lead to complaints, and suggestions from residents groups that some complaints are not being reported through Local Authorities. While a national survey of noise attitudes (SoNA) and annoyance has recently been published (AECOM, 2015), wind turbine noise does not feature in the key findings, a fact that may reflect the relatively small proportion of the UK population exposed to WTN.

1.1.5 A recent study of wind farm impacts in Scotland indicated that AM could be perceived by residents in around two thirds of the ten case study sites, however specifics about the AM (such

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[11] Throughout this report, unless otherwise stated, 'penalty' refers to a numerical decibel penalty, as contrast with other forms, for example financial or legal penalties.

[12] See later reviews in Section 3 for more details.

as the magnitude affecting the descriptions) were less clear (SLR & Hoare Lea, 2015). The study also noted that a large majority of the surveyed residents were not affected by noise from the wind farms.

1.1.6 The Institute of Acoustics (IOA) formed an AM working group (AMWG) in the summer of 2014. The work of the group has been to undertake a review of the current knowledge of AM, to agree a definition of AM which is consistent with the likelihood of complaints, and to define a robust metric and methodology to quantify AM when it is present within wind turbine noise. A proposal for three metrics was consulted upon i n2015, and a preferred metric has been proposed as providing the most robust method to quantify AM in field measurements of wind turbine noise.

1.1.7 The objective of this project is to review the current evidence on the human response to AM, evaluate the factors that contribute to human response (such as level, intermittency, frequency of occurrence, time of day, etc.), and recommend how excessive AM might be controlled through the use of a planning condition. Where possible, a method to assess the likely impacts of the decision on the level of AM control in relation to current Government planning policy, and potential health effects will be set out.

1.1.8 The work has been undertaken in two Phases. This report relates to Phase 2, and should be read in conjunction with the Phase 1 report.

1.2 STUDY AIMS

In order to achieve the project objectives, the aims of this study are:

- To review the evidence on the effects of, and response to, AM in relation to wind turbines, focussing on any peer reviewed literature, and including but not limited to the research commissioned and published by RenewableUK (RUK) in December 2013;
- To work closely with the Institute of Acoustics' AM Working Group, who are expected to recommend a preferred metric and methodology for quantifying and assessing the level of AM in a sample of wind turbine noise data;
- To review the robustness of relevant dose-response relationships, including the one developed by the University of Salford as part of the RUK study;
- To consider how, in a policy context, the level(s) of AM in a sample of noise data should be interpreted;
- To recommend how excessive AM might be controlled through the use of an appropriate planning condition; and
- To consider the engineering/cost trade-offs of possible mitigation measures.

2 METHODOLOGY

2.1 APPROACH

2.1.1 The project work for Phase 2 has involved the following steps:

Phase 2

1. Undertake the search for relevant papers; Obtain copies of all relevant evidence, including the RUK work
2. Critically review the robustness of the relevant studies into the subjective response to AM, and any penalty schemes
3. Critically review the RUK proposed planning condition in the context of ETSU-R-97[13] and the "six tests" for a planning condition. These tests are listed in the NPPF[14] and other Devolved Authority Planning Guidance
4. Summarise (for a non-technical audience) main findings of the review
5. Recommend an appropriate penalty scheme (or alternative) for use in a planning condition, compatible with the IOA AM Working Group's preferred metric
6. Prepare a draft report summarising the main findings and setting out clear recommendations, in a form suitable for publication by DECC.
7. Amend the report in light of peer review comments, and produce a final report.
8. Present the main findings and recommendations to the IOA's AM Working Group and, separately, to DECC's Steering Group.

2.1.2 This report includes the output from steps 1 to 6 inclusive.

2.2 STAKEHOLDER CONTACT

2.2.1 A number of Stakeholders were contacted to raise awareness of the research, and secondly solicit responses on research work in hand, or papers about to be released. These Stakeholders represent a wide range of Local Authorities, Trade Bodies, Residents Groups and Universities

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[13] Energy Technology Support Unit Working Group on Noise from Wind Turbines (1996)
[14] National Planning Policy Framework in England (DCLG, 2012), or equivalent documents in Wales, Scotland and Northern Ireland

involved in research in the field. The list of Stakeholders was drawn up in consultation with the OAM Review Steering Group, and the final list of those consulted is shown in Table 1.

Table 1: Stakeholder List

No.	Body
1	Anglesey/ Ynys Mon Council
2	Armagh, Banbridge and Craigavon Council
3	Cardiff University Psychology Dept
4	Carmarthenshire County Council
5	Chartered Institute of Environmental Health
6	Friends of the Earth / (Cymru)
7	Harrogate Borough Council
8	Highland Council
9	Huntingdonshire District Council
10	Institute of Acoustics AM Working Group
11	Institute of Acoustics Scottish Branch
12	Local Government Association
13	Midlothian Council
14	Montgomeryshire Against Pylons
15 & 16	Planning Scotland
17	Powys District Council
18	Powys Wind Farm Supporters
19	Renewable UK
20	Scotland Against Spin
21	Scottish Borders Council
22	Scottish Government Inquiry Reports Unit
23	Scottish Industry Policy
24	South Cambridgeshire District Council
25	The Independent Noise Working Group
26	The Planning Inspectorate
27	Waveney District Council
28	Welsh Local Government Association
29	West Lothian Council
	Research Institutions:
30	The University of Salford
31	The University of Tokyo
32	Seoul National University
33	Ghent University

2.2.2 A summary of the responses is included in Section 3.1.

2.3 EVIDENCE REVIEW METHODOLOGY

OVERVIEW

2.3.1 The purpose of the literature review was to establish the current level of knowledge of AM, and the extent to which the human response to AM is understood. In order to undertake the reviews, the papers were initially categorised as follows:

1. Research directly addressing a scaled response to a quantified human exposure to amplitude-modulated wind turbine noise (real or simulated)
2. Other papers (e.g. self-reported complaints, anecdotal evidence, etc.)

2.3.2 Category 1 papers were each reviewed by two of the independent external reviewers. Category 2 papers have been catalogued, reviewed by the internal research team, and where deemed to be important, also reviewed by an independent external reviewer. A summary of the review outcomes for Category 1 and 2 papers are contained in sections 3.2 and 3.3 respectively.

PROCESS

2.3.3 The following databases were searched for 'black' literature (i.e. independently peer-reviewed and published in recognised and reputable journals, and searchable in research databases):

- → Web of Science
- → PubMed

2.3.4 The search terms used were those identified and agreed at Phase 1, as summarised in Table 2.

Table 2: Keywords for Literature Search

a)	Wind Turbine Noise	
	NOISE	QUALITY OF LIFE
	WT	SOUND QUALITY
	WIND TURBINE	JUDGEMENT
	AMPLITUDE	FLUCTUATION
	MODULATION	FLUCTUATING
	WIND FARM	FLUCTUATE
	WTG	WIND TURBINE GENERATOR
	DOSE	NUISANCE
	RESPONSE	COMPLAINTS
	DOSE-RESPONSE	EXPOSURE
	ANNOYANCE	ACCEPTABILITY RATING
	ANNOYING	THRESHOLD
	SLEEP	PENALTY
	HEALTH	SWISH
	WELLBEING	THUMP
	AM	MENTAL HEALTH
	RHYTHMIC	NOISE SENSITIVITY
	FLUTTER	EXPERIENCE
	SWOOSH	EXPERIENTIAL
	WHOOSH	LOW FREQUENCY

Table 2: Keywords for Literature Search

b)	Other Areas	
	NOISE	QUALITY OF LIFE
	AMPLITUDE	SOUND QUALITY
	MODULATION	PRODUCT SOUND QUALITY
	AM	JUDGEMENT
	DOSE	FLUCTUATION
	RESPONSE	FLUCTUATING
	DOSE-RESPONSE	FLUCTUATE
	ANNOYANCE	NUISANCE
	ANNOYING	COMPLAINTS
	SLEEP	EXPOSURE
	HEALTH	ACCEPTABILITY RATING
	WELLBEING	HELICOPTER BLADE SLAP
	THRESHOLD	HELICOPTER NOISE
	PENALTY	SWISH
	FLUTTER	MENTAL HEALTH
	RHYTHMIC	NOISE SENSITIVITY
	THUMP	LOW FREQUENCY

2.3.5 These terms were combined where possible using Boolean operators to narrow the results. The date range was generally limited to 2000-present. Example combinations are given in Table 3 (other combinations were also employed):

Table 3: Example Combinations of Keywords for Literature Search

Database	Search terms	Results
Web of Science	TS=((nois* OR sound) AND ((wind NEAR (farm* OR turbine* OR generator)) OR WTG OR WT) AND (AM OR amplitude OR modulation OR rhythmic OR flutter OR swoosh OR whoosh OR fluctuat* OR swish OR thump OR "low frequency") AND (dose OR response OR dose-response OR exposure OR exposure-response OR annoy* OR sleep OR health OR (well NEAR/5 being) OR "quality of life" OR "sound quality" OR judgement OR nuisance OR complaints OR "acceptability rating" OR threshold OR penalty OR (mental NEAR health) OR sensitiv* OR experien*))	146 results on 30/10/2015
PubMed	((((((((nois*[Title/Abstract] OR sound[Title/Abstract])) AND ("wind farm"[Title/Abstract] OR "wind turbine"[Title/Abstract] OR "wind farms"[Title/Abstract] OR "wind turbines"[Title/Abstract] OR WTG[Title/Abstract] OR WT[Title/Abstract]))) AND (amplitude[Title/Abstract] OR modulation[Title/Abstract] OR AM[Title/Abstract] OR exposure[Title/Abstract] OR dose[Title/Abstract] OR response[Title/Abstract])))))	115 results on 03/11/2015

2.3.6 The titles and abstracts of the search results were examined to identify relevant literature. In addition to the searchable databases, conference proceedings were searched for further 'grey' literature (i.e. non-independently peer reviewed, or where peer review status is uncertain), including from the following sources:

- International Commission on the Biological Effects of Noise (ICBEN) Congress
- International Meeting/Conference on Wind Turbine Noise
- International Meeting on Low Frequency Noise and Vibration
- International Congress on Sound and Vibration (ICSV)
- International/European Congress and Exposition on Noise Control Engineering (Inter-noise/EuroNoise)

2.3.7 Finally, any other additional literature made known to the research group or identified from reference lists was added to the database. A total of 134 publications were identified using this process. The full list of identified papers is included in Appendix B.

2.3.8 The titles and abstracts of the list were reviewed to classify the papers in terms of relevance to the study aims. On this basis, papers addressing only physical source mechanisms and measurement techniques for AM WTN were specifically excluded. At the end of this process, 69 separate publications were shortlisted for more detailed review.

2.3.9 The detailed reviews were carried out using a standard process framework to extract specific details about each paper, including the quality, conclusions and risks of bias (see Appendix C for included categories). At the inception of the review process it was hoped that a recognised research quality rating scale could be applied to allow direct comparison, and the Newcastle-Ottawa Scale (Wells, et al.) was initially considered as a potentially useful candidate (Zeng, et al., 2014). It swiftly became clear that the design of the most relevant studies, which were primarily laboratory-based, uncontrolled and cross-sectional in nature, did not lend themselves well to this type of rating scale and the results would therefore not yield useful comparative information. As a result it was decided that weighted consideration would be determined by reviewers based on their judgement of the importance of the study relative to the aims of this research. For the key publications, i.e. those within the first category described above, two external reviewers independently reviewed each paper, and the results were compared. Conclusions and applications to be drawn from the studies were agreed by discussion.

2.3.10 Prior to the first draft of this review report, a final check was made (16th March 2016) in the database sources referred to above, to ensure no relevant new research had been published in the interim.

STUDY LIMITATIONS

2.3.11 It is noted that applying the search terms and filtering the papers as stated could introduce selection and publication bias into the process. The risk of bias in any review cannot be eliminated, but steps were taken to minimise this risk as described above, i.e. by searching more than one database, including searches of grey literature, by defining the categorisation criteria and by defining a protocol for reviewers to complete the reviews.

2.3.12 For studies falling into Category 1, the risks of selection bias are extremely low, given the relatively small body of existing literature.

2.3.13 Selection bias in Category 2 is more probable due to the wider range and volume of studies identified, and it has been acknowledged in section 3.3 that some studies have been specifically excluded. This is most relevant to the epidemiological papers addressing the potential health effects relating to general WTN exposure, in which the AM component has not been specifically quantified or rated. This body of literature is relatively large, and represents a wide range of different theories, results, views and opinions. The current review of this work has focussed on recent, existing systematic reviews, and recent large-scale field studies only. The conclusions drawn from this work may therefore be questioned on the basis of selection bias, but it should be noted that these conclusions do not impose significant practical influence on the outputs of this research, i.e. a recommendation for an AM planning control.

2.3.14 Wind turbine acoustics is a swiftly-developing field of knowledge, and new research is published on a regular basis. The drafting and review process of this report took place over a period of months, and consequently new study material inevitably came to light after the review period had been completed. In particular, two papers appeared in the peer-reviewed literature prior to the final draft that would have met the Category 1 criteria in the review. These papers have not been reviewed by the independent external reviewers, but the main findings and possible implications have been briefly outlined by the internal research team in the Annexes to this report (Annex 1 and Annex 2). To summarise the findings, both studies are believed to broadly support the recommendations made for a proposed planning control.

3 REVIEW SUMMARY

3.1 STAKEHOLDER RESPONSES

3.1.1 A number of Stakeholders identified during the Phase 1 work were contacted by email firstly to raise awareness of the research, and secondly solicit responses on research work in hand, or papers about to be released. A number of the Stakeholders responded to the email, the key points of which are summarised below:

- ✓ No new WTN AM research was identified that the team were not able to find through the searches undertaken, or from previous knowledge that was considered to be relevant to the study. Other non-AM research was noted by two Stakeholders, but was also not relevant to the study;
- ✓ Some of the Local Authorities contacted are currently investigating noise complaints from wind farms sites with suspected AM aspects. None of these investigations had been concluded at the time of writing (Jan 2016); and
- ✓ The papers produced by the Independent Noise Working Group (INWG)[15] were referenced a number of times. These have been included in the Category 2 review in section 3.3.

3.1.2 There was also general feedback that there is a need for an AM control through the planning system.

3.2 CATEGORY 1 PAPERS

INTRODUCTION

3.2.1 The literature search yielded five studies directly investigating a scaled response to quantified AM WTN exposure: 3 laboratory-based and 3 field-based (one study was composed of both field and laboratory components).

3.2.2 The identification details of these studies are summarised below, including the nature of the publication (in square brackets; black = independently peer-reviewed paper; grey = not independently peer-reviewed, or peer review status uncertain).

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15 http://www.heatonharris.com/reports-publications

Table 4: Category 1 Research Papers			
Study	**Lead research group**	**Relevant key publications**	**Study type**
A	Seoul National University, Korea	*An estimation method of the amplitude modulation in wind turbine noise for community response assessment* (Lee, Kim, Lee, Kim, & Lee, 2009) [grey] *Annoyance caused by amplitude modulation of wind turbine noise* (Lee, Kim, Choi, & Lee, 2011) [black] *An experimental study on annoyance scale for assessment of wind turbine noise* (Seong, Lee, Gwak, Cho, Hong, & Lee, 2013a) [black] *An experimental study on rating scale for annoyance due to wind turbine noise* (Seong, Lee, Gwak, Cho, Hong, & Lee, 2013b) [grey]	Lab
B	The University of Tokyo, Japan	*Study on the amplitude modulation of wind tur bine noise part 2 – auditory experiments* (Yokoyama, Sakamoto, & Tachibana, 2013) [grey] *Audibility of low frequency components in wind turbine noise* (Yokoyama, Sakamoto, & Tachibana, 2014a) [grey] *Perception of low frequency components in wind turbine noise* (Yokoyama, Sakamoto, & Tachibana, 2014b) [black] *Subjective experiments on the auditory impression of the amplitude modulation sound contained in wind turbine noise* (Yokoyama, Koboyashi, Sakamoto, & Tachibana, 2015) [grey] *Nationwide field measurements of wind turbine noise in Japan* (Tachibana, Yano, Fukushima, & Sueoka, 2014) [black] *Outcome of systematic research on wind turbine noise in Japan* (Tachibana, 2014) [grey]	Lab/field
C	The University of Salford, UK	*Wind turbine amplitude modulation: research to improve understanding as to its cause & effect. Work package B(2): development of an AM dose-response relationship* (von Hünerbein, King, Piper, & Cand, 2013) [grey] *Affective response to amplitude modulated wind turbine noise* (von Hünerbein & Piper, 2015) [grey]	Lab
D	Ghent University, Belgium	*Wind turbine noise: annoyance and alternative exposure indicators* (Bockstael, Dekoninck, de Coensel, Oldoni, Can, & Botteldooren, 2011) [grey] *Reduction of wind turbine noise annoyance: an operational approach* (Bockstael, Dekoninck, Can, Oldoni, de Coensel, & Botteldooren, 2012) [black]	Field
E	The University of Adelaide, Australia	*Characterisation of noise in homes affected by wind turbine noise* (Nobbs, Doolan, & and Moreau, 2012) [grey]	Field

REVIEW

3.2.3 The research papers discussed in this section were reviewed by the independent external reviewers.

STUDY A

SUMMARY I

3.2.4 A group at Seoul National University conducted a state-funded laboratory study aimed at developing a scale for rating annoyance from AM WTN.

3.2.5 There were two distinct stages to this work: the first (I) is described by Lee et al. (2009), (2011). This experiment used modified turbine sound recordings as stimuli and subjects rated 'annoyance' on an 11-point scale according to ISO 15666:2003 (ISO, 2003). The results indicated a strong and statistically significant association between the annoyance and the overall A-weighted time-averaged level of the noise, as shown in the reproduced Figure 1. The direct relationship between the modulation and the mean annoyance ratings was not presented graphically, but reanalysis of the results produces the charts shown in Figure 2, with overall average level as a parameter. This indicates a broadly increasing trend, but with relatively small changes in mean annoyance over the range of modulation depths[16]; almost all of the samples showed a change in the mean annoyance of less than 1 scale interval across the entire range of modulation depths (compared with 4-5 intervals for changes in level).

3.2.6 The spread in the data was also not presented and the statistical analysis produced a range of results: analysis of variance (ANOVA) indicated a significant relationship between annoyance and modulation depth at the 5% level, but statistically significant differences were not consistent across the stimuli set; only the samples featuring the two maximum and the minimum AM depths[16] could be distinguished in paired comparisons (also at the 5% level).

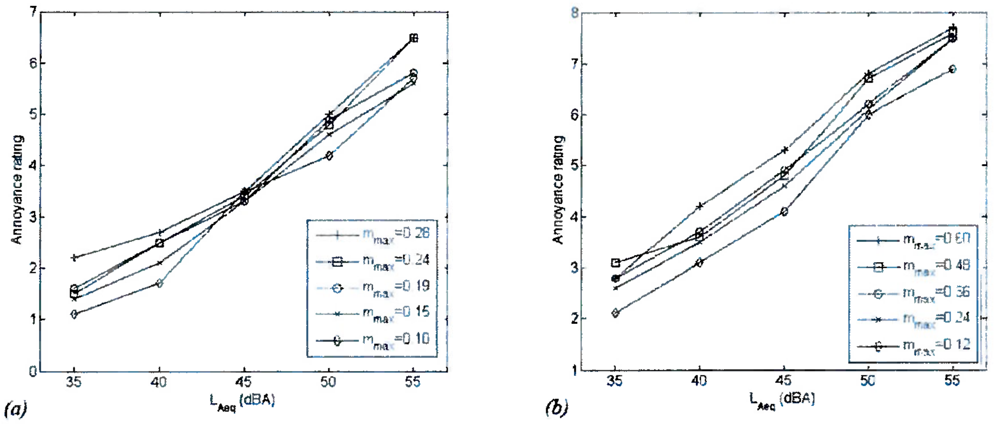


Figure 1: Association of amplitude-modulated wind turbine noise level with mean annoyance ratings over a range of modulation depths (as parameter) for two sample sets, one with higher low-frequency spectral content (left) and one with higher mid and high-frequency content (right), from (Lee, Kim, Lee, Kim, & Lee, 2009)

[16] In terms of $\Delta L = 20\log_{10}(1+m/1-m)$ as defined by Fastl and Zwicker (2007), but replacing the general modulation factor m with the spectral maximum m_{max} obtained using a Fourier Transform method.

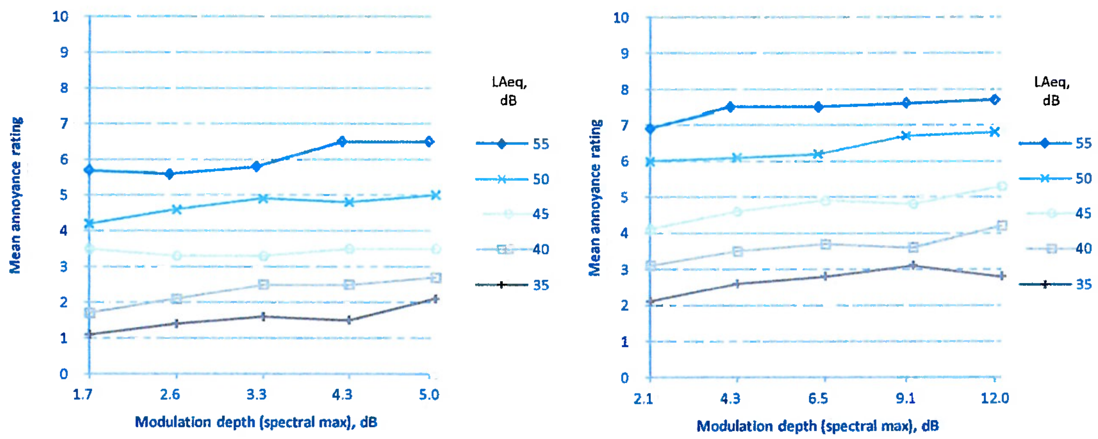


Figure 2: Estimated relationship between wind turbine noise amplitude modulation (maximum spectral modulation depth) and mean annoyance ratings corresponding with the results in Figure 1 with overall average level (L_{Aeq}[17]) as parameter, reanalysed from (Lee, Kim, Lee, Kim, & Lee, 2009)

DISCUSSION I

3.2.7 Great care and attention was applied to the stimuli used in this study to ensure that that the parametric changes were closely controlled. However, the method for obtaining subjective responses is questionable: the application of a social survey technique to a laboratory environment could have an uncertain influence on the results. For example, the briefing of the subjects is likely to affect their interpretation of how to rate 'annoyance', and any contextual information provided to subjects is not detailed. Furthermore, the scale used introduces the idea that the subject is likely to find the noise annoying, when this is not necessarily certain. Although having subjects rate 'annoyance' responses in a laboratory setting is not unusual, it does present potential problems: the responses assigned by subjects to their perception of the noise may not necessarily really reflect 'annoyance' given that people in a 'safe' and artificial environment would presumably feel little, if any, of the emotive experience that feeling real annoyance often entails.

3.2.8 The sample size used in the experiment is small (30 subjects, although again, not unusual for this type of study), and unlikely to be widely representative of a typical population of wind turbine noise-exposed communities (all subjects were aged 20-30 years). It is also noted that the delivery method used employed headphones, which, even with binaural processing, would not give a natural representation of WTN exposure within its typical context.

SUMMARY II

3.2.9 The second phase (II) is reported in two similar papers by Seong et al. (2013a) (2013b). The stimulus used was changed to the output from a simulation turbine noise model and a similar sample recruited (32 subjects aged 20-34) for further laboratory listening tests. A slightly different 7-point response scale was used to record annoyance. Good correlations were shown using linear regression for mean annoyance with equivalent level (L_{Aeq}), fluctuation strength[18], and maximum level (L_{AFmax}), with the correlation value increasing for each respective metric. However, only the maximum level correlation was shown to have equal-variance by residuals testing (i.e. that the regression can be said to be a good model for the relationship between the variables).

[17] A-weighted equivalent continuous sound pressure level.
[18] Defined in (Fastl & Zwicker, 2007). NB: Includes overall broadband noise level as a parameter.

3.2.10 An association was also indicated between annoyance and the simulated direction of incidence relative to the turbine. Examination of the associated model description (Lee, Lee, & Lee, 2013) shows that the position of highest annoyance corresponds to the direction in which both the level (L_{Aeq}) and modulation depth (defined as L_{AFmax}-L_{AFmin}) have high magnitudes; the position of lowest annoyance corresponds to the direction in which modulation depth is at its highest magnitude, but the overall time-average level is at its minimum (due to simulated interference effects in the crosswind direction).

DISCUSSION II

3.2.11 This study shows some interesting results and could indicate an avenue of further research; the authors were contacted to enquire about more recent research developments but no response was received prior to completing this review.

3.2.12 The results again indicate that modulation and level affect subjective laboratory ratings of annoyance, and that the level seems to have stronger influence.

OVERALL

3.2.13 The main conclusion drawn from these studies is that changes in the overall time-average level have a stronger influence on how perception of AM WTN is subjectively assessed than changes in the modulation depth, although the latter is shown to have an observable affect (as might be expected). Application of these lab results to a real situation should be approached cautiously in view of the limitations of the experimental approach and the subject sample.

STUDY B

SUMMARY

3.2.14 These studies formed part of a large-scale investigation into wind turbine noise in Japan, incorporating field measurements and social surveys along with the laboratory exposure-response studies into AM, low-frequency noise (LFN) and infrasound components.

3.2.15 Two papers by Yokoyama et al. (2014a) (2014b) report the results from tests designed to detect thresholds for perception of amplitude modulated LFN and infrasound in WTN. The six stimuli included three samples of recorded AM WTN with depths between 2.1 and 3.7 dB, measured as D_{AM}[19] (roughly equivalent to around 3-5 dB ΔL). The experiment was designed to detect the onset of sensation across the frequency range; it was found that low-frequency spectral components of the WTN below the 31.5Hz third-octave band were inaudible for the majority of subjects.

3.2.16 Another set of experiments continued the work by examining the thresholds of fluctuation sensation using AM WTN recordings; the experiment used filtering to modify the samples in a similar way to the LFN audibility threshold experiments, and it was found that spectral content below around 100 Hz did not contribute significantly to fluctuation sensation for the majority of subjects (Yokoyama, Sakamoto, & Tachibana, 2013) (Yokoyama, Koboyashi, Sakamoto, & Tachibana, 2015).

3.2.17 Further experiments reported by Yokoyama et al. (2013), (2015) directly examined the effect of varying the modulation depth of synthesised AM broadband noise (filtered to simulate WTN) on

[19] Defined as the width in dB between the 5th and 95th percentiles of the difference between fast and slow weighted sound pressure levels in a WTN sample (3-minute samples used).

the perceived fluctuation and 'noisiness' sensation by a method of paired comparison adjustment: 10s samples were compared with and without AM content at two overall time-averaged levels (35 and 45 dB $L_{Aeq,10s}$), and subjects adjusted the level of the AM sound until 'noisiness' was deemed equal with the unmodulated sample. The results broadly indicated a general increase in perceived 'noisiness' with AM depth, although the spread of the responses widened considerably as AM depth was increased, indicating greater uncertainty in the mean result. For AM depths less than 4 dB, the mean changes in the adjusted levels were no greater than 1dB, as shown in Figure 3. It can also be seen that when the signals were effectively identical (i.e. at 0 dB modulation depth), some respondents still made small adjustments of up to 2 dB, indicating the residual uncertainties involved in the perceptual comparison.

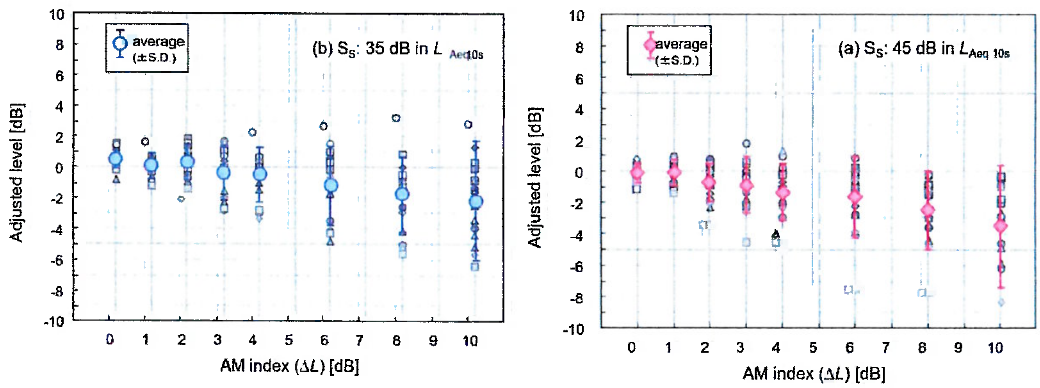
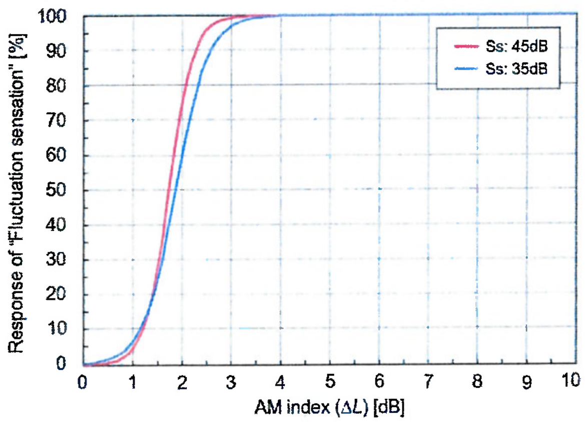


Figure 3: Level adjustments of amplitude-modulated noise to achieve equivalent perceived noisiness with a steady-state noise, from (Yokoyama, Koboyashi, Sakamoto, & Tachibana, 2015)

3.2.18 It is also noted that the mean differences tended to be slightly larger for the 45 dB L_{Aeq} stimuli compared with the 35 dB L_{Aeq} stimuli. Examination of the individual results indicates that one particular subject (represented with circular data points) consistently gave responses for the 35 dB stimuli that were opposite to the general trend, indicating their perception of the steady noise as 'noisier'. This would have influenced the mean differences somewhat, and this result is not replicated in the 45 dB stimuli set. Consequently it appears uncertain whether the results indicate a genuine perceptual difference between the two stimuli sets, or whether this result may reflect some uncertainty in the experimental design and, potentially, differing interpretations of the intended responses.

3.2.19 A subjective assessment of fluctuation sensation was made for each sample using descriptive onomatopoeic words (such as "*zah, zah*", "*guon, guon*"). This allowed an assessment of the AM depth onset of fluctuation sensation, which was analysed as around 2 dB ΔL; this is in agreement with the earlier findings of Vos et al. (2010a) [grey], as reported by van den Berg et al. (2011) [grey].



ΔL derived from $L_{Ap,F}$

Figure 4: Perception of Fluctuation in synthesised amplitude-modulated wind turbine noise, from (Yokoyama, Koboyashi, Sakamoto, & Tachibana, 2015)

3.2.20 The field study component of the research included measurements of WTN at 34 wind farms around Japan, from which useful data for 29 sites were analysed (Tachibana, Yano, Fukushima, & Sueoka, 2014). The social survey aspect of the work, reported by Kuwano et al (2014), did not specifically investigate the influence of AM in the responses received from the 1076 participants (including 332 respondents from 16 non-wind farm sites, used as a control group). The developed D_{AM} metric was applied to the measurements made at 18 of the wind farm sites, which was used to produce a distribution of occurrence of measured modulation depth in the field data, reproduced in Figure 5. The researchers suggested that the distribution indicated that AM might be above the threshold of perception in about 75% of the measured WTN data, at the measurement points. The noise measurement points at each site were uniformly distributed within a distance of 100-1000m from the turbines. The study does not clarify which measurement points were used (i.e. at what proximity to the turbines) to analyse the data to produce the D_{AM} distribution, so the applicability of the 75% AM perception statistic to the experience of residents cannot be ascertained.

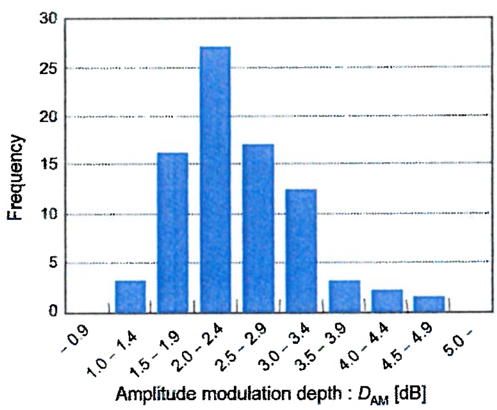


Figure 5: Distribution of D_{AM} in the field data from 18 Japanese wind farm sites, from (Tachibana, Yano, Fukushima, & Sueoka, 2014)

DISCUSSION

3.2.21 The approach of this study had some useful qualities. The laboratory components focussed on perception by i) identifying the onset of fluctuation sensation for subjects, and ii) rating their perception in terms of a subjective assessment of 'noisiness'. It avoided a requirement for subjects to rate 'annoyance', which is a potentially complex, emotional response to perception. Nonetheless, it is not clear how the subjects might have interpreted the request for evaluation of 'noisiness'; the spread in the results may reflect different interpretations, and the variation between individual responses would be exacerbated by the small sample size: results from 15 subjects were reported in the 2013 paper, with 17 reported in the 2015 version (the paper is not explicitly clear as to whether the latter was a fresh attempt at the experiment or simply added more subjects to the existing dataset, but the results presented are very similar). The limitations of the lab study in terms of the sample size and representativeness, as well as the stimuli used and the lab setting should be borne in mind when considering wider application.

3.2.22 The development of the D_{AM} metric was intended to provide a "*simple and practical*" method for measuring AM in WTN. Some shortcomings in applying this method to real long-term field data have been highlighted in later work by Large et al (2015) and by the IOA AMWG (2015a), due to its susceptibility to influence by extraneous non-WT noise. It is unclear whether this issue was detected by the original research team and to what extent the results reported by Tachibana et al (2014) may have been affected by extraneous noise, or what mitigating controls were put in place to protect against this possibility.

3.2.23 The conclusions that can be drawn from this study include i) the onset of fluctuation sensation for the sounds is somewhere around 2 dB modulation depth, using the AM index adopted by the Tokyo group; ii) there appeared to be relatively small perceptual differences (i.e. in terms of 'noisiness', which might be considered as the distinctiveness between the sounds used) for changes in modulation of less than 4 dB depth; and iii) for changes in modulation depth of 4 dB and above, perceived differences in 'distinctiveness' of the AM stimuli increasingly varied; a small number of the subjects perceived a relatively large difference, while the majority perceived differences in a smaller range, averaging to around 1.5-3.5 dB.

STUDY C

SUMMARY

3.2. 24 Research was carried out by the Acoustics Research Centre at the University of Salford on behalf of RenewableUK (RUK) and reported by von Hünerbein et al (2013), (2015). A staged approach to the study investigated sensitivity to a range of possible parameters with a potential influence on perception of AM WTN. The noise exposure employed synthesised WTN samples that allowed the parameters to be systematically varied, including level, modulation depth, envelope shape, spectral character and modulation frequency. The results of the preliminary tests were used to identify which parameters would be carried forward for final testing, which included level and modulation depth; other parameters were either fixed at a representative setting or considered of negligible influence. In the final test subjects were asked to imagine the exposure as if they were at home relaxing in the garden, and some additional measures were taken to reinforce the contextualisation. The subjects rated their 'annoyance' using a modified scale based on ISO 15666:2003 (ISO, 2003).

3.2.25 As reproduced in Figure 6 and Figure 7, the results bear similarity to those obtained by Lee et al. (2009) (2011) (i.e. compare with Figure 1 and Figure 2, however, it should be noted that the 'modulation depths' used are derived using quite different methods in each study). Increases in average level corresponded with relatively large increases in the annoyance rating; increases in modulation depth (keeping average level constant) resulted in smaller changes in rated annoyance, which were not found to be statistically significant at the 5% level (although a relational trend can be observed). It was concluded that average level dominated the annoyance response (von Hünerbein & Piper, 2015).

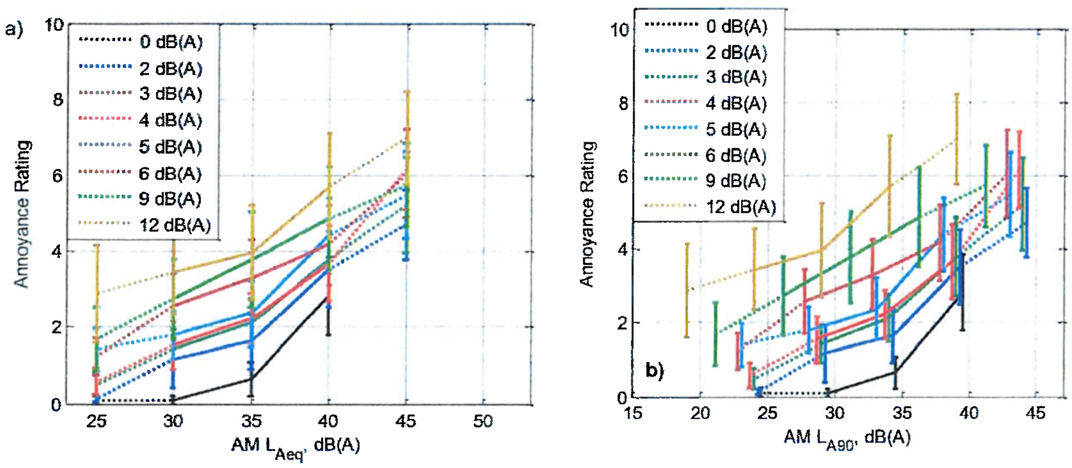


Figure 6: Association of amplitude-modulated wind turbine noise level measured as L_{Aeq} (left) and L_{A90}[20] (right) with annoyance ratings, with modulation depth as parameter, from (von Hünerbein, King, Piper, & Cand, 2013) – dotted lines indicate results from reduced sample, error bars: 95% confidence intervals (CI)

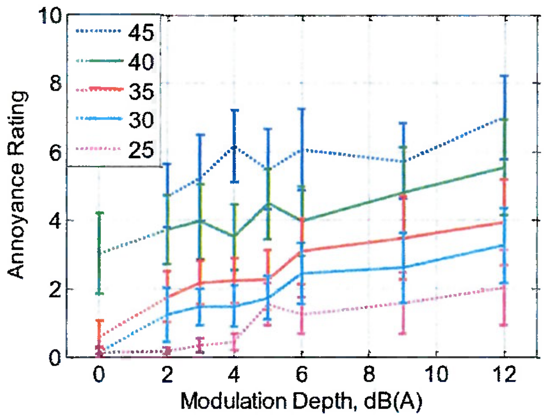


Figure 7: Relationship between modulation depth and annoyance rating with overall average level (L_{Aeq}) as parameter, from (von Hünerbein & Piper, 2015) – dotted lines indicate results from reduced sample, error bars 95% CI

3.2.26 The tests also examined the 'equivalent annoyance' using a method of paired comparison adjustment in a similar way to Yokoyama et al. (2013). The experiment compared an 'Adaptive Broadband Stimulus' (ABBS) signal (a noise signal of steady starting amplitude, that could be modified, or adapted, by the participant to achieve equivalence of annoyance with the paired AM signal). The results of this experiment broadly indicated that most subjects perceived relatively small or inconsistent differences for changes in modulation depths > 2 dB, even up to 12 dB depth, as reproduced in Figure 8. An anomalous result was obtained for 0 dB depth (comparison of identical stimuli), attributed to possible expectation bias amongst participants (i.e. they may have assumed that every stimuli pair presented must be different).

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[20] A-weighted sound pressure level exceeded for 90% of the measurement interval.

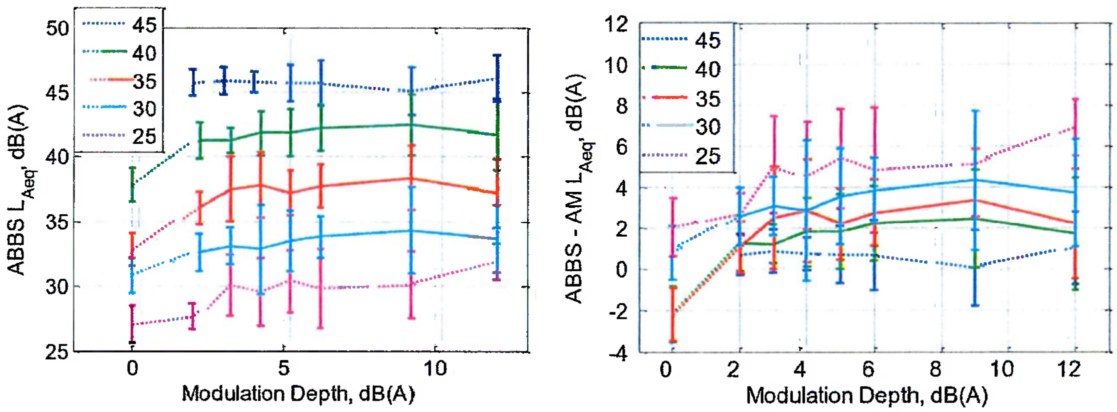

Figure 8: Level adjustments of broadband noise to achieve equivalent annoyance compared with amplitude-modulated noise of a fixed average level (as parameter), as adjusted levels (left), and normalised to adjustment level differences by subtracting the average level (L_{Aeq}) of the amplitude-modulated noise (right), reproduced from (von Hünerbein, King, Piper, & Cand, 2013) – dotted lines indicate results from reduced sample, error bars 95% CI

3.2.27 The analysis produced average adjustments of 1.7 dB at 40 dB L_{Aeq} and 3.5 dB at 30 dB L_{Aeq}; this trend (i.e. smaller adjustment differences with increasing level) was confirmed across the level range, with an overall average adjustment value of 2.3 dB. This scale of level adjustments is similar to those obtained by Yokoyama et al. (2015), despite differences in the experimental design: i) in the Salford study, subjects adjusted the levels to give equivalent 'annoyance' responses, whereas in the Tokyo study, subjects adjusted the levels to give equivalent perception of noisiness; ii) the modulation depth metrics used were derived using different approaches; iii) the adjustment method employed was the reverse in each study, i.e. one approach (Salford) adjusted the steady broadband noise to be subjectively equivalent to the AM, while the other (Tokyo) adjusted the AM to be equivalent to the steady broadband; and iv) the stimuli used and the delivery systems were slightly different.

3.2.28 The RUK study also analysed the same adjustments against the L_{A90} of the AM signal. The results of this analysis are shown in Figure 9.

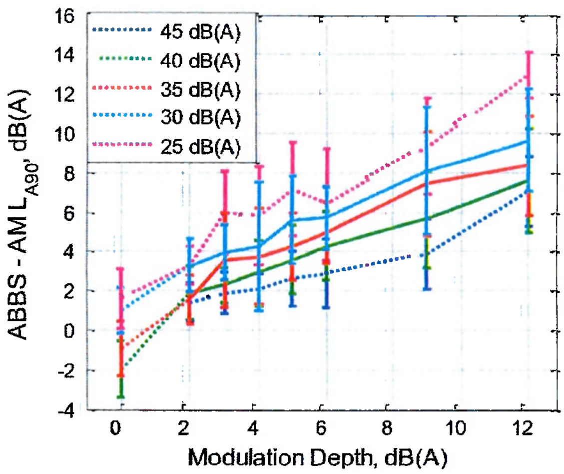

Figure 9: Level adjustments of broadband noise to achieve equivalent annoyance compared with amplitude-modulated noise of a fixed average level (L_{Aeq} as parameter), as normalised by subtracting the 90% exceeded level (L_{A90}) of the amplitude-modulated noise (right), from (von Hünerbein, King, Piper, & Cand, 2013) – dotted lines indicate results from reduced sample, error bars 95% CI

3.2.29 The results in Figure 9 appear to show a more linear relationship for L_{A90}-normalised equivalent annoyance with modulation depth than using the L_{Aeq} normalisation (for example, compare with the right side of Figure 8). In analysing these results, the study authors note that "*in summary L_{A90} might be a suitable parameter to express annoyance ratings in the psychoacoustic context and should be investigated more closely in future studies*". This is discussed further below.

3.2.30 In 'sensitivity tests' conducted using smaller sample sets, the authors examined a number of other parameters that were thought to have potential to influence the results, including modulation frequency. The results indicated that the AM signal with a 1.5 Hz modulation frequency was rated more annoying than a signal with a 0.8 Hz modulation frequency. This is also discussed further below.

DISCUSSION

3.2.31 The similarity of these results with those from Lee et al. (2011) is especially notable given that there were differences in the exposure method used: in particular the Salford approach (in the final test) delivered the stimuli over an ambisonic loudspeaker array rather than headphones. The scales used in the studies to measure response were also similar but had differences: the Salford approach allowed subjects to input their rating on a continuous scale, whereas the Seoul rating used a discrete numerical input. These factors might be expected to somewhat affect the outcome of the results, but there is a remarkable consistency between the study outcomes.

3.2.32 The L_{A90}-based analysis of the equivalent annoyance test results partly illustrate a feature of the synthetic stimuli employed; as the modulation depth increases and the average level (L_{Aeq}) is held constant, the L_{A90} is reduced. As a result, the normalisation of the adjusted broadband noise level by subtracting the amplitude-modulated L_{A90} results in a larger difference (between ABBS L_{Aeq} and AM L_{A90}), which increases in magnitude with increasing modulation depth. In field signals, this would not necessarily be the case, as the average level of a real modulating WTN signal is not constant, and could increase with increasing modulation depth, whereas the non-WT background noise may be relatively steady in level.

3.2.33 The sample size used for the final tests in the Salford study was again small, with 20 subjects, across an age range of 20-50 (average approx. 30). The recruitment process detailed suggests a risk of selection bias, in that it was clear that the study would be looking at the response to wind turbine noise, although it is acknowledged that it may have proved difficult to find willing participants for vaguer, masked study intent. Again, the representativeness of the sample to the wider population of WTN-exposed people must be questioned.

3.2.34 The aforementioned issues of briefing and applicability of lab-rated annoyance results are also relevant to this study: one external reviewer suggested that the context of 'relaxing in the garden' may not necessarily be compatible with the scenario in which AM WTN could be most problematic. For example, an alternative or augmenting scenario may have included 'trying to get to sleep on a summer night with the window open'. Similar types of laboratory tests conducted to specifically investigate LFN (not generated by wind turbines) have used a sleep/night-time scenario (Moorhouse, Waddington, & Adams, 2009) [black], which enables a comparison of sensitivity to be made; given the comparability with WTN this suggests a possible further avenue of investigation.

3.2.35 It was noted on review that the reported tests conducted to examine the influence of the stimulus envelope shape on the annoyance rating were carried out using a constant modulation depth close to the bottom of the range employed (1.7 dB). The results of this study and other works already discussed indicate that a depth of this magnitude would be very much on the edge of fluctuation perception, and so it is a fair assumption that varying skew and width of AM signals with such a small AM depth would be very difficult for subjects to perceive and distinguish. This also indicates another avenue of investigation that does not appear to have been fully explored in the literature, and may be of some value given the subjective descriptions (e.g. 'thumping') sometimes attributed to AM WTN, and often highlighted as the most disturbing to those affected.

3.2.36 The main exposure-response results were obtained using AM WTN stimuli with a modulation frequency of 0.8 Hz. The sensitivity test results indicated that increasing the modulation frequency to 1.5 Hz could result in increased absolute annoyance ratings. This suggests that the equivalent annoyance decibel ratings might also be expected to be slightly greater than those shown above. However, results from the sensitivity tests must be considered with caution: the sample sizes were considerably smaller than the main tests and consisted only of subjects that would normally be considered 'expert listeners', i.e. staff and students of the University Acoustics Research Centre.

3.2.37 The main conclusions drawn from this study tend to reinforce those obtained from the similar Seoul and Tokyo experiments: overall average level was the dominant factor in perception of the AM noise; once the sound was established as clearly modulating, further increases in modulation depth did not greatly affect the perception.

3.2.38 Consideration only of averages in the response results masks the extremities, in which some subjects noticed a larger perceptual change with much finer distinctions in modulation depth, while conversely some subjects actually indicated a lower annoyance with an increase in modulation depth. These observations illustrates the difficulty some subjects had in distinguishing the changes – this is reflected in the appended participant observations: "*sounds were perceived by a number of participants to be very similar*" (von Hünerbein, King, Piper, & Cand, 2013).

STUDY D

SUMMARY

3.2.39 This field study, reported by Bockstael et al. (2011) (2012), was aimed at investigating the connection between operational parameters recorded from a set of wind turbines, WTN exposure and annoyance self-reported by residents neighbouring the installation. It should be noted that the study followed complaints about WTN from the neighbours and a consequent mitigation strategy implemented by the operator. Self-reporting was enabled over a 6-month study period via an online application based on a simple question on annoyance and a 5-point response scale.

3.240 The study examined detailed aspects of turbine operation from the data supplied by the operator, including production yield, blade velocity and hub height wind speed. Meteorological data was also collected. Logistic regression was used to form a model of the statistically significant relationship between reported annoyance and blade velocity, which itself was related to the WTN level extracted from measurements at the properties. A 'fluctuation indicator' was derived using a Fourier transform method from minute-long samples of the noise measurements. This metric was found to broadly increase with increasing annoyance, as indicated in Figure 10. Unfortunately the scaling used for the derivation of this indicator is not fully explained and so direct comparison with other AM measures discussed is not possible. The extent of the error bars are probably a reflection of the very small sample size (3 regular respondent households from a sample of 8); in some cases the results indicate that a fluctuation of a relatively low level (measured by the indicator) could produce a 'not at all' annoyed report from some subjects, and an 'extremely' annoyed report from others.

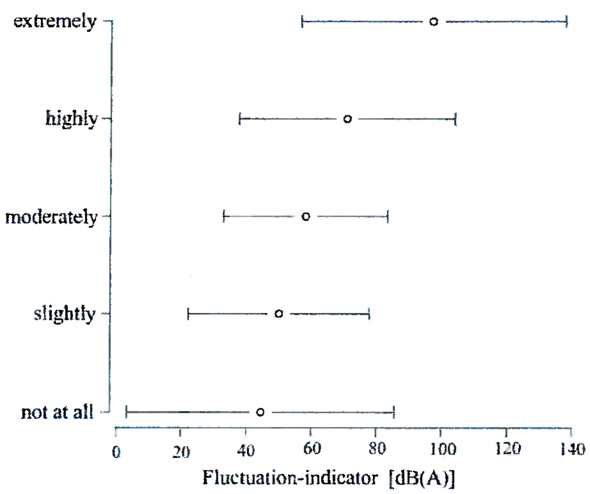

Figure 10: Relationship between fluctuation indicator and reported annoyance (error bars show +/-σ), from (Bockstael, Dekoninck, Can, Oldoni, de Coensel, & Botteldooren, 2012)

DISCUSSION

3.2.41 Given the context of existing noise issues at the site, the representativeness of the results for wider application is open to question. Nonetheless, this is the only study in which the perceptual response could be expected to be a strong representation of that felt by the subject within a suitable residential amenity context, i.e. their own home.

3.2.42 This study shows a good example of careful design and analysis of data for a field experiment. The considerable limitations due to the sample size and situational background (together with the difficulty in cross-comparison of the results due to the lack of clarity in the AM metric employed) restrict its wider application, but it might be regarded as a promising pilot study.

3.2.43 One suggestion made by a reviewer to improve the reliability of this type of response data collection in the field was for self-reports of perception to be prompted at irregular intervals, e.g. by SMS[21], perhaps reverting to self-prompted reporting during periods used for sleeping. This could improve the rate of responses from otherwise low-rate responders and widen the dataset for analysis. More importantly, it would help to reduce any bias potentially introduced by the natural tendency for some subjects to report when most annoyed and not at other times (as documented in this example).

3.2.44 One serious and inevitable drawback on this study is the lack of controls on confounding factors such as personal attitude etc., and this could be significant in a situation where respondents may already have a negative view of the noise source. Research discussed under the Category 2 studies highlight some of the factors shown to influence subjective responses in field survey work relating to WTN.

[21] Short message service (text messaging)

STUDY E

SUMMARY & DISCUSSION

3.2.45 Researchers at the University of Adelaide carried out a preliminary field study designed to test a wind turbine noise measurement and subjective response recording system (Nobbs, Doolan, & and Moreau, 2012). Automated measurements were conducted inside a resident's home near to an operational wind farm, triggered by the occupant and including a 10-point annoyance scale rating and optional notes. The recordings were analysed to produce a measure of AM depth and plotted against recorded annoyance rating, with no apparent association. The results of this study (apparently designed as a simple pilot test for the proposed AM measurement and rating system) are deemed to be of no meaning or use for this research, due to the smallest possible sample size (1), and the lack of any controls or analysis of confounding factors that may have influenced the results.

CATEGORY 1 CONCLUSIONS

3.2.46 The main conclusions from the Category 1 studies are summarised as follows:

- Within laboratory and field test environments, increasing overall time-averaged levels of AM WTN-like sounds showed a strong and significant association with increasing ratings of annoyance.
- Within a laboratory test environment:
  - subjects rated modulating WTN-like sound as more annoying than similar noise without significant modulation;
  - the onset of fluctuation sensation for a modulating WTN-like sound appeared to be in the region of around 2 dB modulation depth (the peak-to-trough level difference in the Fast-weighted sound pressure $L_{pA,F}$ time-series);
  - increasing modulation depth above the onset of fluctuation sensation showed a broadly increasing trend in mean ratings of annoyance, but changes in mean annoyance rating tended to be relatively small, sometimes inconsistent, and typically not statistically significant[22];
  - equivalent annoyance ratings of AM and steady WTN-like sounds derived by level adjustment did not show a very strong increasing trend with increasing depth of modulation; average differences were in the region of around 1.7-3.5 dB; and
  - equivalent 'noisiness perception' of WTN-like AM sounds compared with a steady sound showed a gradually increasing trend with modulation depth, but with a tendency for the spread in perceptual results to also increase. On average the differences were in the region of around 1.5-3.5 dB.
- Wider representativeness of both the laboratory and field results should be approached with caution: sample sizes are very small and may not be fully representative of the wider population of WTN-exposed people; stimuli employed in the laboratory often are very carefully controlled to allow fine adjustment of specific parameters – this kind of regularity in the signal will not be closely reflective of temporal variations experienced in the field, which may further affect subjective responses.

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[22] Subsequent research summarised in Annex 1 indicates a more consistent relationship between modulation depth and annoyance.

3.3 CATEGORY 2 PAPERS

INTRODUCTION

3.3.1 During the literature search, category 2 studies were broadly separated into the following sub-categories:

a. Primary study or review of elements of the human exposure-response relationship with AM WTN that did not meet the category 1 criteria
b. Case study examining un-scaled responses (e.g. complaints) to AM WTN exposure
c. Primary study or review of the human exposure-response relationship with non-wind-turbine amplitude-modulated noise (e.g. HVAC[23] plant)
d. Primary study or review of the human exposure-response relationship with WTN, without specifically addressing responses to quantified AM characteristics (priority given to studies investigating potential adverse health effects other than subjective annoyance, as the association of environmental noise, including WTN, with subjective annoyance has been well-established for some time)
e. Study examining further aspects of AM WTN with potential or partial relevance (excluding source generation theory / testing and AM measurement / quantification techniques)
f. Study examining the application of a planning control or penalty scheme for AM WTN

3.3.2 In addition, relevant publications from an "Independent Noise Working Group" made available on the website of Christopher Heaton-Harris MP (Conservative, Daventry) were also included in the review.

3.3.3 Unless otherwise indicated, the research papers discussed in this section were reviewed by the internal research team. The status of each paper is indicated in square brackets at first reference.

ASPECTS OF THE HUMAN RESPONSE TO AMPLITUDE-MODULATED WIND TURBINE NOISE EXPOSURE

Review Papers 1 & 2

3.3.4 A useful review of relevant literature is given by van den Berg (2009) [grey] and later by van den Berg (2011) [grey], including the following studies.

Psycho-acoustic characters of relevance for annoyance of wind turbine noise (Persson Waye & Öhrström, 2002) [black]

3.3.5 Five different WTN recordings were played to 25 subjects in a laboratory setting. In general, the sounds rated as more annoying were also given higher ratings on descriptors of "*lapping*" and "*swishing*". Derived psychoacoustic metrics such as 'fluctuation strength' and 'modulation %' could not explain the variation in annoyance.

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[23] Heating, ventilation and air-conditioning

Perception and annoyance due to wind turbine noise – a dose-response relationship (Peders en& Persson Waye, 2004) [black]

3.3.6 A cross-sectional field study incorporating social survey questionnaire results from 351 respondents in Sweden, over an area covering 30km^2 and containing 16 turbines. Of those within the sample who reported noticing WTN (64%), around a third also reported being annoyed by a "swishing" character (a feature that was significantly correlated with noise annoyance), while annoyance due to "pulsating / throbbing" characteristics was also reported by around 1 in 5. Noise annoyance was also significantly correlated with further subjective factors including "attitude to visual impact", "attitude to wind turbines" and "sensitivity to noise".

The beat is getting stronger: the effect of atmospheric stability on low frequency modulated sound of wind turbines (van den Berg G. P., 2005) [black]

3.3.7 This paper provides a broad view of the issues surrounding AM WTN and potential effects on people. Measurement results from three sites are analysed to indicate typical fluctuation level variations (i.e. AM), focussing on the influence of the atmospheric conditions. The reported fluctuations in terms of the difference between the maximum and minimum sound pressure levels (L_{Amax} – L_{Amin}) are 4 to 6 dB for single turbines and 5 to 9 dB for multiple (i.e. a wind farm). However, the author acknowledges this measure can easily be influenced by incidental extreme values, and also results for the difference between the L_{A5} and L_{A95} measures, yielding somewhat lower values of 3 to 4 dB.

3 .38 It is reported from the author's experience of the Rhede wind farm (Germany/The Netherlands) that operations on a clear night at times produced a beating sound likened to "*distant pile driving*", and that the sound character during the daytime (with low atmospheric stability) could be very different (i.e. less intrusive).

3.3.9 An analysis of the fluctuation strength metric is presented, indicating that a change in modulation depth ΔL from 3 to 6 dB for a broadband noise corresponded to an increase in fluctuation strength from negligible to 0.18 vacil. The conclusion is drawn that the fluctuations of modern wind turbines are likely to be readily perceivable under stable atmospheric conditions. Any possible links from the measured data with site-specific resident responses are not reported.

Auralization and assessments of annoyance from wind turbines (Legarth, 2007) [grey]

3.3.10 Five different WTN binaural recordings were made and auralised for different distances using a computer propagation model. Twenty subjects were played the recordings using headphones and simultaneously presented with a visual image of a turbine at an appropriate distance. AM was quantified using fluctuation strength applied to specific frequency bands relevant to the "swishing sound" (350-700 Hz) where fluctuation was stronger. A logistic regression model for annoyance was presented based on the relationship with L_{den}[24]. It was stated that the annoyance model could be "improved by including the metrics for prominent tones and for the swishing noise", although the supporting results were not provided.

Response to noise from modern wind farms in The Netherlands (Pedersen, van den Berg, Bakker, & Bouma, 2009) [black]

3.3.11 Another cross-sectional field study, this time conducted in The Netherlands, analysed data collected from 725 respondents living within 2.5km of a wind turbine installation. Of those who

[24] 'Day evening night' equivalent noise level, i.e. a period-weighted L_{Aeq} measure commonly used for EU Directive noise mapping

noticed WTN at their dwellings (46%), 3 in 4 reported a "swishing / lashing" sound, while "thumping / throbbing" was reported by less than 10%, and few of the respondents described the WTN as low frequency. The results showed a strong correlation between noise annoyance and negative opinion of visual impact. Economic benefit from wind turbines was also significantly associated with the likelihood of a respondent reporting 'no annoyance', despite detection of the WTN being the same between benefit/no benefit comparison groups. A large proportion (40%) of respondents reported hearing WTN more clearly at night.

Effects of sound on people (van den Berg F. , 2011) [grey]

3.3.12 In reviewing the issue, the author proposes that the modulation component in WTN, when perceived, could be the most important factor influencing subjective disturbance, due to the unpredictability and perceived lack of control for those exposed.

Review Paper 3

Wind turbine noise: an overview of acoustical performance and effects on residents (van den Berg F. , 2013) [grey]

3.3.13 Includes a review of factors contributing to AM, and suggests that AM is reported to occur more often at night.

Review Paper 4

3.3.14 Another review of relevant literature is found in the report by the Council of Canadian Academies (2015) [grey], prepared for the Canadian Government, including (amongst reviews of the category 1 studies summarised in section 3.2) the following paper.

Psychoacoustic aspects of noise from wind turbines (Fastl & Menzel, 2013) [grey]

3.3.15 A laboratory study was conducted by exposing 13 subjects to a single recording of AM WTN at a range of levels; one of the samples had been modified to remove the AM component of the sound. Subjects rated annoyance using a 'free magnitude estimation' technique by stating a number for each sample but without any defined scale; these were then converted to relative annoyance ratings. A statistically significant relationship between the sound level or loudness and annoyance was shown, but there was no significant difference in rated annoyance between the modulated and un-modulated versions of the signal at equivalent loudness. No data to indicate a relationship for annoyance with modulation / fluctuation was presented, and the results did not include any quantification of AM signal content.

DISCUSSION

3.3.16 The papers reviewed in this section appear to reinforce the suggestions that periodic AM increases annoyance due to WTN, as does increasing level. A number of non-acoustic factors are also identified as influencing the annoyance attributed to noise.

CASE-STUDIES INVESTIGATING UN-SCALED HUMAN RESPONSE TO AMPLITUDE-MODULATED WIND TURBINE NOISE EXPOSURE

Acoustic noise associated with the MOD-1 wind turbine: its source, impact and control (Kelley, McKenna, Hemphill, Etter, Garrelts, & Linn, 1985) [grey]

3.3.17 A very early investigation into the disturbing 'thumping' noise, infrasound pulses and vibration experienced by neighbours of an experimental downwind[25] turbine installation. The study examined the source generation mechanisms and possible remedial measures. The source was identified as complex interactions between the rotating blades and the tower structure, exacerbated by local stall conditions and the design of the aerofoil. A number of possible design solutions were proposed, including a modified aerofoil shape and operational angle of attack.

3.3.18 This paper presents a technical and high quality investigation of a specific WTN problem. Increased (or 'enhanced'/'excessive' etc.) AM WTN associated with upwind turbines is most likely due to fundamentally different mechanisms than the blade-tower interaction case studied here, as shown in recent research developed by Makarewicz et al. (2015) [black], Oerlemans (2015) [black] Cand et al. (2015a) [grey] and Smith (2013) [grey]. Nonetheless, the information on the acoustical characteristics within residents' rooms and the influence of meteorology provide some background information that may help to explain why the annoyance reported in some cases can be more intensive than might be expected from outdoor measurements or perception of AM WTN near to the turbines.

Wind turbine noise assessment in a small and quiet community in Finland (Di Napoli, 2011) [black] & Case study: wind turbine noise in a small and quiet community in Finland (Di Napoli, 2009) [grey]

3.3.19 A field study carried out in response to complaints made to a local authority about noise from a single turbine installation.

3.3.20 Measurements were made over a day and night period primarily to quantify the sound power of the turbine. In addition the author analysed the data and recordings to examine spectral and AM content.

3.3 21 A number of relevant sound characteristics are noted: an apparent increase in low frequency noise around 40 Hz when hub height wind speeds increased above a particular value, modulating at the blade passing frequency (NB. this was noted from measurements made at close range to the turbine only; at further distances different sounds were noted, including a "rumbling", "clapping" and "swish"); greatest modulation depths when the WTN aggregate level was steady, rather than in transition (i.e. the measured AM depth reduced when the overall turbine sound was increasing or decreasing due to changes in wind speed); evidence of 'double peaks' in the AM noise level, i.e. peaks occurring more often than the blade passing frequency.

3.3.22 It was noted that the maximum recorded AM depth in the measurement was around 5 dB, but no statistical analysis of the AM results is reported.

3.3.23 There is very little information provided on the complaints that triggered the study, and the measurements were necessarily carried out at closer range to the turbine than the locations of residential dwellings, due to very low audibility of the WTN during the survey.

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[25] A downwind design places the blades downwind of the supporting tower; most modern turbines employ the opposite configuration, i.e. upwind.

3.3.24 The study makes some interesting observations and suggestions as to possible causes of the observed sound characteristics, such as blade-structure interactions, and blade phase interference.

Wind turbine amplitude modulation: research to improve understanding as to its cause & effect (Bullmore, Jiggins, Cand, Smith, von Hünerbein, & Davis, 2011) [grey]

3.3.25 This summary of AM WTN case-related measurements and complaint reports is provided by Bullmore et al. (2011), also reviewed by Bullmore et al. (2013) [grey], including the following study.

3.3.26 The results of an investigation by van den Berg, G.P. (2004) [black] indicated measured AM depths (in the A-weighted levels) at one site of up to 5 dB, and sounds that were described as 'pulse-like' and 'thumping', a character considered by the author likely to have contributed to annoyance reported by the residents. It is also noted that complaints were focussed in late evening and night-time periods.

Amplitude modulation and complaints about wind turbine noise (Gabriel, Vogl, Neumann, Hübner, & Pohl, 2013) [grey]

3.3.27 A medium-scale field study carried out to record complaints about WTN from neighbours of a wind farm in Germany. A questionnaire and complaints form were issued together with audio recorder to 212 residents. Sampled noise measurements were taken at specific outdoor locations, and meteorology was also recorded.

3.3.28 Around 45% of the sample returned complaint sheets. Analysis of the complaints sheets showed that around 32% of the sample made complaints about noise that were clearly related (by the complainant) to a subjective description fitting with AM. Compared with the total number of complaint sheets reported (95), this proportion was around 72%.

3.3.29 The authors note that the results show a distinct increase in complaints immediately after a public presentation of the project, which could be due to a) distinct operational or meteorological conditions that increased annoying noise from the site; b) increased noise sensitisation among residents (i.e. respondents becoming more conscious of the noise as a response to awareness of the investigation), c) a decrease in the possible perception of futility in complaining, or d) complainants seeking to maximise any subsequent action taken to reduce the operational capabilities of the wind farm. It is not possible from the presented information to understand which factors could have influenced the results.

3.3.30 Some of the audio recordings of noise made by the residents were analysed, and modulation metrics derived; the results presented show a relatively large sound pressure level difference of over 14 dB ΔL in and around the 160 Hz 1/3 octave band, although it must be presumed that this is a maximum difference as the sample durations and variation are not detailed. It is also noted that this sample represented the only AM WTN recording lasting longer than 1 minute from any of the 28 samples analysed; in all other cases any perceptible AM WTN lasted less than 10s.

3.3.31 The study was launched in response to concerns raised about WTN, and respondents were fully aware of the nature and intent of the investigation. As such there is a strong risk of selection bias in the results, which makes interpretation of the prevalence of AM annoyance from the complaints data potentially problematic. There is no detailed analysis presented of the complaints distribution, but it is noted that 95 complaints had been documented from 10 residents. Of these, 80% were reported in relation to the night-time or early morning. This suggests that, for those making complaints, these periods are especially critical.

3.3.32 There is interesting speculation in the paper on the possibility of short periods of AM being an 'attention trigger' that provides a pathway towards increased noise disturbance, rather than being highly disturbing in and of itself. This suggests a possible avenue of further research.

Noise characteristics of 'compliant' wind farms that adversely affect its neighbours (Large & Stigwood, 2014) [grey]

3.3.33 This is a discussion paper incorporating field data from 4 wind farm sites where complaints about noise have been recorded or made known to the authors. Details of the complaints themselves (e.g. status, frequency, distribution, time of day etc.) are not presented.

3.3.34 The study examines relatively short sampled periods of measurement data recorded at each site, and analyses the samples using a range of AM assessment metrics to compare the results.

3.3.35 A speculative discussion on nuances of AM WTN perception, based on an analogy with musical dynamics and expression, is presented as a set of possible psychoacoustic explanations for subjective responses.

3.3.36 All of the response evidence presented is anecdotal and un-scaled, and wider representativeness would not be reliable: non-acoustic factors contributing to complaints at the sites cannot be ruled out or the potential effects isolated (for example, attitude of the complainants, attitude of the site operators, history of planning and development of the sites, visual impacts, sensitisation due to the investigative work etc.). No causal relationship between the noise characteristics and complaints (as suggested by the authors) could be robustly established from the data.

3.3.37 The objective of the paper is really to raise a wide range of discussion points and questions about character assessment, rather than to derive an exposure-response relationship (while numerical AM values are quoted for the samples analysed, this is primarily with the aim of comparing demonstrable efficacy of different measures in quantifying AM, and showing high ratings, despite apparent compliance with national guidelines).

3.3.38 This study provides an interesting discussion with lots of pertinent questions raised but few answers given. It does raise the important point as to the likely success or otherwise of a penalty system aimed solely at controlling AM in isolation, rather than looking more broadly at combinations of characteristics, as well as the cumulative effects of intermittency, duration and changes in character.

Initial findings of the UK Cotton Farm Wind Farm long term community noise monitoring project (Stigwood, Stigwood, & Large, 2014) [grey]

3.3.39 This paper reports analysis of 10 months' field data measured near to a UK wind farm, with the intent of establishing prevalence of occurrence of AM, investigating the relationship with wind behaviour, and examination of different AM assessment metrics.

3.3.40 In reviewing the earlier work published by RUK (von Hünerbein, King, Piper, & Cand, 2013), the authors point out the potential problems with translating laboratory annoyance rating methods to the annoyance experienced by WTN-exposed populations, due to the contextual and stimulus differences (these issues have also been discussed in section 3.2).

3.3.41 There is very little analysis of subjective responses, although the authors note that the community have made complaints to the local planning authority concerning noise. A section of the paper is also dedicated to a description of an online software platform devised by the authors to allow members of the public to subjectively rate recordings made at the monitoring location.

Perception and effect of wind farm noise at two Victorian wind farms (Thorne, 2014) [grey]

3.3.42 This report was prepared at the request of residents living in the vicinity of a wind farm subject to complaints about WTN. The version reviewed comprises an update to the original 2012 publication.

3.3.43 The study investigated the possible relationship between adverse health effects and WTN exposure in the local population at two sites. Questionnaires were issued to 25 participants to enable self-reporting of a range of possible factors, including sleep disturbance, annoyance and sensitivity. The questionnaires included use of some recognised health / quality of life metrics.

3.3.44 The results show a very high proportion of self-reported sleep disturbance (over 90%), and annoyance (over 80%) attributed to WTN exposure. The report argues that adverse health effects due to WTN are marked by a range of acoustical thresholds, including:

- 32 dB $L_{Aeq,10min}$ outside a dwelling
- 22 dB $L_{Aeq,10min}$ inside a dwelling
- "*Unreasonable or excessive modulation*" in audible, regularly varying[26], WTN[27]: 4 dB AM depth (peak-trough) is 'unreasonable'; 6 dB AM depth is 'excessive'

3.3.45 The results reported suggest the participants feel strongly that their quality of life has worsened due to the presence of the wind farms. However, the suggestion that specific health effects are attributable directly to the wind farm noise exposure (and AM in particular) are not supported by the evidence presented.

3.3.46 There are details provided in the paper to demonstrate how the apparent health effects reported have been linked to the specific acoustic thresholds identified. The author notes that the report is in summary form, which may explain the lack of supporting analysis; it is also stated that cause and effect information was submitted during related planning hearings and a 2011 Australian Senate Inquiry, but is not presented in the paper. The Senate Inquiry concluded that there was insufficient rigorous research to establish whether adverse health effects were caused by WTN exposure (The Senate Community Affairs Reference Committee, 2011).

3.3.47 Despite the presence of a range of non-specific questions about noise within the questionnaire, which would in other situations typically be used to mask the intent of the survey, the context of the study (within planning hearing / inquiries) means that the respondents would be likely to have already been fully aware of the study objectives and hypotheses.

3.3.48 This is a cross-sectional field study conducted with a small sample size (25), no equivalent control group and within the context of a planning inquiry; wider applicability of the results is therefore limited.

Quantifying the character of wind farm noise (Hansen, Zajamšek, & Hansen, 2015) ***[grey]***

3.3.49 This paper analysed data obtained during a monitoring program carried out by the South Australia Environmental Protection Agency in response to noise complaints relating to Waterloo Wind Farm, the results and data from which are freely available online (South Australia Environmental Protection Agency, 2015).

3.3.50 Hansen et al. (2015) selected a sample of the diary entries completed by neighbouring residents and corresponding periods of the noise monitored at locations nearby. The diary entries, which included an unclearly-scaled subjective rating of "*strength of noise event*" (rated 1-4) together with descriptive words to qualify the nature of the sound (e.g. "*rumbling, thumping*") and confirmation of whether the turbines were turning at the time of the entry, were compared with a wide range of

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[26] The criterion is defined as applying to WTN that exceeds the numerical AM thresholds for a total of 1 minute or more in a 10-minute period.

[27] Measured in terms of short-term L_{Aeq} or L_{pAF} using 100 to 125ms averaging.

possible AM assessment metrics to detect any relationship. There is no description of the briefing that residents may have received to gain an understanding of the intention of the noise strength rating. No agreement was observed for the subjective rating with the AM metrics, but better agreement was obtained by comparison with loudness[28]. A-weighted, C-weighted and G-weighted sound pressure levels were also presented but not mentioned in the analysis discussion.

3.3.51 The representativeness of this study is limited due to the likely selection bias, the relatively small sample (four respondents' diaries), and the very short duration of audio data analysed (a total of 50 minutes).

Measurements demonstrating mitigation of far-field AM from wind turbines (Cand & Bullmore, 2015b) [grey]

3.3.52 This study presents results from an investigation into remedial measures designed to reduce the occurrence of transient blade stall, believed to be the primary source mechanism in generating a high degree of AM.

3.3.53 Data from two different sites are included, both of which are reported as having been subject to AM WTN-related complaints, and a different mitigation strategy is examined at each, i) physical treatments directly on the blades, and ii) software modifications to reduce the angl e of attack during the conditions (i.e. specific wind speed ranges) in which high AM had been associated with complaints. Measurements were conducted at multiple synchronous positions at both sites, including near and far field locations, over a period of months, although the datasets were reduced in both cases: at the blade-treated site to consider only data obtained during shutdown of un-treated turbines; at the modified-software site only periods known to have generated prominent AM were analysed, with matched post-mitigation measurement periods.

3.3.54 The results are presented in a different form for each site: at the blade-modified site, the prevalence of AM periods in which the measured modulation (quantified in terms of AM magnitude rating[29]) was above a defined threshold (set to ≥ 3 dB) were recorded as proportions of the total measurement dataset (10 hours pre-treatment, 23 hours post-treatment). It was shown that, over a similar wind speed range, the prevalence of AM with a magnitude above the threshold for more than 30s in a 10-minute period was around 50% prior to the treatment, reducing to slightly over 3% following the blade modifications.

3.3.55 For the modified-software site, the results are presented in terms of the AM magnitudes measured over the wind speed range for each condition. The analysis indicates a reduction in AM magnitude at the worst-case wind speed of around 0.5 dB on average, and 1 dB for the upper 68% confidence interval (CI). Further statistical analysis of these results to examine the results could lend greater support to the conclusions and establish the significance of the pre- and post-treatment differences.

3.3.56 In terms of changes in the subjective response, very little information is given beyond noting that for the modified-software site, complaints were understood to have subsided following implementation of the strategy. Another dimension to the study might have looked more closely at the subjective element, to establish the efficacy of the treatment from an exposure-response perspective. It is clear however that the focus of the experiment was aimed towards validating the suspected cause of increased AM severity at the same time as testing effective mitigation measures. The results suggest that relatively small reductions in AM of the order of a few dB (in terms of the magnitude metric used) may have an effect in reducing complaints (and by

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[28] Evaluated according to the model proposed by Fastl and Zwicker (2007)
[29] The metric developed by the IOA AMWG specifically to quantify the AM component of WTN.

extension, annoyance), although further testing and analysis would be needed to investigate this fully.

DISCUSSION

3.3.57 The case-study research has value in highlighting the issue of AM in WTN, and provides persuasive supporting evidence, in the form of complaints or descriptions, that is an important factor in determining or exacerbating subjective annoyance responses. The research also points towards increased sensitivity to AM during quiet periods typically used for rest and relaxation, i.e. evening and night-time.

3.3.58 Case-study research has the drawback of limited wider applicability; in some cases the studies are carried out in response to complaints about WTN, and as such it is impossible to isolate effects caused by acoustic phenomena from the influence of non-acoustic factors that modify responses.

3.3.59 Recent work has highlighted the typical causes of increased AM from wind turbines, and the potential for methods of mitigation.

HUMAN RESPONSE TO NON-WIND-TURBINE AMPLITUDE-MODULATED NOISE EXPOSURE

The identification and subjective effect of amplitude modulation in diesel engine exhaust noise (Kantarelis & Walker, 1988) [black]

3.3.60 This study presented simulated diesel engine noise modulating at around 8 Hz with two different AM depths (5 and 13 dB) and was rated for subjective annoyance on a 10-point scale.

3.3.61 The authors suggest the results indicate an association between AM and annoyance for this type of noise, although information on the exposure and subject group is not reported, and there is no statistical analysis included to support the finding. The presented results appear to show a slight increase in rated annoyance for the greater modulation depth, but there is no unmodulated 'control' sound, and without an indication of the number of subjects and associated spread in the results it is difficult to have confidence in the conclusion. There is a clearly-observable relationship between increasing maximum level (L_{Amax}) and rated annoyance for both modulation depths.

Review Paper

3.3.62 A useful review of further material is provided by van den Berg (2011), covering the following papers.

Annoyance caused by constant-amplitude and amplitude-modulated sounds containing rumble (Bradley, 1994) [black]

3.3.63 A laboratory experiment examining subjective response to synthesised fluctuating noises designed to resemble HVAC[30] sources. A total of 9 subjects (age range 16-50) were asked to compare both modulated and un-modulated test sounds 'containing rumble' (i.e. with greater energy in the low frequencies) with a reference steady noise and adjust the test signals to be equally annoying with the reference. Two modulation depths and five modulation frequencies (in steps between 0.25 and 4 Hz) were used to modulate the low frequency content of the test signal;

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[30] Heating, ventilation and air conditioning

although the overall AM depths of the final signals are not given, the L_{10}-L_{90} parameter[31] was shown to be around 3-5 dB over the 31.5 – 250 Hz octave bands.

3.3.64 On average, for the particular case of a 2 Hz modulation frequency, subjects attenuated the modulated test signal by an extra 4 dB when compared with the equivalent un-modulated test signal, both paired against the reference. Unfortunately there is virtually no information presented on the recruitment and briefing of the subjects, so their understanding and any contextualisation of equalising 'annoyance' is unknown.

The effect of fluctuations on the perception of low frequency sound (Moorhouse, Waddington, & Adams, 2007) [black]

3.3.65 This study, also later documented by Moorhouse et al. (2009) and Moorhouse et al. (2013) [black], was part of a Defra[32]-funded investigation into low frequency noise (LFN) disturbance and methods for assessing complaints.

3.3.66 A total of 18 subjects were recruited for the laboratory experiment, with an average age range of 32-62 (overall average 50), intentionally including 3 subjects self-reportedly highly sensitive to LFN. The results from the subjects were analysed both combined and separately in 3 groups divided according to both sensitivity and age. The briefing given to the subjects is detailed, and was based around the subject determining whether they felt they would find a presented sound acceptable if they heard it within their own home. This study also presented a night-time condition, switching the lights off and asking the subject to evaluate the sounds as if they were trying to get to sleep.

3.3.67 The stimuli presented included both real recordings and artificially-generated low frequency tonal signals. Subjects adjusted the level of the presented signal until deemed acceptable within the scenario context. The fluctuation in each signal was quantified using the percentile level difference L_{10}-L_{90}. The results indicated that the average acceptability thresholds were around 5 dB lower for fluctuating sounds with L_{10}-L_{90} values above 5 dB, when compared with those for steady sounds. Fluctuating sounds with L_{10}-L_{90} of around 4 dB had average thresholds of 1-4 dB lower than the steady sounds. The results were interpreted as evidence to support an assessment scheme for fluctuating LFN based on a 5 dB penalty value applied to sounds incorporating modulation exceeding 4 dB L_{10}-L_{90} (Moorhouse, Waddington, & Adams, 2013)[33]. A second criterion also required the noise under assessment to have a rate of change in fast-weighted[34] sound pressure level exceeding 10 dB/s.

3.3.68 The results are presented as averages without error bars, and there is limited statistical analysis presented to lend additional weight to the conclusions (this may be due the small sample size, which would limit the usefulness of significance testing). Nonetheless, it is informative to see a difference in sensitivity (i.e. in terms of mean acceptability thresholds) expressed by subjects for a simulated night-time situation, a contextual factor was not addressed in the category 1 laboratory studies reviewed in section 3.2. In this case the average threshold differences (i.e. between stimuli with or without modulation) for the tonal signals between day and night-time were shown to be in the region of 3-4 dB.

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[31] The difference between the 10th and 90th percentiles of the signal sound pressure level

[32] Department for Environment, Food and Rural Affairs (UK)

[33] This publication comprised an erratum slightly modifying the original conclusion stated in the related paper.

[34] Time-weighting used to evaluate root-mean-square sound pressure, fast = 0.125s.

A comparison of the temporal weighting of annoyance and loudness (Dittrich & Oberfeld, 2009) ***[black]***

3.3.69 This laboratory study presented 12 subjects (mostly students, aged 20-31 years) with artificial randomly fluctuating broadband noise. It was shown that the variation of the stimuli in terms of standard deviation σ had a significant effect on rated annoyance but not on estimation of loudness; paired stimuli with σ = 4 dB were judged more annoying than those with σ = 2 dB, despite having equal L_{eq}.

Annoyance caused by low frequency sounds: spectral and temporal effects (Vos, Houben, van der Ploeg, & Buikema, 2010b)

3.3.70 In this laboratory study, 32 subjects (half with mean age 26, and half with mean age 53) were presented with a range of AM stimuli, including a 31.5 Hz tone, 31.5 Hz 1/3-octave bandpass filtered pink noise and road traffic-like filtered broadband noise, all modulated at 1 Hz frequency. AM depths of 6 and 12 dB were used for the broadband noise, with an additional depth of 18 dB used for the tones and 1/3-octave band noise.

3.3.71 The results for the tone signals showed a significant effect of both loudness and AM depth on rated annoyance. The stimuli were presented at 10, 25 and 40 phon loudness; for the 25 and 40 phon tones, the modulated versions were given significantly higher mean annoyance ratings compared with the unmodulated, with rated annoyance apparently increasing up to 12dB depth; at 18 dB AM depth there was no significant increase, suggesting subjects could not distinguish between 12 and 18 dB AM depth.

3.3.72 The results for 1/3-octave band noise showed no relationship with AM.

3.3.73 The results for the AM broadband noise again showed a significant increase in rated annoyance for modulated versus unmodulated, but there was no significant difference between the 6 and 12 dB AM depths used, again suggesting subjects had difficulty making a distinction once AM was detected in the signal.

3.3.74 In another experiment the subjects were played sound recordings of fluctuating aircraft and road traffic noise, which were compared with steady noise modified to have equal spectral content to the modulating sounds. The results for the sound recordings showed no significant effect due to fluctuation, but a strong relationship between overall time-average level and rated annoyance.

3.3.75 The author suggests that the results may indicate an equivalent annoyance steady noise level difference in the region of around 10 dB for the AM depths tested (i.e. ≥ 6 dB ΔL). This value appears to have been obtained by comparing the results from the artificial signal tests with those from the sound recordings.

Effects of sound on people (van den Berg F. , 2011) [grey]

3.3.76 In summarising the above studies, van den Berg concludes that the laboratory work indicates an association of increasing annoyance with AM broadband noises compared with the steady equivalent, but that the effect on annoyance may not continue to increase with greater modulation depth. The equivalent annoyance level difference (i.e. steady vs. modulating noise) is suggested as at least 3 dB.

Other Papers

3.3.77 Further studies identified in the literature search include the following publications.

Sound characteristics in low frequency noise and their relevance for the perception of pleasantness (Bengtsson, Persson Waye, & Kjellberg, 2004) [black]

3.3.78 This study was aimed at investigating subjective response to HVAC-like noise within the context of an occupational environment. 30 subjects were presented with an artificial stimulus combining recorded HVAC sound with filtered noise and modulating tones.

3.3.79 The subjects generally showed a preference for noise modulating at frequencies as far from the 2-6 Hz interval as possible within the 0.1-10 Hz range used, essentially confirming findings from earlier studies, including those reported by Fastl & Zwicker (2007). There was no investigation of the effect of altering modulation depth.

Annoyance of time-varying road traffic noise (Kaczmarek & Preis, 2010) [black]

3.3.80 This laboratory experiment prepared four auditory scenarios by arranging recorded road traffic passes into different temporal configurations, controlling the total number and type of vehicles within each structure. Nineteen subjects (aged 19-24) rated annoyance for 3 variations of each of the scenarios using an 11-point scale, and psychoacoustic parameters for each stimulus were also calculated.

3.3.81 The results showed that rated annoyance was significantly correlated with fluctuation strength, loudness and roughness. There were significant differences in the rated annoyance between the different temporal structures / scenarios. However, the differences were relatively small, in total (highest to lowest) spanning around 1 interval on the annoyance scale, based on averaged results. The scenario with highest annoyance ratings was composed from regularly spaced car passes at around 0.2 Hz (i.e. 5 second gaps between events), whereas the least annoying comprised discrete groups of 24 passes at around 2 Hz.

Spectral and modulation indices for annoyance-relevant features of urban road single-vehicle pass-by noises (Klein, Marquis-Favre, & Weber, 2015) [black]

3.3.82 This study used experimental results from a listening test with 14 subjects to derive proposed new measures for subjective characteristics, including the temporal description 'sputtering'. Sputtering was found to have a correlation with the fluctuation strength metric, however this type of character is typically found in engine-like noises and unlikely to have wider applicability to WTN. There was no separate examination of modulation depths or frequency.

DISCUSSION

3.3.83 Most of the research in this section appears to support the idea that modulated noises are generally considered less pleasant than a steady equivalent at the same energy-average level. The metrics used to quantify modulation and the stimuli types vary considerably between studies, but broadly-speaking this difference in perception might be translatable to a level difference somewhere in the region of around 3-4 dB on average. It is noted that the stimuli used in the studies varied and was not necessarily WTN-like; in one study using broadband noises, a greater difference of up to 10 dB was proposed, though this conjecture was based on a comparison between different stimulus types.

3.3.84 There is some evidence to indicate that sensitivity to a modulating noise is greater in the context of a 'getting to sleep' situation than in a general 'relaxation' setting.

HUMAN RESPONSE TO WIND TURBINE NOISE EXPOSURE (HEALTH EFFECTS)

3.3.85 The literature search highlighted at least 30 separate papers that could be included in this category using the relatively specific search criteria defined in section 2. Since the vast majority of these studies were not deemed directly relevant to the aims of the project (as they did not attempt to quantify the AM component in the exposure), only a relatively small proportion have been reviewed, with the emphasis firmly on recent systematic reviews of the existing literature and large-scale epidemiological field studies aimed at establishing the likelihood of relationships between WTN and a range of possible health effects. Although somewhat relevant (since WTN inherently involves a degree of AM), this section is not intended to be an exhaustive review of individual studies into general WTN (i.e. where AM is not quantified) and health effects. Instead, a summary set of conclusions are presented based on interpretation of the main study outcomes and the weight of the evidence.

3.3.86 The following studies have been considered:

- ***Health impact of wind farms*** (Kurpas, Mroczek, Karakiewicz, Kassolik, & Andrzejewski, 2013) [black]
- ***Systematic review of the human health effects of wind farms*** (Merlin, Newton, Ellery, Milverton, & Farah, 2013) [grey]
- ***Wind turbine noise and health study – summary of results*** (Health Canada, 2014a) [grey], including supporting information from[35]:
  - ***Self-reported and objectively measured health indicators among a sample of Canadians living within the vicinity of industrial wind turbines: social survey and sound level modelling methodology*** (Michaud, et al., 2013) [grey]
  - ***Health impacts and exposure to sound from wind turbines: updated research design and sound exposure assessment*** (Health Canada, 2014b) [grey]
- ***Wind turbines and health: a critical review of the scientific literature*** (McCunney, Mundt, Colby, Dobie, Kaliski, & Blais, 2014) [black]
- ***Health effects related to wind turbine noise exposure: a systematic review*** (Schmidt & Klokker, 2014) [black]
- ***Wind turbines and human health*** (Knopper, et al., 2014) [black]
- ***Social survey on wind turbine noise in Japan*** (Kuwano, Yano, Kageyama, Sueoka, & Tachibana, 2014) [black]
- ***Wind turbine amplitude modulation & planning control study – Work Package 3.2: Excessive amplitude modulation, wind turbine noise, sleep and health*** (Hanning, 2015) [grey]
- ***Understanding the evidence: wind turbine noise*** (Council of Canadian Academies, 2015) [grey]
- ***The effect of wind turbine noise on sleep and quality of life: a systematic review and meta-analysis of observational studies*** (Onakpoya, O'Sullivan, Thompson, & Heneghan, 2015) [black]

3.3.87 On review of these publications, it is clear that the study of human health effects (such as stress, anxiety, sleep disturbance, tinnitus, psychological and mental health) potentially caused by WTN exposure is a developing area of research, and there remain differences of opinion in the

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[35] Subsequent to completion of the literature review component of this research, the final results of this study have been published in peer reviewed literature, listed in Annex 3. The published results confirm the earlier preliminary findings, i.e. the study found no significant association between the reported WTN levels (up to 46 dB(A) outdoors) and self-reported or objective measures of sleep disturbance.

literature. The following conclusions are considered by the internal research team to represent the current state of knowledge:

- There is strong evidence to show that exposure to WTN can cause increased annoyance amongst exposed populations .
- There is evidence to suggest that exposure to WTN is associated with increased risk of sleep disturbance for external WTN levels exceeding 40 dB(A). Much of the research indicates that where sleep disturbance is identified, this is more closely associated with annoyance than with levels of WTN exposure. For many people within exposed populations, it therefore seems likely that sleep disturbance may occur as a result of increased annoyance due to the presence of wind turbines, and at least part of this annoyance can be explained by the noise component (other factors are also important as discussed below). In other words, sleep disturbance could be an indirect effect of WTN exposure in cases when an individual feels increased annoyance, but direct causality cannot currently be robustly and consistently demonstrated.
- Similarly to sleep disturbance, there is limited evidence to indicate that increased stress or anxiety are associated with WTN exposure, and any effect may also be indirectly due to heightened annoyance responses rather than as a direct result of exposure.
- There is a body of evidence, generally anecdotal, suggesting a range of other possible (adverse) health effects and quality of life impacts that some people attribute to WTN exposure. These cases are not currently supported by the weight of the epidemiological evidence. It is acknowledged that prolonged exposure to levels of environmental noise has been linked with long-term health issues (WHO, 2011), but such effects have so far not been consistently or robustly demonstrated in the case of wind farm noise. Again, this could be explained by the small numbers of exposed persons and the relatively low levels of noise emitted, as well as further subjective modifying factors discussed below.
- A range of non-acoustic factors have been identified as potentially contributing to or modifying the annoyance that some people feel and attribute specifically to noise from wind farms. These include:
  - Specific visual impacts (shadow flicker, lights, rotation);
  - General attitude to wind farm appearance in the landscape;
  - Direct economic benefits from wind energy generation or specific wind turbine installations;
  - General attitudes to wind energy generation;
  - Type of area (urban / rural);
  - Exposure to positive / negative media coverage of wind energy and wind farm noise, and the activities of campaign groups; and
  - Sensitivity to noise and possible sensitisation due to awareness of wind farm noise research.

DISCUSSION

3.3.88 On the basis of this review, it is considered that at the current time there is insufficient evidence to indicate that the AM component in WTN at typical exposure levels directly causes any significant adverse effects beyond increased annoyance. However, it is noted that virtually none of the reviews of health effect studies explicitly address quantified AM exposure within the noise, and almost all solely consider time-averaged levels in their findings.

3.3.89 Since it is generally accepted that environmental noise can cause sleep disturbance (WHO, 2009), it seems likely that the apparent difficulty in consistently demonstrating a direct causal relationship between WTN and sleep disturbance in the field might be partly explained by the relatively low levels of WTN compared with other forms of environmental noise to which people are quite often exposed. Nonetheless, it should be noted from the research already discussed that increased distinctiveness of WTN is attributable (in part) to AM, and so it is not an unreasonable assumption that in the cases where people feel annoyed, and AM increases their annoyance, any indirect effects that may be associated with this annoyance, such as sleep disturbance or stress, could be exacerbated. In cases where people are situated in close enough proximity to hear WTN when trying to sleep, it is also possible that greater AM will increase the direct risk of disruption to sleep, in particular to the period of 'getting to sleep', due to increased awareness of and focus toward the noise; this suggestion seems to be somewhat supported by anecdotal descriptions, however more research would be needed to investigate this fully.

3.3.90 The publication by Hanning (2015) is notable here mainly as it appears to be somewhat in opposition to the findings of many of the above studies and reviews. The paper has also been reviewed by the independent external reviewers and is discussed below in sections 3.3.136 to 3.3.138. It is noted that the paper highlights supporting evidence from the case-study conducted by Thorne (2014), which has also been reviewed in the relevant section herein; it is considered there is little robust analysis in the case-study that upholds the specific findings claimed and subsequently quoted by Hanning (2015). Two other primary study references used to establish the author's conclusions stem from research reported by Nissenbaum et al. (2012) [black] and Krogh et al. (2011) [black]. Concerns about the potential for significant risk of bias introduction in the designs of these studies and a questionable approach to the results analyses and subsequent conclusions have been raised by McCunney et al. (2014) and Ollson et al. (2013) [grey].

3.3.91 The great difficulty of isolating potential confounding factors in the field studies is clear: many of the review papers highlight sources of potential bias that are not considered to be adequately controlled in the primary research. There is also a significant drawback in that the studies are cross-sectional, and so it is not possible to assess the existence of health issues prior to exposure to WTN, and consequently causality. Moreover, it is not possible to assess the specific effects, including annoyance, which could be attributed to a change in the local noise environment as opposed to an on-going or 'steady state' situation. The 'change' situation is arguably more immediately relevant in a 'complaints' context, since the initial response would be to the introduction of a new wind energy installation or, alternatively, expansion of an existing one. Research based on a steady state situation may under- or overestimate the response to WTN in general, and to AM in particular.

3.3.92 It is debatable as to whether further observational studies of a cross-sectional design will add value to the existing knowledge base, and may serve only to further cloud the issue due to the difficulties in isolating confounding factors. Future field studies should consider the potential for a longitudinal design, with effective masking and control groups in place to minimise some of the risks of bias. Well-designed studies considering quantified AM exposure-response would be valuable. In particular, objective measures of health, such as those used in the Health Canada (2014a) research (including sleep actimetry[36], stress hormone and blood pressure measurements), could serve to verify data obtained from typical self-reporting methods such as questionnaires and interviews.

[36] A non-invasive method of monitoring human rest/activity cycles in medical studies

FURTHER RELEVANT STUDIES

Audible amplitude modulation - results of field measurements and investigations compared to psychoacoustical assessment and theoretical research (Stigwood, Large, & Stigwood, 2013) [grey]

3.3.93 This study is a discussion document providing background, features, possible causes and contributing factors of AM WTN. The discussion draws on examples derived from measurements at 13 wind farm sites in the UK.

3.3.94 The main conclusions are that AM propagation is affected by meteorology and air profiles, WTN AM depth at some sites reaches 6-10 dB under some conditions, measurement of AM WTN is problematic and unlikely to be successfully conducted by regulators, and that psychological aspects relating to specific characteristics of the sound may play an important role in subjective responses.

3.3.95 This paper presents a very thorough analysis of a limited set of measurement data. It makes the useful observation that the atmospheric conditions that may contribute to higher risk of increased AM (such as stable atmospheres, temperature inversions, etc.) are more likely to occur during the evening, night or early morning.

WIND FARM PUBLICATIONS PRODUCED BY AN 'INDEPENDENT NOISE WORKING GROUP'

3.3.96 This section outlines a review of a recently-published portfolio of documents reporting on aspects of AM WTN that are relevant to this research. The aims and objectives of the authors are outlined, followed by reviews of the individual reports. It is understood that these papers have been presented to a number of Government departments, and DECC made a specific request to the research team to ensure that they were included in the formal review.

3.3.97 The documents discussed in this section were examined by the independent external reviewers. NB. All review commentary in this section is directly quoted from the review summaries received, as indicated by text in blue font. Any text added by the internal research team is indicated [in square brackets].

3.3.98 It was not possible within the scope limitations of the review to exhaustively check all source references and analyses made within these publications. Consequently the validity and accuracy of interpretative review and analysis of reference literature contained therein has necessarily been taken at face value.

Wind Turbine Amplitude Modulation & Planning Control Study – Terms of Reference (Independent Noise Working Group, 2015) [grey]

SCOPE

3.3.99 This document defines the Independent Noise Working Group (INWG) terms of reference (TOR), taking a holistic view of the current problem with wind turbine AM noise.

3.3.100 It is in response to real concerns about the strategy being implemented by the wind power industry via the IOA.

3.3.101 It was felt that the IOA AM study and report would be narrowly defined with limited scope to address the real problems of AM noise at both existing and new wind turbine sites.

3.3.102 The Objectives of the INWG were given as:

- → To protect communities and wind turbine neighbours from amplitude modulation noise.
- → This protection is urgently needed by communities close to existing wind turbines, wind turbines where planning consent has been given but the turbines not yet constructed and wind turbines being proposed through the planning system.

3.3.103 The document sets out the membership of a Steering committee which will define the TOR and a set of four deliverables:

- → Report providing a rationale for introducing effective controls
- → Workable and tested AM planning control or condition for new turbine schemes
- → Effective method to control AM noise from turbines where planning consent has already been given
- → Produce evidence to demonstrate the effectiveness or otherwise of the AM planning condition being proposed by the IOA NWG

3.3.104 The document sets out plans for wider consultation.

3.3.105 The TOR notes that the report and recommendations will be subject to a thorough review process plus an EHO panel to test the proposed AM control method.

3.3.106 The TOR set out the various Work packages

- ❖ WP1: Define and quantify AM
- ❖ WP2: Literature and evidence review
- ❖ WP3: Effects of AM
- ❖ WP4: Den Brook
- ❖ WP5: Draft AM planning condition
- ❖ WP6: Control of AM noise from existing wind turbines
- ❖ WP7: Test the IOA NWG proposed AM planning condition
- ❖ WP8: Review the IOA AM study and methodology
- ❖ WP9: The Cotton Farm monitoring experience

QUALITY, ROBUSTNESS, RELEVANCE

3.3.107 The TOR document itself, being reviewed here, talks of the Steering Group developing the TOR, [which raises the question as to whether] the TOR were changed during the course of the project.

3.3.108 The document is particularly relevant to the issue of what constitutes adequate planning conditions and effective control measures.

Wind turbine amplitude modulation & planning control study – Work Package 1: The fundamentals of amplitude modulation of wind turbine noise (Yelland, 2015) [grey]

SCOPE

3.3.109 This paper explores aspects of AM and EAM[37] relating to their definition , causes and measurement.

3.3.110 [The] main chapter headings are:

- *The Characteristics of AM and EAM*
- *Causes of AM – wind shear, transient stall pressure pulses, vortex shedding, blade/tower interaction etc.*
- *The RUK[38] report*
- *Measurement problems*

QUALITY, ROBUSTNESS, RELEVANCE:

3.3.111 Much of the section on Conclusions does not actually relate to the preceding content but includes unrelated comment on such issues as [in the INWG author's view] the increasing inadequacy of the ETSU document and the nocebo[39] effects. There are also alarmist comments on potential health hazards and anecdotal claims about various serious effects on animal life, e.g. aborted mink.

3.3.112 The report is very strong, clear and objective on the technicalities of the characteristics and causes of AM. However, when it comes to comments on the RUK report, the tone changes completely. [The INWG author of the paper] starts by impugning the motives of the authors [of the RUK report], the links with industry, lack of peer review etc. He states that the report is "*technically unsound and highly misleading*".

3.3.113 An example of the tone used:

> "*The claim of 'peer reviews' by an author's colleagues who rely on the same customer base and belong to the same professional institution as the author is worthless and serves only to demean the author and the institution.*"

Wind turbine amplitude modulation & planning control study – Work Package 2.1: Review of reference literature (Cox, 2015) [grey]

SCOPE

3.3.114 This work package presents the results of a review of the literature WTN. Over 160 documents were reviewed by the INWG for this study of AM.

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[37] Excessive/excess/enhanced amplitude modulation
[38] RenewableUK – renewable energy trade association (UK)
[39] Describes a response that is caused by a subject's expectation of adverse effects from a stimulus - in this case, exposure to wind farm noise

3.3.115 The report reviews the literature relevant to WTN AM and consolidates the reference material considered by the INWG in the various work packages (WP) making up the study into AM.

3.3.116 Objectives are given as:

- → *Review the evolution of knowledge regarding WTN and AM;*
- → *Collate the reference literature relevant to this INWG study of WTN AM and produce a common reference list for the study work packages;*
- → *Provide a short description of each reference document*

3.3.117 The main chapter headings (which give an indication of the 'tone' of the report) are:

- *Executive Summary*
- *Introduction*
- *Knowledge Evolution*
- *The Case regarding Low Frequency Noise*
- *The Case Against ETSU*

CONCLUSIONS FROM THE PAPER

3.3.118 This review of evidence spanning over 30 years shows a clear evolution of knowledge relating to the science behind WTN and its effects on people. Starting with the NASA research conducted during the 1980s through to the NIA[40] inquiry report of March 2015 and beyond, many of the key scientific aspects are now well understood and well defined.

3.3.119 The most important conclusion from this evidence is that [in the INWG author's view] the official UK WTN guidance, ETSU, is totally unfit for purpose and is failing to protect against the effects of EAM noise. Despite it being updated and acquiring an IoA-developed Good Practice Guide, it was [in the INWG author's view] developed using evidence relevant only to small turbines far removed from the 80m hub height devices being deployed almost twenty years later, and does not reflect the more recent science.

3.3.120 [Original INWG author's description] *Throughout this period since 1997 the wind industry, aided by its acoustic, political and legal consultants has sought to hide the true science behind EAM in WTN and its effects on people though a concerted strategy of obfuscation and political interference. This has been aided by compliant government officials who have been focused on removing barriers to the deployment of wind power generating capacity and by the wind industry effectively taking control of the Institute of Acoustics (IOA). The IOA Good Practice Guide to the application of ETSU subsequently approved by government is an example of how commercial interests and political lobbying have triumphed against science and wind turbine neighbours. At no point does it tackle any of the issues identified by the research into EAM that we have reviewed above. Complaints regarding wind turbine noise currently classified as AM or EAM or OAM[41] or 'greater than expected AM' by the wind industry is an obfuscation of the true nature of*

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[40] Northern Ireland Assembly
[41] 'Other' amplitude modulation, another description for AM outside the expected norm.

the problem. As a result, all efforts to date by third parties to have the ETSU noise guidelines revised or replaced with a science-based alternative have been successfully resisted.

QUALITY, ROBUSTNESS, RELEVANCE

3.3.121 The conclusions listed above are not listed as overall conclusions of the report. They come at the end of section 3 on knowledge evolution, which is a discursive and somewhat rambling account of 30 years of research. AM features highly in this account in a rather unstructured way. There are no helpful conclusions on AM itself. Other main parts deal with 'LFN' and the 'Case against ETSU'.

3.3.122 Much of the rest of the report is taken up with extensive summaries of literature.

Wind turbine amplitude modulation & planning control study – Work Package 2.2: AM Evidence Review (Large, 2015) [grey]

SCOPE

3.3.123 This work package deals only with audible EAM. It looks primarily at measurements of AM in support of its existence and prevalence. It looks secondly at reports of AM, which is a limitation of this review as it relies on anecdotal evidence.

3.3.124 This work package is not intended to be a discursive document but simply as a collation of evidence with a brief resume of the AM noted in the relevant study or research project.

CONCLUSIONS OF THE PAPER

3.3.125 [Original INWG author's description] *There exists an international history of evidence that documents the presence and regular occurrence of AM. Empirical data and subjective reports demonstrate that the manifestation of AM and the presence of AM within wind farm noise are effectively linked to increased annoyance. [This review] of AM research provides only a summary of documents and measurements from a single UK consultancy and open-access papers. Access to papers published in subscription-only journals or to the resources available to larger consultancies can only be expected to increase documented cases of AM and provide further evidence supporting the prevalence of AM.*

QUALITY, ROBUSTNESS, RELEVANCE

3.3.126 The title is misleading in that the evidence is a 'mish-mash' of reported complaints, comments on research papers, plus objective measurement data assessed as constituting AM.

3.3.127 The papers included some of those being considered by [the current study on behalf of DECC] such as Lee et al. (2009). However, no systematic assessment is made.

3.3.128 Appendix A [in the paper] gives a table of more than 70 sites where complaints were noted. This seems unrelated to the main text. No documentary evidence is provided about the form of complaint, e.g. written, telephone etc.

Wind turbine amplitude modulation & planning control study – Work Package 3.1: Study of noise and amplitude modulation complaints received by local planning authorities in England (Sherman, 2015) [grey]

SCOPE

3.3.129 [Original INWG author's description] *This study uses survey data to provide insights into the current views of involved English Local Planning Authority (LPA) professionals on how to prevent, control and mitigate industrial wind turbine noise including the phenomenon of excess amplitude modulation (EAM) that gives rise to most complaints. The three questions asked were:*

- *Have you received noise complaints?*
- *Have you received AM complaints? And*
- *If yes, how do you deal with them?*

CONCLUSIONS FROM THE PAPER

3.3.130 [Paraphrased from the INWG author's description] In England, 54 LPAs from 203 responses report having received complaints about noise from industrial wind turbines. Of these 54 LPAs, 17 report having also investigated complaints about EAM. There is a high level of awareness amongst LPAs of EAM, but no consistent approach to complaints. 'Noise only' complaints are generally resolved but most 'AM related' complaints remain unresolved and there is no working solution to the problem. EAM is more common than suggested by government policy. Compliance with ETSU does not correspond with likelihood of AM complaints. EAM nuisance is a 'noise character' not a 'noise level' issue. Guidance is needed on detecting and remedying EAM.

QUALITY, ROBUSTNESS, RELEVANCE

3.3.131 A number of inherent limitations of the study are acknowledged by the author – including that the overall number of noise complaints about WTN or EAM cannot be accurately established. In addition, the survey was introduced via a letter from Christopher Heaton-Harris MP that may have influenced the number and nature of LPA responses: 203 LPAs responded from 265 "*relevant*" LPAs (i.e. deemed likely to have experience of turbines by the authors) within an overall total of 423 LPAs in England. This is an unusually high response rate for a survey of this type. [Responses were based on] only three simple questions. [There are] some inherent limitations to the methodology. The author has relied upon the fuller responses received from a subsample of respondents to produce the discussion.

3.3.132 The statement in 1.1 of the Executive Summary that EAM "*gives rise to most complaints*" is a little misleading because, for example, the total number of complaints cannot be accurately established; the complaints information may be skewed by responses from one or two LPAs; and only 17/54 of those LPAs reporting complaints specifically said they were about AM. However, the author may be drawing on additional information supplied by LPAs to support this statement.

3.3.133 There is no time-frame mentioned in the survey questions, so, the numbers of reported complaints should be regarded as all-time totals and trends over time cannot be reliably ascertained.

3.3.134 There is no attempt to provide context by comparing the reported numbers of complaints about WTN with the total number of consented turbines, nor with the reported numbers of noise complaints about other sources that are received by LPAs, in particular by Environmental Health Practitioners (EHPs).

3.3.135 There is no detailed analysis of why only 4 Noise Abatement Notices were "*considered or served*". A constructive suggestion from one LPA that 'Energy Generation' should become a specific Land Use Category to facilitate a more systematic consideration of wind farms (and solar farms) in the planning system may be worth examining as part of the wider aspects of [the current study on behalf of DECC]. The analysis lacks wider context.

Wind turbine amplitude modulation & planning control study – Work Package 3.2: Excessive amplitude modulation, wind turbine noise, sleep and health (Hanning, 2015) [grey]

SCOPE

3.3.136 Relevant aspect of [the] review: review of effects of EAM on people living close to wind turbines in terms of annoyance, sleep and health effects. In fact [there is] not a lot on AM in the report.

CONCLUSIONS FROM THE PAPER

3.3.137 [As presented]

- → Current setback distances for wind turbines recommended by ETSU are not safe for health.
- → Reports that wind turbine noise is more annoying than aircraft, road and rail noise, controlling for intensity.
- → Disputes that WTN is masked by background noise.
- → Suggests that there are effects of low frequency noise on health.
- → AM [is deemed] more annoying than unmodulated WTN. [The INWG author] suggests that 2dB AM depth is negligible, 4dB is unreasonable and 6dB is excessive.

QUALITY, ROBUSTNESS, RELEVANCE

3.3.138 A selective review of peer-reviewed literature plus internet-based reports and anecdote. The literature review is not systematic and the interpretation and conclusions are selective. There is little consistent evaluation of the different strengths of the evidence although some studies are pointed out as being uncontrolled. [There is] not a lot on AM in the report.

Wind turbine amplitude modulation & planning control study – Work Package 4: Den Brook (Hulme, 2015) [grey]

SCOPE

3.3.139 To document legal, planning and technical aspects surrounding the Den Brook (North Tawton, West Devon) planning conditions[42]. Den Brook Judicial Review Group (DBJRG) established to ensure acoustic impacts from proposed wind turbines were properly "*conditioned and controlled*" and to represent the interests of local residents. Work package 4 describes the Den Brook timeline where it relates to amplitude modulation.

3.3.140 This paper presents the process of agreeing the conditions for AM in wind farm operations at Den Brook. Inevitably it presents the case from one side.

CONCLUSIONS FROM THE PAPER

3.3.141 [According to the INWG author] The EAM conditions imposed [at Den Brook] seem unclear. Suggestion that conditions might be unenforceable due to false positive background noise. The condition 20 methodology alone cannot reliably distinguish periods of data that do/not contain AM.

QUALITY, ROBUSTNESS, RELEVANCE

3.3.142 The paper outlines the disputes between the developer, the planning authorities and courts and the DBJRG. Technical details on noise are relatively limited. [According to the INWG author] Initial acoustic assessments by the developers were "*found to be flawed*" so the initial planning permission was quashed. The developer then submitted a proposal for substantially weakening the noise conditions; examination on behalf of DBJRG found this to be flawed too. The developer then devised a written scheme. However, precautions taken within this scheme (stage 4c) to filter out "*apparently invalid complaints*" revealed "*substantial discrepancies*" – meaning that EAM noise would be "*significantly and materially understated*". In further meetings it was conceded that EAM is not a rare occurrence. Following this DBJRG plan to carry out 24/7 noise monitoring.

3.3.143 This paper presents the process of agreeing the conditions for AM in wind farm operations at Den Brook. Inevitably it presents the case from one side. The process as reported here is conflictual and does not show parties in a good light. It is also clear that the issues generate high levels of emotion.

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[42] A number of references are made to the "Denbrook" AM condition in various documents. It should be noted there is: a) the AM condition as originally applied at the first Inquiry (referred to as the 'original'); b) the AM condition as amended through the course of various legal challenges; and, c) the AM condition as it currently stands at the time of writing (referred to as the 'final') following a recent amendment by the applicant and subsequent legal challenge.

Wind turbine amplitude modulation & planning control study – Work Package 5: Towards a draft AM condition (Large, Stigwood, & Bingham, 2015) [grey]

SCOPE

3.3.144 [INWG author's description] *Four main methods for assessing or limiting EAM have been critically examined in this work package. These methods are representative of the range of assessment / control methods currently proposed for EAM. Each method was tested with real world data from six different sites ranging from smaller single turbines to large wind farm developments. The methods tested were the RenewableUK template planning condition, a methodology proposed by RES*[43] *for the Den Brook case, the original Den Brook EAM condition and the Japanese DAM*[44] *methodology. In addition BS4142:2014 and BS4142:1997 were tested with data from two of the six sites.*

CONCLUSIONS FROM THE PAPER

3.3.145 [INWG author's description] *This work package shows that existing methods of controlling and assessing AM can be successfully modified and implemented to provide a prescriptive and unified assessment process for EAM. Where wind farm noise level and wind farm noise character require simultaneous assessment the use of BS4142:2014 is recommended. The difficulty of rating EAM for frequency of occurrence and duration in the absence of research looking at long term impact of EAM and subjective response is acknowledged.*

3.3.146 It is concluded that "*assessment of the extent of impact should remain the responsibility of those assessing and enforcing impact*".

3.3.147 [Original INWG author's description] *There are several different methodologies for deriving an AM value but two main differences in how this relates to a control for AM. Firstly the AM value can be used to derive a penalty that ultimately influences the overall noise limit. Thus, AM is controlled by way of lowering the noise level or noise exposure level. Examples include the RenewableUK method. Secondly the AM value is used to judge whether or not AM is acceptable. A higher AM value indicates that AM is not acceptable and that the noise must be mitigated, the lower the value the more likely it will be considered reasonable. Thus the AM value is treated as a trigger point for mitigation measures. Examples include the Den Brook condition. BS4142 provides a hybrid methodology where a penalty is derived to acknowledge intrusive character features and applied to the overall noise level, but importantly this is then compared to the background sound level rather than a threshold noise limit. This latter method has the benefit of adding context to the assessment, both in terms of context of the noise within a specific environment and a human / subjective context.*

QUALITY, ROBUSTNESS, RELEVANCE

3.3.148 First impression is that this is a thorough and balanced review. It contains relevant detail on the derivation of suitable planning conditions and any wider approach to control the impact of AM in the planning system.

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[43] Renewable Energy Systems (developer of the Den Brook Wind Farm)
[44] Refers to the AM depth metric D_{AM}, discussed in section 3.2

3.3.149 The report predates the recommendations of the IOA AMWG[45] for the IOA preferred AM indicator but it uses an approach to compare the available AM indicators that addresses the need for such indicators to go beyond the (acoustic) identification and quantification of AM and to relate to the (human) impact of the noise in a way that will work robustly and fairly in a wider (planning and complaints assessment) context.

3.3.150 The report contains a brief but useful discussion of how the impacts of other sources of noise with character are currently assessed, including judgements of acceptability.

3.3.151 The report contains a useful discussion of the Government's six [tests] for planning conditions with a focus on WTN and a further six objectives that the authors consider desirable.

3.3.152 The need for the chosen AM indicator to relate to the assessment of impact is highlighted and the report provides a logical process diagram to assist with the derivation of a suitable AM planning condition.

3.3.153 The various reviewed AM indicator methodologies are grouped into one of four categories in a useful table that highlights the current differences in approach:

a) Application of a penalty to overall noise limit.

b) Trigger value.

c) Derivation of AM indicator only (no application to impact assessment).

d) Use of context/human judgement.

3.3.154 The report finds that several of the available methodologies work to some extent and could be applied, with some adaptions, to produce a workable method for assessing and controlling EAM.

3.3.155 There is detailed discussion about the strengths and weaknesses of the different methods, including a favourable appraisal of a BS4142:2014 type of approach to the control of wind farm noise with character.

3.3.156 The following quotation is relevant:

> "*There is currently little knowledge or understanding of how features such as frequency and duration, context with background sound environment and time of occurrence specifically impact on the perception of EAM. Based on experience gained from impact of other noise sources it is expected that the more frequent and long lasting the EAM the more intrusive. Evidence suggests that those impacted by noise with character do not habituate to the noise but conversely become sensitised.*"

3.3.157 The discussion concerning the absence of a clear dose-response relationship is particularly pertinent:

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[45] Amplitude modulation working group, formed from membership of the IOA and the Chartered Institute of Environmental Health at the behest of Government to investigate the formulation of a metric for quantification of AM WTN.

"*However, it is common for all noise with character that the more periods of intrusion, the longer the noise occurs, the more noise penetrates dwellings and cannot be escaped, the more noise sensitive periods are effected* [sic] *(i.e. sleep vs. labour or rest and relaxation), then the greater or more extreme the impact will be. It is suggested that in the absence of any clear dose response relationship assessment of these aspects remains addressed through subjective, professional judgement and on the basis that intrusion of more sensitive activities and areas of a dwelling should be prevented.*"

3.3.158 The report recommends that two separate assessment/enforcement methods for EAM should be used. Where the noise from a wind farm is steady, continuous and anonymous ETSU-R-97 could continue to be used for assessment at the planning stage and for compliance testing. Where wind farm noise complaints indicate a variety of impacts including noise level, noise character, and/or tonality then BS4142:2014 can be used as a stand-alone assessment independent of any other assessment. It is suggested that the rating noise level of the wind farm/wind turbine noise should not exceed +10dB above the background sound level. There is no detailed analysis of the implications of this suggestion, in particular whether or not the adoption of such a criterion would have an undue effect on the day to day operation of wind farms.

Wind turbine amplitude modulation & planning control study – Work Package 6.1 (inc. 6.1a Supplementary Paper): Legal issues: the control of excessive amplitude modulation from wind turbines (Cowen, 2015) [grey]

SCOPE

3.3.159 [INWG author's description] *The Objectives of this Work Package are:*

- *Objective 1 – To assess the legality of the Den Brook Condition relating to EAM following the judgement of the Court of Appeal;*
- *Objective 2 – To assess the legal appropriateness of other remedies such as Statutory and Private Nuisance that have been recommended since that judgement or may be available to persons affected by EAM;*
- *Objective 3 – To recommend the most appropriate course of action that will provide legal protection to residents hosting wind farms should EAM occur.*

CONCLUSIONS FROM THE PAPER

3.3.160 [INWG author's description] *Objective 1 has been met by a complete review of the situation regarding a planning condition to control EAM since the judgment of the Court of Appeal in the Den Brook case. The advantage of this procedure is that a suitably worded condition strikes at the heart of this problem. However, it also has to be acknowledged that there are procedures to be followed and these can take time. The question is whether this is the most effective way of addressing the problem.*

3.3.161 [INWG author's description] *Objective 2 has been addressed through discussion of other remedies available under the TCP*[46] *Act if a planning condition is in place, namely the power to serve a stop notice, to serve a breach of condition notice or to seek an injunction. Of these, a Stop Notice runs the risk of substantial compensation being paid and a Breach of Condition notice*

[46] Town and Country Planning

does not have real 'teeth'. However, if an injunction can be obtained, this is likely to be a powerful tool. It may be expensive and perhaps risky to obtain, but if the Court should grant one, it should quickly resolve the problem. It cannot be considered costlier or more protracted that alternative approaches such as SN[47]*.*

3.3.162 [INWG author's description] *In answering Objectives 2 and 3, other potential remedies have been considered. Some of these such as SN have been actively advocated by the Wind Industry and supported by Planning Inspectors. Evidence however suggests that an Abatement Notice is not an effective control to protect nearby residents from EAM. Others such as private nuisance and similar legal actions have been considered but these place too much risk and burden on residents for a problem not of their making with likely long term adverse financial implications. They may however be the only remedies available if a suitably worded condition is not imposed in the Planning Certificate. The inability of the alternative procedures to bring about effective control and exemption from those procedures in some cases may indicate action under the EHRC*[48] *is the only realistic option. This is also a complex, potentially lengthy and dauntingly uncertain process.*

3.3.163 [INWG author's description] *Consideration has also been given to Blight action. This could provide a speedy remedy if there were power to enforce it but, under the current law, this is not an option that is open to residents.*

3.3.164 [INWG author's description*] A final purpose of this paper is to recommend the most effective course of action to protect residents if there is a potential problem caused by EAM from a wind farm or turbine. While no course of action may provide the speedy remedy that is sought, it is firmly recommended that the adoption of a modified Den Brook type condition is appropriate.*

QUALITY, ROBUSTNESS, RELEVANCE

3.3.165 [This is a] carefully written legal review that recommends that control of AM through the planning system is the most appropriate formal/legal course of action, and that the [original] Den Brook condition is the most suitable of the conditions currently available.

3.3.166 This paper assumes that the EAM problem exists, is sufficiently widespread and of such impact (on residential amenity, health and quality of life) that it should be subject to formal control.

3.3.167 The conclusion supports the use of a modified Den Brook condition but it is caveated that a "*suitably worded alternative condition may need to be drafted*" and "*imposed in every planning permission for a wind turbine unless there are clear reasons to show that it is unnecessary*".

3.3.168 The paper describes legal issues surrounding the need for a suitable EAM planning condition, but contains no new proposals.

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47 Statutory Nuisance
48 European Convention on Human Rights

Wind turbine amplitude modulation & planning control study – Work Package 6.2: Control of AM noise without an AM planning condition using Statutory Nuisance (Gray, 2015) [grey]

SCOPE

3.3.169 To contrast the effectiveness of Statutory Nuisance versus a statutory planning condition for dealing with AM noise from wind turbines.

CONCLUSIONS FROM THE PAPER

3.3.170 [Paraphrased from INWG author's description] Statutory Nuisance is a reactive response to complaints about noise from a householder to the local authority. It does not offer the same protection in law as a clearly defined AM planning condition. Statutory Nuisance should be a fast remedy but it is not. The consequence of using Statutory Nuisance seems to be that the wind farm operator has no legal obligation to control WTN AM. ETSU guidance allows a small amount of AM up to 3dB close to turbines – but apparently this doesn't deal with AM further than 50m from the WT. Despite many complaints about noise reportedly no EHOs have shut down or restricted the activity of wind turbines. Reluctance by local authorties (LAs) to use SN for fear of counter loss of income claims from WT owners. Fines are relatively small for WT owners. DEFRA Guidance for LAs is not practically helpful.

3.3.171 If "*average dB readings fall within the ETSU LA90 limits, which by design ignore the contribution from the peaks of noise, then the peaks and troughs of AM noise can be at any level of modulation.*"

3.3.172 Example given of Cotton Farm, Cambridgeshire, where continuous noise monitoring demonstrated more EAM than was anticipated.

3 3.173 [INWG author's description] *Statutory nuisance is therefore unlikely to provide a route to resolving an EAM problem. A planning condition is required.*

QUALITY, ROBUSTNESS, RELEVANCE

3.3.174 A reasonable case is made here (particularly because of the permanent nature of the noise source and the possibility of designing in mitigation at the development stage) that a statutory nuisance approach is not the right way to approach this and does weight the outcomes in favour of wind turbine owners.

3.3.175 A planning condition would be better. There is an issue here about if annoyance is largely dependent on sound intensity wil a simple reduction in sound intensity reduce the effect on annoyance or distress specifically related to AM?

Wind turbine amplitude modulation & planning control study – Work Package 8: Review of Institute of Acoustics amplitude modulation study and methodology (Cox, 2015) [grey]

SCOPE

3.3.176 [INWG author's description] *To review and summarise the activities of the Institute of Acoustics and its Noise Working Groups with respect to wind turbine noise amplitude modulation.*

CONCLUSIONS FROM THE PAPER

3.3.177 [INWG author's description] *This chronology of the activities by the IOA shows that its NWG and specialist subgroup the AMWG devoted to the study of excess amplitude modulation have consistently operated for the benefit of the onshore wind industry in the UK and to the detriment of local communities hosting wind turbines. This is also arguably against both the IOA code of ethics and that of the Engineering Council. The effect has been to both obfuscate and hide problems related to wind turbine noise assessment from government and from the Planning Inspectorate. Whether or not this behaviour is carried forward into the future remains to be seen (July 2015).*

QUALITY, ROBUSTNESS, RELEVANCE

3.3.178 This paper contains allegations of conflict of interest, and professional malpractice that are outside the scope of this review.

3.3.179 However, paragraph 49 contains a useful critique of the IOA AMWG consultation that is of direct relevance and is therefore reproduced below:

"Comments on, and criticism of, the IoA AMWG consultation document include:

→ *The definition of EAM is too narrow as there are also many variable sound characteristics other than simply modulation depth that contribute to what is generally considered as EAM;*

→ *Turbine sound emissions also include low frequency sound both audible and non-audible that should not be ignored as it all contributes to the sensation effect;*

→ *Consideration of LFN is conspicuously absent from the consultation document. By excluding frequency data below 100Hz, much of the low frequency energy will be eliminated resulting in EAM being under reported;*

→ *Turbine sound and EAM should be measured where people will experience it. This should include close to buildings where reflections can affect the noise levels and inside buildings where room resonance effects combined with low background noise can amplify its effects;*

→ *Class 1 instrumentation as recommended by the IOA NWG in their Good Practice Guide have been shown to be inadequate in that its 'noise floor' is too high for low background noise environments and is unsuitable for the low frequency measurement capability required for wind turbine sound;*

→ *The IOA and wind industry appear obsessed with 'automating' the AM measurement process using software. This will have the effect of removing transparency from the process when what is required is a simple transparent process that a local authority EHO can carry out with or without an acoustics consultant;*

→ *The IOA AM study is too narrowly defined and avoids looking at the big picture with regard to AM and how it affects people. This IoA AM study is also widely seen as another wind industry attempt at obfuscation to ensure EAM planning conditions will not unduly constrain wind power development and has nothing to do with protecting those affected by the noise.*"

3.3.180 Observations on these points, based on the subset of literature that has been reviewed as part of [the current study on behalf of DECC], are as follows:

→ There is evidence in the reviewed research literature that other WTN and AM characteristics, in addition to modulation depth, are likely to be relevant to adverse effects such as annoyance and sleep disturbance. There is a lack of well-designed long term field based dose-response research in this field.

→ There are some attempts in the reviewed research literature to include noise measurements both inside and outside homes, and to relate this to human response, however a number of difficulties and shortcomings in the assessment of both dose and response have been identified in the reviewed research.

- There are a number of competing demands that are important in the choice of a suitable AM indicator. For the purposes of setting an effective policy control criterion the indicator will need to be more than 'simply' a technically robust metric. In [the opinion of the reviewer], in addition to transparency, repeatability and reproducibility, the indicator will also need to be relevant to perception and to the management of impact (on residential amenity, health and quality of life).
- The [the current study on behalf of DECC] has attempted to systematically identify and review all relevant research literature, particularly on the effects of AM on people. However, there are difficulties in conducting longer term ('big picture') field studies and there are limitations in the amount and quality of the underlying research.

Wind turbine amplitude modulation & planning control study – Work Package 9: The Cotton Farm monitor experience (Gray & Tossell, 2015) [grey]

SCOPE

3.3.181 [INWG author's description] *To document the experience of fighting a wind farm application and the decision to carry out long term noise monitoring by the local community to prove the existence and frequency of noise emanating from a newly built wind farm.*

CONCLUSIONS

3.3.182 [INWG author's description] *Existing wind turbines, as has been proven by the Cotton Farm monitor experience, should be constantly monitored and the data recorded. There has to be a clear understanding of the problems caused by noise and a clear directive for immediate action by the authorities and operators when unacceptable noise conditions do occur. The experience pioneered by the local community around the Cotton Farm wind farm proves this is not only practical but essential for legal and health reasons.*

QUALITY, ROBUSTNESS, RELEVANCE

3.3.183 Continuous unattended noise monitoring (over 2.5 years), met data and resident complaint logs are available. It is not clear if this can be linked with operational data from turbines themselves. There may be an opportunity to undertake dose-response analysis of the data being collected at Cotton Farm but this is not discussed or reported here. It's difficult to assess quality and robustness of measurement of dose and/or response from the information provided. [Response is not scaled on any] standardised rating of annoyance. Residents are able to decide when to complete diaries and how to describe the effects.

3.3.184 Only one measurement position is being used for long term measurements so [the data] may not be representative of levels at all properties.

3.3.185 It is likely only to be those who object to the wind turbines or WTN that are taking part in this project so there is an unavoidable risk of bias.

3.3.186 [There is] no information of direct relevance to [the current study on behalf of DECC] but possible relevance to compliance monitoring [in relation to] planning conditions and to future design of longer term field research studies.

CATEGORY 2 CONCLUSIONS

3.3.187 The category 2 papers reviewed in section 3.3 provide supporting evidence that:

- Perception of amplitude modulation in WTN and other environmental sounds affects subjective annoyance;
- There is an potential association between WTN-related annoyance and increased risks of sleep disturbance and stress;
- There are other non-acoustic factors that play an important role in influencing the subjective annoyance attributed to noise from wind turbines, including sensitivity, attitude, situation, aesthetic perception and economic benefits; and
- Annoyance due to AM WTN seems to be increased during normal resting periods, i.e. late evening / night-time / early morning. This could be due to increased sensitivity, greater AM prevalence or magnitude (e.g. due to diurnal variations in atmospheric conditions) or a combination of these factors.

3.4 LIMITATIONS OF EVIDENCE

3.4.1 The following paragraphs list recommendations for future research based on the identified limitations of the category 1 & 2 papers, and summarises how the conclusions of these papers can be used in their current form.

CATEGORY 1 PAPERS

3.4.2 None of the laboratory studies reviewed address possible differences in sensitivity that might be encountered in different contexts, for example, when trying to get to sleep at night-time. Further work to closely investigate the effects of potential differences in diurnal sensitivities to AM WTN would be informative. Any laboratory results should also be compared or augmented with field study data. This could be especially valuable in view of the results of broader field studies (discussed further in section 3.3), some of which report increased complaints due to WTN in the night-time hours, and generally include much larger samples than the Category 1 studies reviewed.

3.4.3 The limitations of an artificial environment present significant difficulties for achieving wider applicability of the results. One particular difficulty with the laboratory studies that focussed on rating absolute annoyance is the relatively short duration of the stimuli generally used compared with what may be encountered in the field. Consequently, 'annoyance' ratings obtained in this way are unlikely to be closely representative of the potentially emotional response that could be experienced by people over varying exposure durations, periods and intermittency, and within other contexts and environments. There was only a single field study (D[49]) identified with potentially useful exposure-response data in this area, which unfortunately had drawbacks of a small sample and high potential for bias. A strong need has been identified for studies focussing on quantifying exposure-response relationships that reflect conditions likely to be experienced by those within the exposed population. The Tokyo study (B) did include large-scale field measurements and social survey data, producing exposure-response relationships for time-averaged levels (L_{Aeq}) (Yano, Kuwano, Kageyama, Sueoka, & Tachibana, 2013). The study also analysed measurement data from 18 wind farm sites, and applied the developed AM metric to produce an estimate of fluctuation sensation at the measurement points. However, the group

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[49] (Bockstael, Dekoninck, Can, Oldoni, de Coensel, & Botteldooren, 2012); (Bockstael, Dekoninck, de Coensel, Oldoni, Can, & Botteldooren, 2011)

have not yet published an investigation of direct links between the perceptual results on AM with those obtained from the social survey work. Any such link, if established, could provide potentially valuable information in this area.

3.4.4 None of the category 1 studies reviewed directly investigated the effect of *changes* in an existing noise environment due to (the introduction of) AM WTN, which understandably in a laboratory setting would be very difficult to design representatively. Further work in this area could be valuable, and would ideally be investigated via a longitudinal field study, in which noise measurements and associated social survey data are obtained in an area prior to an impending wind turbine installation that is later developed. Post-installation measurements and survey data, including those from a control group not exposed to WTN could then be compared to establish changes in the environment due to (AM) WTN and any associative changes in perceptual response. Unfortunately it must be acknowledged that this type of study design could be difficult to realise, not least because of the relatively small proportion of the UK population exposed to WTN, and the sensitivities surrounding wind farm proposal sites and public awareness. Further field studies and the implications of the lack of assessment of noise environment changes are discussed in the Category 2 papers section 3.3.

CATEGORY 2 PAPERS

3.4.5 A number of avenues of future investigation are raised:

- Longitudinal field studies incorporating subjective *and* objective measures of response to WTN exposure, with quantification of AM verified with measurement data.
- Studies aimed at identifying the influence of AM WTN exposure on observed responses in realistic situations, specifically addressing:
  - duration;
  - magnitude;
  - frequency of occurrence;
  - both 'steady state' and 'change' environments; and
  - differences in sensitivity over a range of applicable contexts (e.g. including rest / sleep periods).
- Research to further establish the effectiveness (in terms of subjective perception and response) and availability of mitigation methods for AM in WTN.

SUMMARY

3.4.6 None of the available research reviewed as part of this study has been designed to answer the main aim of the study in its entirety. That research would have ideally included a longitudinal field-based exposure-response study, specifically quantifying both the AM character of WTN, and a scaled response from the sample subjects. The Category 1 study results have questionable applicability to a wider population, due to limited sample representativeness and associated potential for bias (which may be practically unavoidable in laboratory studies), whereas the Category 2 studies generally do not directly address the issue of AM WTN exposure-response (and also carry potential risks for bias). A meta-analysis of the identified studies was not possible due to the incompatibility of the various methodologies employed.

3.4. 7 In order to progress this study, it has been necessary to look at all of the available research and make some professional judgements to link the various relevant elements together. This process has been undertaken by the researchers, and reviewed by the independent external reviewers. It should therefore be recognised that the discussions and recommendations made are based on professional judgement and consideration of the best currently available evidence.

3.5 INSTITUTE OF ACOUSTICS METHOD FOR RATING AM

3.5.1 As noted in paragraph 1.1.6, the IOA AMWG have been working on the development of a method for the collection of data for subsequent identification and then rating of amplitude modulation in wind turbine noise. A draft of the Final Report "*A Method Rating Amplitude Modulation in Wind Turbine Noise*" (IOA AMWG, 2016) was made available to our project team in January 2016 for review by the internal research team. The draft Final Report contained the group Terms of Reference in Appendix A and Scope of Work in Appendix B.

SCOPE

3.5.2 [AMWG author's description] *This document has been prepared by the Amplitude Modulation Working Group (AMWG) established by the UK Institute of Acoustics (IOA) to propose a method or methods for measuring and rating amplitude modulation (AM) in wind turbine noise. Amplitude modulation (in this context) is a regular fluctuation in the level of noise, the period of fluctuation being related to the rotational speed of the turbine. This characteristic of the sound might be described by a listener as a regular 'swish', 'whoomph' or 'thump', depending on the cause and the severity of the modulation.*

CONCLUSIONS FROM THE PAPER

3.5.3 [AMWG author's description] *As a result of this analysis, and taking input from the responses to the Discussion Document, the AMWG has now identified a method (the 'Reference Method') for adoption in reliably identifying the presence of amplitude modulated wind turbine noise within a sample of data, and of deriving a metric that, in the AMWG's view, best represents the degree of amplitude modulation present. The method is described in detail in Section 4. It is essentially a development of the 'Hybrid Reconstruction' method (i.e. Method 3) previously described in the Discussion Document* (IOA AMWG, 2015a). *It also draws on elements of the proposed Methods 1 and 2 and incorporates a newly developed 'prominence' criterion which has been found to be very effective at discriminating wind turbine AM from other sources, thereby reducing (but not eliminating) the need for detailed scrutiny of the data.*

3.5.4 [AMWG author's description] *Although* [the Reference Method] *is relatively complex, a degree of complexity is considered inevitable in a method that is sufficiently robust for determining compliance or non-compliance with specific thresholds or limits. A simple preliminary assessment method (the Indicative Method) is also described; this may be useful in some situations where wind turbine AM is subjectively apparent and when noise measurements with minimal contamination by other noise sources are available. However, the Indicative Method must be used with caution and is to be considered as secondary to the Reference Method and in no circumstances as a substitute for it.*

QUALITY, ROBUSTNESS, RELEVANCE

3.5.5 This report contains the details of the work undertaken by the IOA AMWG leading to their recommendation of a 'preferred' metric for AM. A definition for AM is provided, and the limitations of the metric to turbines of typically 500 kW and above are noted due to a focus on turbines with a rotational speed of less than 32rpm.

3.5.6 The report describes the various steps involved with the rating method, illustrating the process in flow charts. The various steps are explained in more detail in the text, with worked examples, and references to the work undertaken or additional research that underpinned the decision making process. The various decisions on analysis techniques are set out and justified. An additional 'prominence test' has been added to the method which further serves to identify clear WTN AM in a range of corrupted signals, addressing a previously identified weakness of other analysis methods.

3 5.7 The report also includes a summary of responses to points raised during the consultation stage in Appendix C, which covers the IOA AMWG's response to many of the points raised in the INWG's WP8 (see 3.3.179).

3.5.8 The methodology proposed by the IOA AMWG has been designed to provide a robust method for providing a precise and reliable determination of the presence of AM within wind turbine noise. As discussed below, the final metric is compatible with several of the Category 1 studies. However, as the AMWG authors note, the method will not necessarily be applicable to turbines of less than 500 kW, or with rotational speeds in excess of 32rpm. Further work would also be needed to develop a method for smaller turbines.

3.5.9 The Institute of Acoustics report is directly relevant to this study as it offers the definitive position of an industry body with a wealth of experience in acoustics and WTN. The IOA AMWG-proposed WTN AM metric is designed to work effectively for field data, addressing the difficulties encountered in analysing real WTN signals for AM content. Their report demonstrates that in overcoming the problems associated with earlier metrics, the proposed metric could provide a robust means for rating AM for assessment in a planning compliance situation. The report also demonstrates that the proposed metric can, over the range of interest, effectively be substituted for the metrics used in the laboratory studies reported by von Hünerbein et al (2013) (2015), and by Yokoyama et al (2013) (2015) with relativ ely small differences, indicating that values of the IOA AMWG metric can be related directly with the exposure-response research results discussed herein.

4 FACTORS AFFECTING DEVELOPMENT OF A PLANNING CONDITION

4.1 PLANNING POLICY GUIDANCE

4.1.1 Planning Policy for wind turbines in the United Kingdom is devolved to authorities in England, Wales, Scotland and Northern Ireland. Where developments may otherwise be refused, it is normal for planning conditions to be imposed which are designed to mitigate the adverse effects of the scheme. The objectives of planning are best served when the power to attach conditions to a planning permission is exercised in a way that is clearly seen to be fair, reasonable and practicable.

4.1.2 In England, paragraph 206 of the National Planning Policy Framework states "*Planning conditions should only be imposed where they are:*

1. *necessary;*
2. *relevant to planning and*
3. *to the development to be permitted;*
4. *enforceable;*
5. *precise; and*
6. *reasonable in all other respects."*

4.1.3 The policy requirement above is referred to in the NPPF as the 'six tests'. Similar guidance for the use of planning conditions is used by all Devolved Authorities. The key questions that arise against each test are listed in Table 5 (taken from the Communities website[50]).

Table 5: Validity Tests for Planning Conditions

TEST	KEY QUESTIONS
1. Necessary	• Will it be appropriate to refuse planning permission without the requirements imposed by the condition? → A condition must not be imposed unless there is a definite planning reason for it, i.e. it is needed to make the development acceptable in planning terms. → If a condition is wider in scope than is necessary to achieve the desired objective it will fail the test of necessity.

50 http://planningguidance.communities.gov.uk/blog/guidance/use-of-planning-conditions/application-of-the-six-tests-in-nppf-policy/

Table 5: Validity Tests for Planning Conditions	
2. Relevant to planning	• Does the condition relate to planning objectives and is it within the scope of the permission to which it is to be attached? → A condition must not be used to control matters that are subject to specific control elsewhere in planning legislation (for example, advertisement control, listed building consents, or tree preservation). → Specific controls outside planning legislation may provide an alternative means of managing certain matters (for example, works on public highways often require highways' consent).
3. Relevant to the development to be permitted	• Does the condition fairly and reasonably relate to the development to be permitted? → It is not sufficient that a condition is related to planning objectives: it must also be justified by the nature or impact of the development permitted. → A condition cannot be imposed in order to remedy a pre-existing problem or issue not created by the proposed development.
4. Enforceable	• Would it be practicably possible to enforce the condition? → Unenforceable conditions include those for which it would, in practice, be impossible to detect a contravention or remedy any breach of the condition, or those concerned with matters over which the applicant has no control.
5. Precise	• Is the condition written ina way that makes it clear to the applicant and others what must be done to comply with it? → Poorly worded conditions are those that do not clearly state what is required and when must not be used.
6. Reasonable in all other respects	• Is the condition reasonable? → Conditions which place unjustifiable and disproportionate burdens on an applicant will fail the test of reasonableness. → Unreasonable conditions cannot be used to make development that is unacceptable in planning terms acceptable.

4.1.4 In considering a planning condition to control AM, it is noted that the project team does not contain legal expertise, but does have a wealth of experience of writing planning conditions. For this reason, an expert legal opinion should be sought to ensure that any AM condition derived from the output of the report stands up to scrutiny, as would happen in most planning situations as a matter of course.

4.1.5 h order to meet the 'six tests', the following aspects are considered by the project team to be 'mportant:

- → The presence and level of AM should be robustly identified, ideally objectively;
- → The threshold of unacceptability should be clearly stated (i.e. the point at which the control mechanism begins;
- → The enforcement of the control method should reflect other factors such as the frequency of occurrence, and time of day;
- → The control method should be clear and unambiguous; and

→ The intent of the condition should be to prevent unacceptable impacts, avoid significant impacts, and mitigate to minimise other adverse impacts from AM and WTN. It is likely that for most sites that this condition will be 'mitigating' by bringing about a reduction in the level of AM using engineering methods, such as blade modifications or operational controls. Where the level of AM cannot be reduced, then the control method or 'penalty' should bring about a reduction in the overall time-averaged level of WTN during breach conditions.

4.1.6 Further discussion on these tests is included in Section 4.5.

4.2 FURTHER PLANNING CONDITION CONSIDERATIONS SUGGESTED BY THE INWG

4.2.1 In WP5, the INWG has proposed that there are additional objectives that are desirable for any planning condition to control AM should meet. These are suggested as:

> "*a. The condition must work with real world data. As described above this can vary from single turbines to multiple turbines. It might include cases where a clean AM peak to trough is visible in data and cases where the trace is influenced by multiple peaks and is less clearly defined. It must be able to deal with influences from other noise sources.*
>
> *b. The condition must be comprehensible and practicable to implement. This is both in terms of accessing the location of compliance monitoring but also in the actual assessment of compliance. The condition should be aimed at those most likely to use it, local authority officers, and the tools and skills available to them. It should not require specialist expertise to interpret the data.*
>
> *c. The condition should relate to the impact it is being designed to prevent. Any control should take account of the psychoacoustic response associated with the impact and reported complaints in existing cases.*
>
> *d. The condition should be transparent. The methodology of the condition should be clear and detail any data manipulation or filtering steps. The ability to test data for compliance should be open access including any software required to analyse the data.*
>
> *e. Others have proposed the preference for the condition to be workable with large amounts of data and therefore be largely automated.*
>
> *f. Most importantly it must be shown that the condition is effective, the control(s) must prevent periods of adverse AM.*"

4.2.2 Some of these suggestions are arguably already inherent in the 'six tests'. Any other proposals are not contained in Government planning policy, and therefore fall outside the scope of this study.

4.3 EXISTING PLANNING CONDITIONS

4.3.1 The existence of AM within WTN was acknowledged in ETSU-R-97 (1996), but the types of turbines then in existence were substantially smaller than those found on the larger wind farm sites now. The emergence of AM as being a potential problem grew during the 2000s, and a planning condition to control AM was first discussed and imposed by the Inspector for the Den Brook scheme in 2009. Additional research has since been carried out to further the knowledge of AM, and this has resulted in evolutions of the (original) 'Den Brook condition', and a planning condition proposed by RUK based on their own funded research.

4.3.2 Discussion of these planning conditions and the potential limitations of these conditions are included in the IOA AMWG consultation documents (IOA AMWG, 2015b), and the INWG WP5

(Large, Stigwood, & Bingham, 2015). Whilst there is broad agreement between the various documents on the limitations of the existing conditions, there are differences of opinion on the methods needed to rectify them.

4.4 OT HERPOTENTIAL PL ANNING CO NDITIO NMETHODS

4.4.1 The INWG WP5 review proposes additional methods using the Japanese D_{AM} method, BS4142:1997 (BSI, 1997) and BS4142:2014 (BSI, 2014). They conclude that the D_{AM} method works for sites where levels are not heavily influenced by extraneous noise and that a methodology following the requirements of BS4142:2014 also worked well.

4.4.2 It should be noted that the BS4142:2014 method contains a number of objective and subjective elements, which work well at the planning adjudication stage when the relative merits of each element can be debated and agreed, but introduce additional uncertainty when it comes to enforcement. The 'new' penalty method within BS4142 has not yet been tested in the field, and it is unclear at the present time whether the more subjective tests would work as intended; an element that could be acceptable to one enforcement officer may be unacceptable to another, leaving the operator uncertain as to the level of penalty they will be exposed to. A more objective approach would be more likely to comply with the one of the 'six tests' that advocates precision.

4.5 DISCUSSION

4.5.1 In order to recommend a planning control for AM, the various component parts have been broken down as suggested in paragraph 4.1.5. It should be noted that the information provided upon which to base the writing of a planning condition has been designed only for new planning applications. The applicability for use in Statutory Nuisance investigations on existing wind turbine sites has not been considered as part of this review, since methodologies and acceptability criteria are different to those used for planning enforcement. It is possible that the method may be used as an objective test as part of a nuisance investigation, subject to further testing and evaluation.

DENTIFICATION AND RATING OF AM

4.5.2 Of the various methods discussed previously, the internal research team considers that the IOA AMWG proposals for the AM metric provide the most robust method available for the identification of AM. The metric is compatible with the available Category 1 papers reviewed, and with the available evidence on exposure-response, subject to the limitations previously noted. The methodology is objective, precise, and has overcome many of the criticisms of previously used metrics for AM in the field. It is acknowledged that the IOA AMWG method does not include some subjective elements which may be relevant to the human perception of AM, (such as impulsivity, distinctiveness, etc.) but the use of these is not clearly supported in the available research, and therefore cannot be recommended at this time.

THRESHOLD OF EXCESSIVE AM

4 5.3 The setting of a threshold for excessive AM is not straightforward. The available research does not identify a clear onset of increased annoyance from AM. The research also does not identify a clear level at which the impact of WTN or AM becomes 'significant', 'excessive' or 'unacceptable'. It *does* suggest an onset of *perception* for AM at about 2 dB (peak-to-trough level difference in the Fast-weighted sound pressure level), and an association of rising annoyance with increasing depth of AM above 2 dB, when relating to L_{Aeq}. Moreover, the research highlights a very strong relationship between annoyance and the overall time-averaged level of noise, with the presence of AM in the noise increasing the annoyance.

4 .54 As the setting of the threshold of excessive AM is related to current Government policy, it is helpful to review the available policy evidence. ETSU-R-97 is recognised as Government

guidance by all of the Devolved Authorities, and notes that the *"modulation of blade noise may result in a variation of the overall A-weighted noise level by as much as 3 dB(A) (peak to trough)... if there are more than two hard, reflective surfaces then the increase in modulation depth may be as much as +/- 6 dB(A) (peak to trough)"*. This statement relates to the available turbines at the time, and it is often alleged that it does not necessarily translate to the taller turbines in use now. However, the IOA AMWG report notes that *"On the basis of the comments in ETSU-R-97, the value of 3 dB ('level of AM' or 'modulation depth') is sometimes referred to as the 'expected level' of AM. The Den Brook AM condition*[51] *adopts a 3 dB peak-to-trough value as the threshold above which AM is deemed to be 'greater than expected'"* (IOA AMWG, 2016). The 3 dB value is not supported in any of the available research as being the onset of unacceptable AM, but that does not mean that it is not an appropriate policy stance if there is sufficient policy support towards on-shore wind turbines.

4.5.5 More research is needed to test whether 3 dB peak-to-trough is still 'normal' today (i.e. typical with current turbine models), as, by necessity, the threshold could not penalise the level of AM that was considered to be 'normal' unless this was shown to give rise to complaints; this is not yet proven in the available research. Indeed, commentary from the INWG WP5 concludes that *"If the Den Brook condition (a peak to trough method) were to be treated as a simple metric or trigger value a higher peak to trough value in the region of 6dB would need to be used"* (Large, Stigwood, & Bingham, 2015).

4.5.6 A recently published report[52] on a long term field study of AM from wind farm noise in Massachusetts from both flat and mountainous sites concluded that *"while amplitude modulation is correlated with various meteorological parameters, prediction of the level of amplitude modulation at typical residential distances would not be reliable or practical. At these distance, local and regional background sounds have a significant impact on modulation depth. The analysis shows that larger modulation events (over 4.5 dB) can and do occur at the flat sites, but these events were observed less than 0.13% of the time. They were less common at the mountainous site (0.004%), likely because the multiple turbines at this site turn asynchronously, which tends to blur out modulation events."* This would lend some weight towards confirming that the ETSU-R-97 considerations relating to AM remain valid at least for the 78-80m hub height turbines that were included in the study.

4.5.7 The above statements highlight the variability in AM, and have formed the basis for the subsequent planning conditions drafted to date. ETSU-R-97 states that the absolute noise limits were chosen reflecting the AM character expected, with the addition of a penalty for tonality. It is clear from this statement that the character included the degree of AM experienced from the turbines existing at the time of writing, and therefore it could be considered that, if that AM character has materially changed, then the setting of the absolute limits should be reviewed. ETSU-R-97 also acknowledged that the noise limits were chosen to provide "*a reasonable degree of protection*", or to put it another way, the potential for some loss of local amenity in favour of wider national economic and sustainability benefits of renewable energy. This statement reflects the policy stance adopted by the UK Government at the time ETSU-R-97 was written, and may need to be reviewed against the various planning policies of the respective Governments today. For example, in England the aims of the NPPF are to avoid noise giving rise to significant adverse impacts, mitigate and reduce other adverse impacts, and identify and protect areas of tranquillity. It is unclear if the noise limits in ETSU-R-97 would still accord with these current aims without the policy support for on-shore wind.

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[51] see http://www.masenv.co.uk/Den_Brook_AM_Condition

[52] *Massachusetts study on wind turbine acoustics* (RSG et al., 2016)

4.5.8 It is also recommended that, as the AM control will target an element considered as 'above normal' in the ETSU-R-97 guidance, the control should be over and above the existing provisions for adverse sound characteristics, i.e. the control for AM should be considered in addition to the existing provision for tonality. This recommendation is not unprecedented: tonality and other adverse acoustic characteristics (impulsivity, intermittency etc.) are also considered separately within BS 4142:2014 (BSI, 2014), which is supported by the research cited in the standard. It follows that the two decibel WTN character penalties (tonality and modulation) should be additive in this case.

4.5.9 Successive UK Governments to date have stated their support for onshore wind, and confirmed the reliance on the ETSU-R-97 guidance, although the UK Government has set out proposals to end financial subsidies for new onshore wind projects across Great Britain and has introduced additional planning considerations for projects in England through a Parliamentary statement[53] . It could be argued that there is policy support for the choice of a 'normal AM' unacceptability limit (or a higher cut-in for the 'penalty'), whatever normal may be considered to be. This is based on the current policy statements, and may be subject to a wider review by the relevant Government Departments in the future.

4.5.10 To summarise the potential range of excessive AM thresholds, and initially generalising for the sake of simplicity, i.e. not taking into account whether the threshold relates to a single instantaneous event or the average of a series of events:

- the onset of perception for AM is around 2 dB 'peak-to-trough value';
- 'Normal AM' is considered to be in the range 2 to 6 dB 'peak-to-trough value'; and
- 'Excessive AM' may be above 6 dB 'peak-to-trough value'

4.5.11 In the Phase 1 report, it was suggested that it may be possible to define the AM penalty range in terms of the effect levels defined in the Noise Policy Statement for England (DEFRA, 2010) for the:

- No Observed Effect Level (NOEL);
- Lowest Observed Adverse Effect Level (LOAEL); and
- Significant Observed Adverse Effect level (SOAEL).

4.5.12 Planning Practice Guidance issued in 2014[54] added a further effect level for impacts increased beyond the SOAEL range:

- Unacceptable Adverse Effect level (UAEL).

4.5.13 Based on the research, the NOEL would likely be set at 2 dB, since up to 2 dB there is no apparent perception for most people. It would not be possible to set a LOAEL, SOAEL or UAEL without taking other factors into account such as the absolute noise level, which is outwith the scope of this report, and contextual factors considered below.

4.5.14 As noted, the choice of a threshold level only addresses a component of the expected response or effect, with how often and when the threshold is breached being important as well. Wind turbine operations can vary considerably over the course of even a 10 minute period, where wind

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[53] http://www.parliament.uk/documents/commons-vote-office/June%202015/18%20June/1-DCLG-Planning.pdf
[54] http://planningguidance.communities.gov.uk/blog/guidance/noise/noise-guidance/

speed and directions can change. Similarly, noticeable AM can occur as infrequent short bursts, or continuously in long periods of several hours. Whilst the number of incidences of 'unacceptable AM' are disputed, there now seems to be a broad consensus emerging in the most recent research (e.g. INWG WP5) that a single 10 second breach occurring over a period of two weeks would not be sufficient cause for planning enforcement, whereas a two hour continuous period occurring for several nights in a row clearly would. This suggests that an AM 'accumulative dose' might be the way forward, similar to the daily dose used for vibration in British Standard BS 6472:2008 (BSI, 2008), in which exposure levels and durations aggregate into a single number for easy analysis. There is currently no research to support the development of a suitable AM accumulative dose parameter, although one may be desirable if, through experience or further research, a suitable parameter and dose can be defined.

4.5.15 Analysis of the RUK conditions reveals that (presumably in order to account for frequency of occurrence), the amount of AM is rated for a 10 minute period (consistent with the ETSU-R-97 time periods for noise level), and a best fit line is drawn for each of the 10 minute periods at each integer wind speed. The penalty is then derived from the best fit curve. No separate account is made for time of day. This method is consistent with that used for the derivation of noise limits within ETSU-R-97 (albeit without the separation of day and night periods), and makes some attempt to account for duration of exposure. However, by averaging what is already an average number of AM peaks, there is the potential to under-rate the level and duration of AM. This in turn could potentially lead to a lower level of protection in some situations. Whilst this could be overcome with setting a lower threshold of unacceptability, this may not be reasonable given that the solution may also affect non-AM periods and / or may not be supported by the available research.

4.5.16 As previously noted, analyses of the evidence indicates that:

- The 'penalty' scheme should be linked to the absolute level of the noise; and
- It may be appropriate to set a sliding scale of 'penalty' since overall average levels are controlled at present using the L_{A90}.

4.5.17 In view of the limited specific, robust research into the effect of duration and frequency of occurrence of AM exposure on the response, gauging acceptability at the current state of knowledge is largely reduced to professional judgement; these judgements can be made at the enforcement stage.

4.5.18 Acousticians and planning decision makers are used to making occurrence frequency and duration judgements for noise sources as a matter of routine, the general rule being that the more often it occurs, and the more sensitive the time period, the more likely it is to need controlling. It is widely reported that complaints related to AM occur in the early to late evening, night, and early morning periods of the day (these are the periods of highest wind shear, and the periods when properties are most likely to be occupied), which covers a wider period than just the night time – a factor that needs to be recognised when setting the penalty level as different noise limits can apply during these times. That is not to say that AM does not need to be controlled at other times if it does occur.

4.5.19 To summarise the difficulty in identifying how often the AM threshold needs to be breached to trigger a penalty, it is concluded that there is currently no identified targeted research on which to base this decision. It is therefore recommended that the judgements on when enforcement action[55] is taken will be reliant on professional judgement based on elements such as the time of day, the number and frequency of occurrence of the 10 minute breaches. Clearly, the expectation would be that the more breaches that occur over a given time period, the more adverse the response effect, and the more unacceptable the potential impact. However, in line with other policy guidance, such as the NPPF in England, the context of potential environmental effects also needs to be considered when defining the parameters of a condition; sensitivities of receptors vary, as do the environments in which they are located. It could be that the respective Government Departments consider it necessary to be prescriptive over the interpretation of compliance, but as stated before, a 'one size fits all' solution may not work as intended.

4.5.20 The prevalence of unacceptable AM has not been evaluated as part of this study, and current state of the art is that the likely occurrence cannot be predicted at the planning stage. That does not preclude future research to determine the likelihood of AM occurring coming forward, and the development of a risk based evaluation, or similar. Due to the lack of ability to predict AM occurring on a site, and the reported difficulties in applying Statutory Nuisance provisions to control AM on existing sites, it is likely that the default position for a decision maker would be to apply the condition on all sites unless evidence is presented to the contrary.

CONTROL SCHEME FOR AM

4.5.21 As noted in paragraph 4.1.5, the main purpose of the control or 'penalty' is to bring about a reduction in the impact as a result of the period of unacceptable AM, and as currently proposed this consists of a two-tiered approach. The first tier would be seeking a reduction in the depth and/or occurrence of AM of ≥3 dB depth (rated using the IOA metric) by way of engineering methods, i.e. reduce the AM to an acceptable degree of impact. Where the degree of AM cannot be reduced, then, in order to prevent, avoid or mitigate the impact, the penalty should bring about a reduction in the overall average level of WTN during periods of complaint / breach conditions[56]. Therefore a decibel penalty added to the overall average noise level during periods of unacceptable AM should lead to a breach of the planning condition for the overall average level of wind turbine noise, and subsequent action to reduce the noise level to bring the site back into compliance.

4.5.22 Therefore in its simplest form, the condition would be worded to the effect that, where an AM exceedance in level and duration occurs, steps must be taken to reduce the AM, or to reduce the overall noise level. The work by Cand et al. (2015b) shows two potential methods for reducing AM, one involving a modification to the turbine blades, and one through reprogramming of the turbine to reduce periods of blade stall. Although these methods are relatively new, both were demonstrably successful at reducing AM, but it is not necessarily expected that either of these methods will be available to every model of turbine. In this situation, the Category 1 papers by von Hünerbein et al. (2015) and Lee et al. (2011) clearly show that to reduce annoyance at the same level of AM, a suitable reduction in absolute noise level would be effective.

4.5.23 Planning conditions based on the RUK proposal suggest a penalty starting at 3 dB of AM (albeit rated using a slightly different parameter to the IOA metric now proposed) and a sliding penalty scale from 3 to 5 dB, which is similar to the tonal penalty in ETSU-R-97 as shown in Figure 11.

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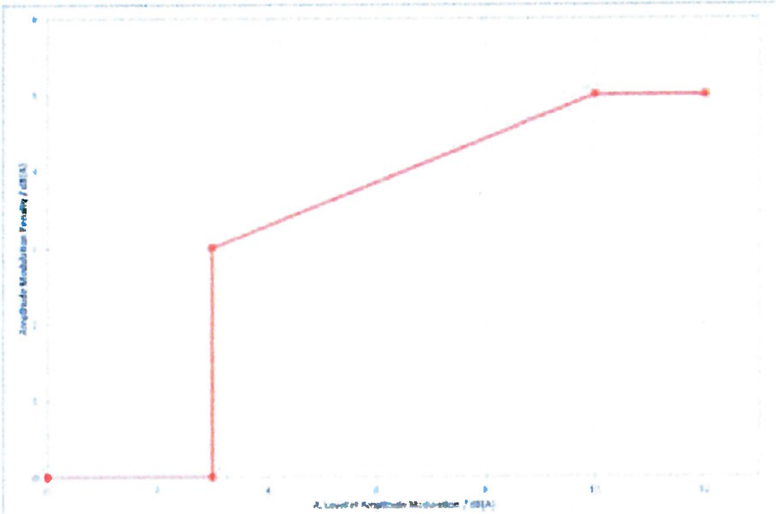
[55] It is noted that the NPPF (for England) states that enforcement action is discretionary, and local planning authorities should act proportionately in responding to suspected breaches of planning control. It therefore follows that not every breach of the AM condition would lead to enforcement and / or require the operator to take action. This may not be the case in other areas.

[56] Whilst the inherent problem of a 'reactive' approach to control AM is acknowledged, it would be unreasonable to penalise operators when periods of AM are not cause for complaint, thus the condition is targeted only to periods that give rise to valid / justified complaints. It is possible that high levels of AM may occur at other times of the day which, for a number of reasons, do not lead to complaints.



The interpretation of this penalty scheme is as follows:

- *for AM with a peak to trough level of < 3 dB there is no AM penalty*
- *for AM with a peak to trough level of 3 – 10 dB there is a sliding scale of penalties ranging from 3 – 5 dB*
- *for AM with a peak to trough level of ≥ 10 dB there is 5 dB penalty.*

Figure 11: RenewableUK Proposed Penalty Scheme[57]

4.5.24 The internal research team have compared the RUK penalty scheme to the outcomes of the research review, and concluded the following:

- The onset for the penalty at 3 dB of AM (derived from the IOA metric) appears to be consistent with starting the penalty scheme above the level of AM currently considered to be 'normal', and representative of the approximate onset of fluctuation perception for the majority of people;
- The magnitude of the decibel penalty starting at 3 dB is considered appropriate, for two main reasons:
  - i. A 3 dB difference represents a reduction that would be expected to be clearly noticeable by people in the real situations that the penalty is intended to address;
  - ii. Although the laboratory studies examining the equivalence of an AM signal with a steady-amplitude noise suggest a smaller 'lower bound' penalty of around 1.5-1.7 dB, the evidence is based on tests conducted using a modulation frequency of less than 1 Hz; to support the use of the penalty up to the slightly higher rotational speeds considered (equivalent to a blade-pass frequency of around 1.6 Hz), a 3 dB penalty would be more appropriate[60].
- The research evidence behind a sliding penalty above the 3 dB onset (e.g., in contrast with a stepped increase) is not definitive, but the general principle that increasing depths of AM should be avoided is considered reasonable[58]; and

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[57] *The Development of a Penalty Scheme for Amplitude Modulated Wind Farm Noise Description and Justification*, (RenewableUK, 2013).

- The upper penalty magnitude of 5 dB initially appears to be higher than the evidence suggests would represent perceptual equivalence with a steady noise; typically, the laboratory adjustments to make a modulating noise subjectively equivalent with a steady noise are no more than around 3.5 dB[59]. However, these results are typically based on a modulation frequency of slightly below 1 Hz. In view of the intention to control AM impacts in the range up to (approximately) 1.6 Hz, an upper penalty limit of 5 dB is considered appropriate[60].

4.5.25 The above considerations are based on the available evidence, and the limitations identified.

4.5.26 ETSU-R-97 accommodates different noise lower bound limits for day and night time[61], the latter being less stringent. Application of the above penalty method without further consideration of this difference could in some cases result in a situation in which an AM-penalised WTN level does not breach the associated limit (implying no requirement for enforcement action), despite on-site evidence to the contrary. The conclusions drawn from the category 2 studies indicate that the greatest period of residential AM sensitivity is typically sunset to sunrise, with more focus around the onset of sleeping hours. Therefore it is recommended that to account for the higher ETSU-R-97 lower bound limits at night, an additional allowance be added to the penalty at night equivalent to the difference between the night and day limits for each integer wind speed bin. NB. This addition would not apply to situations in which specific planning conditions dictate the limits to be set as lower for night-time than for daytime.

4.5.27 Therefore the resulting action imposed on the operator during periods of AM complaint would be to either:

a) reduce the degree of AM to below the 3 dB rating threshold during the complaint periods identified; or

b) reduce the penalised overall time-average level below the limit. The sliding scale decibel AM penalty would be added to the overall noise level (day or night), plus the addition of X dB at night (where X is the difference between the night and day limits for each integer wind speed bin, applicable if, and only if, the numerical limit for night-time is set higher than that for daytime), again during the periods in which AM impacts had been identified.

4.5.28 It is acknowledged that enforcement of the planning condition relating to the overall time-average level of noise requires consideration of the background noise level, and methods are currently in place to account for background based either on averaging in situations where the turbine noise level is close to or below the prevailing background noise level, or by periodic shut-down of the turbines. This 'averaging' may not be a suitable approach for the determination of a specific 10 minute period of an AM breach, and an alternative method may be required to be devised or agreed as part of the enforcement process, along with the less desirable option (for operators) of a periodic shut-down.

4.5.29 With current technologies, mitigation in most cases will likely be achieved through pitch control of the turbine blades, or in the worst case the switching off of one or more turbines during periods of

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[58] This is also supported by the subsequent research summarised in Annex 1.

[59] This is also supported by the subsequent research summarised in Annex 2.

[60] Human sensitivity to modulation in a noise signal has been shown [e.g. by Fastl & Zwicker (2007)] to rise with increasing modulation frequency to a peak within the range of around 2-6 Hz (4 Hz is the peak value most often-quoted).

[61] Daytime is defined in ETSU-R-97 as 07.00 to 23.00, and has lower bound limits of 35-40 dB L_{A90}. Night time is defined as 23.00 to 07.00 and has a lower bound limit of 43 dB L_{A90}

unacceptable AM. Note that a more proactive mitigation solution is desirable as opposed to a reactive one, but it may not be possible to separate out periods of AM leading to complaint from the available meteorological data, resulting in mitigation being applied at times not leading to AM complaints. Further research by turbine manufacturers and wind farm operators may assist with making more effective proactive solutions in the future, which could help to reduce curtailments to energy yield, as well as minimising the noise impacts.

4.5.30 This method is by necessity an interim recommendation based on the available evidence to date, and supplemented with professional experience. It is suggested that any planning condition derived from this report would be subject to a period of testing and review. The period should cover a number of sites where the condition has been implemented, and would be typically in the order of 2-5 years from planning approval being granted. The review would involve the analysis of any new AM research at the time, and case studies from sites where a condition has been implemented.

SUMMARY OF PLANNING CONDITION CONSIDERATIONS

4.5.31 To summarise, the planning condition to control AM should apply during periods of complaints, and first seek to reduce the AM in the WTN, since this is a trigger for increasing annoyance. Where this is not possible, it is recommended that the 'penalty' should bring about a reduction in the overall noise level during complaint / breach periods, since this also controls the annoyance response. An outline suggestion for a possible condition is as follows (noting that the example given is intended for information only; the setting of specific planning conditions is a matter for Local Planning Authorities (LPAs) to determine, and producing a recommendation for a specific condition wording to be applied by LPAs is not within the scope of this research report. Legal advice would need to be sought to ensure any proposed condition meets the NPPF 'six tests' requirements):

> During periods of complaint, the IOA metric should be applied to the data collected[62] to derive the reconstructed AM values for consecutive 10-minute periods. For each period with an AM value of equal to or greater than 3 dB, a penalty should be assigned in accordance with Figure 11, and added to the absolute level of noise. Each summed value of Overall average level (corrected for background where necessary) + AM penalty + Tonal Penalty (if applicable) should be binned into wind speeds of 1 m/s intervals over the range of the data for when the turbine is operating and complaints occurring. Where the number of 10-minute breaches at any given wind speed during the period of complaint is considered to be unacceptable, the operator should be required to submit details of a scheme describing proposals for suitable mitigation of the unacceptable AM periods to reduce the number of breaches during the operational conditions giving rise to the complaint, to that considered acceptable by the relevant authority.

4.6 OPERATIONAL IMPACTS AND MITIGATION

4.6.1 It is to be expected that any reduction in operational capacity of a wind turbine will have an impact on the power generation of the development, and consequent reduction in the operating revenue. It is not known at this stage whether an AM control can be brought in by Government as a

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[62] Data should be collected in accordance with the IOA Supplementary Guidance Note 5 at http://www.ioa.org.uk/sites/default/files/IOA%20GPG%20SGN%20No%205%20Final%20July%202014.pdf (Checked 29.03.16)

practical enhancement to the existing planning guidance, or whether it would be necessary to consider it as a formal change of policy.

4.6.2 In either event, it is helpful to ascertain the likely burden to industry of the proposed changes through consideration of the engineering/cost trade-offs of possible mitigation measures. The last work package in the RUK study is an investigation on the likely cause of AM, and the suggested methods of mitigation. These include pitch control on the blades, reprogramming the power curve of the turbine to avoid stall conditions, and, ultimately, curtailment of the turbine completely in the wind conditions where it occurs. The results will vary from one site to the next due to different turbine models, and different wind regimes.

4.6.3 A potential cause of unacceptable AM is the occurrence of blades stalling only during part of the rotation. This mechanism is described in (Cand & Bullmore, Understanding amplitude modulation of noise from wind turbines: causes and mitigation, 2015a) along with results of mitigation measures involving both modifications of the blades and the operational characteristics of wind turbines.

4.6.4 Although the modification of blades is mentioned as a potential mitigation measure, costs and details related to these modifications are not currently available. Therefore only the curtailment strategies involving changes to the operational characteristics of wind turbines can be estimated. Also it should be borne in mind that turbines cannot be programmed (at the current state of the art) to respond to individual 10-minute breaches, and therefore a proactive mitigation strategy may currently also have to target non breach periods without complaints in order to address the meteorological periods during which complaints occur.

4.6.5 Wind speed will impact on the yield and therefore the cost of any curtailment strategy. More accurate estimates could be made where the site in question is known. The impact of the curtailment strategy itself is also very site-specific. It is therefore concluded that insufficient data exists on which to accurately predict the likely impact of restrictions imposed on a wind turbine as a result of having to comply with an AM penalty. The expectation is that this could range between 0 and 5% in terms of yield reduction, but at sites more prone to AM the value could be greater.

5 CONCLUSIONS

5.1 AM

5.1.1 WSP | Parsons Brinckerhoff has undertaken a review of research into the effects of and response to the acoustic character of wind turbine noise (WTN) known as Amplitude Modulation (AM). The objective was to review the current evidence on the human response to AM, evaluate the factors that contribute to human response, and to recommend how excessive AM might be controlled through the use of a planning condition.

5.1.2 The work has involved the collation and critical review of relevant papers, existing planning conditions, and existing planning policies where they relate to AM from wind turbines. The review established a clear need for AM control, a clear link between overall turbine noise level and annoyance, and a correlation between the degree of AM and an equivalent level without AM. It also established that the sensitive period for wind farm neighbours to AM coincides with operational conditions (between sunset and sunrise) where the prevalence of AM occurs. These findings raise the question about whether the noise limits in ETSU-R-97, which are generally higher at night, accord with current Government policies to avoid, significant adverse noise impacts, and mitigate or minimise adverse impacts.

5.1.3 Based on the evidence found, a recommendation has been made on the elements required to construct a planning condition to control AM. It is noted that the AM control has only been designed for use with new planning applications, and applicability for use in Statutory Nuisance investigations on existing wind turbine sites, where the regime is different and outside the project scope, has not been considered as part of this review.

5.1.4 Any condition developed using the elements proposed in this study should be subject to a period of testing and review. The period should cover a number of sites where the condition has been implemented, and would be typically in the order of 2-5 years from planning approval being granted.

5.2 PROPOSAL FOR PENALTY SCHEME

5.2.1 The review found that the penalty scheme should include the following elements:

- ✓ The AM condition should cover periods of complaints (due to unacceptable AM);
- ✓ The IOA metric should be used to quantify AM;
- ✓ Analysis should be made using individual 10 minute periods, applying the appropriate decibel 'penalty' to each period (according to the regime illustrated in Figure 12), with subsequent wind speed analysis;
- ✓ The AM decibel penalty should be additional to any decibel penalty for tonality;
- ✓ An additional decibel penalty is proposed during the night time period to account for the current difference between the night and day limits on many sites to ensure the control method works during the most sensitive period of the day;
- ✓ Professional judgement should be used for planning enforcement of the AM condition in terms of frequency and duration of breaches identified; and

✓ The scheme is designed for upwind, 3-bladed turbines with rotational speeds up to 32 RPM[63]. Further research would be needed to address turbines with blade-pass frequencies higher than 1.6 Hz.

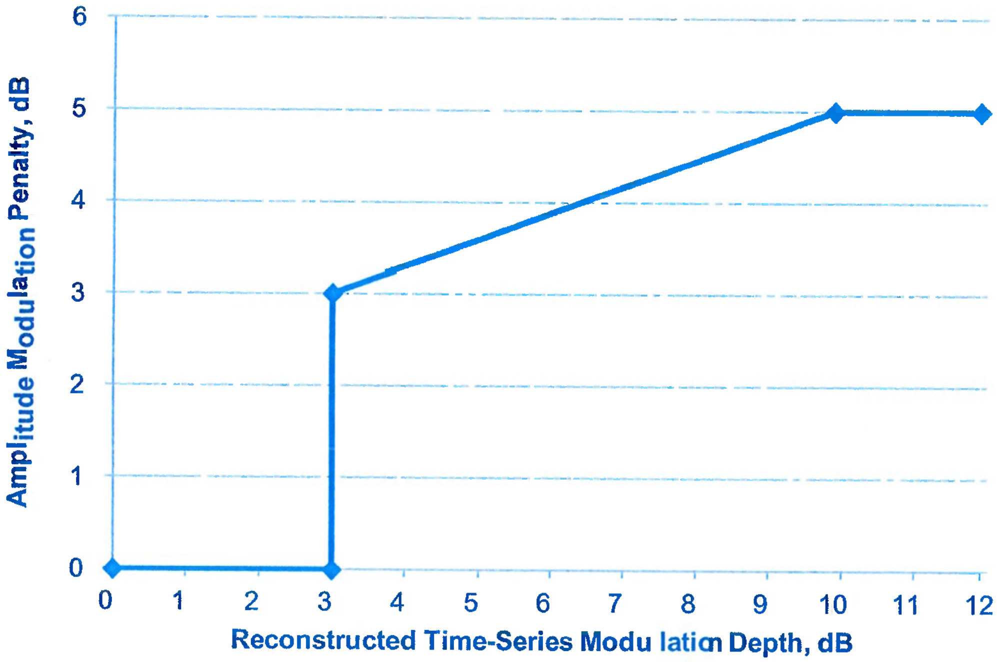

Figure 12: Proposed Level Penalty Regime

5.2.2 Further research has been recommended to supplement the limitations of the available research which underpins the above recommendation, although if the proposed penalty system, when implemented in a suitable planning condition, achieves the aim of reducing the impact from AM, then this research may not be required.

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[63] Specifically, the IOA metric is limited to a working upper modulation frequency of around 1.6 Hz, and the exposure-response research underpinning the proposed penalty system addresses modulation frequencies up to approximately 1.5 Hz. This does not preclude faster rotating turbines with lower numbers of blades, provided the blade-pass frequency is no higher than 1.6 Hz.

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Appendix A

GLOSSARY & CONCEPTS

GLOSSARY

Term	Description
Amplitude Modulation	The variation of amplitude with time. In the context of rotating machines, e.g. wind turbines, the modulation of the amplitude typically has a periodic character.
Amplitude Modulation Factor	The degree of variation in a modulated sound pressure relative to its mean value. Modulation factor is defined as $(A_{max} - A_{min}) / (A_{max} + A_{min})$, where A is the signal amplitude.
AM Depth / Modulation Depth	The depth of amplitude modulation in a signal with varying level is a measure of the difference between the highest (peak) and lowest (trough) levels. In real signals the peak and trough levels vary and there is no agreed definition in this context. Typically for WTN, the modulation depth is taken as the peak-to-trough level difference ΔL (dB) between the L_{pAF} level envelope, or the 'short term' L_{Aeq} integrated over contiguous 100-125ms periods. As the peak/trough levels will typically vary, the overall 'modulation depth' within an interval is sometimes established via a statistical method, e.g. arithmetic averaging. As a simple level difference parameter, modulation depth is often applied to filtered sound pressure levels (e.g. A-weighted, or individual third-octave bands). Therefore comparisons of 'modulation depths' must be made with caution; the sound level parameter must be identical for comparability. See the Concept Diagrams for an illustration.
A-Weighting	The human ear can detect a wide range of frequencies, from 20Hz to 20kHz, but it is more sensitive to some frequencies than others. Generally, the ear is most sensitive to frequencies in the range 1 to 4 kHz. The A-weighting is a filter that can be applied to measured results at varying frequencies, to mimic the frequency response of the human ear, and therefore better represent the likely perceived loudness of the sound. SPL readings with the A-weighting applied are sometimes denoted as 'dB(A)', or with the weighting subscripted in the level descriptor, e.g. 'L_{pA}'.
Background Sound or Background Noise	A component of the ambient sound environment, comprising the steady sounds underlying those sources that fluctuate in level within a period of consideration. This can be evaluated using the L_{90} metric. In UK wind turbine noise assessments, background sound levels are typically established from statistical analysis of relatively long periods of measurements. When sound is considered 'unwanted' it is usually termed 'noise'.
Band-Pass Filter	A band-pass filter allows defined sound frequencies with a certain range (or band) to pass with little or no impediment, while removing or impeding any other frequencies in the signal.
Blade Passing Frequency (BPF)	The frequency with which a blade passes any particular point in a rotation cycle per second. Applicable to any rotating mechanism with blades (fans, turbines etc.). BPF is related to revolutions-per-minute (RPM) as BPF = Number of blades × RPM/60.
C-Weighting	As for A-weighting, but only follows the frequency sensitivity of the human ear at very high noise levels. The C-weighting scale is quite flat, and therefore includes much more of the low-frequency range of sounds than the A scales.

GLOSSARY

Term	Description
Decibel (dB)	The logarithmic decibel scale is used in relation to sound. The decibel scale compares the level of a sound relative to another. The human ear can detect a wide range of sound pressures, typically between $2x10^{-5}$ and 200 Pa, so the logarithmic scale is used to quantify these levels using a more manageable range of values.
Equivalent Continuous Level ($L_{eq,T}$)	The Equivalent Continuous Level represents a theoretical continuous sound, over a stated time period, T, which contains the same amount of energy as a number of sound events occurring within that time, or a source that fluctuates in level. For example, a noise source with an SPL of 80 dB(A) operating for two hours during an eight-hour working day, has an equivalent A-weighted continuous level over eight hours of 74 dB, or $L_{Aeq,8hrs}$ = 74 dB. The time period over which the L_{eq} is calculated should always be stated.
Fast/Slow Time Weighting	The sound pressure level is calculated from the root-mean-square (RMS) value of the instantaneous acoustic pressure. Calculation of the RMS value requires a finite time interval over which to calculate the mean. Sound level meters use a time-weighted average, which multiplies the squared pressure sample by an exponential function of the constant time interval over which the average is calculated. Standard time constants in current use include 'Fast' and 'Slow', which have values of 0.125s and 1s respectively, and are represented by designated subscripts attached to a level descriptor, e.g. $L_{p,F}$; L_{Smax} etc.
Fluctuation Sensation	The auditory perception of a sound which exhibits temporal variation.
Fluctuation Strength	A psychoacoustic metric for perception of sounds that fluctuate in amplitude, based on the model devised by Zwicker and Fastl. Parameters included in the model are modulation frequency, modulation factor and overall sound level. Measured in units of *vacil*, where 1 vacil is the fluctuation strength of a 60dB 1kHz sinusoid 100% modulated (i.e. modulation factor = 1; see footnote[64]) at a modulation frequency of 4Hz.
G-Weighting	As for A-weighting, but G-weighting is designed to reflect human response to infrasound. The curve is defined to have a gain of zero dB at 10Hz. Between 1Hz & 20Hz the slope is approximately 12dB per octave. The cut-off below 1Hz has a slope of 24dB per octave, and above 20Hz the slope is -24 dB per octave.

[64] In general the modulation factor and modulation percentage do not take the same value, but in the special case of an AM sinusoid, they are equal.

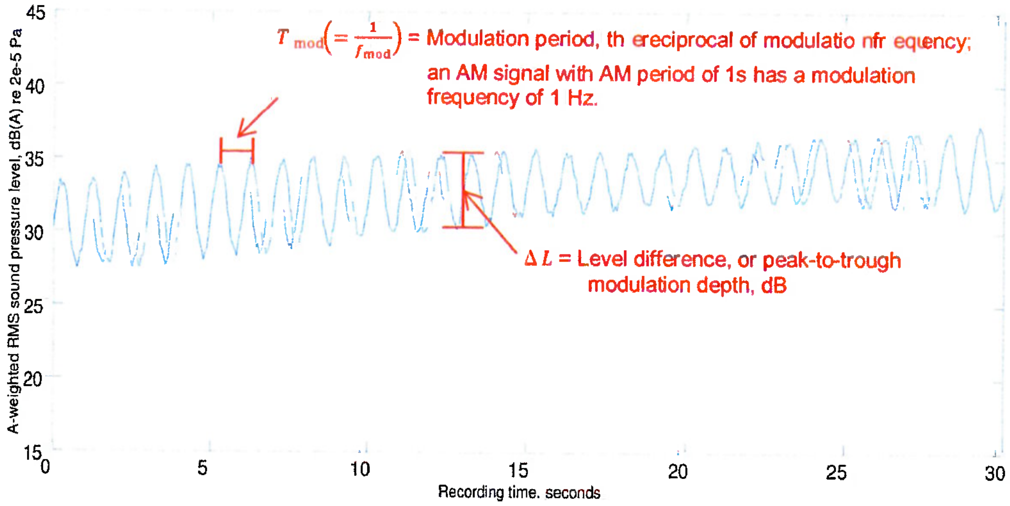
GLOSSARY

Term	Description
L_{90} or L_{A90} (and/or other 'percentile' measures)	Represents the SPL which is exceeded for 90% of the measurement time, expressed in dB or dB(A). L_{A90} is typically used to quantify background sound levels and, in the UK, wind turbine noise levels. In UK WTN assessment, the L_{A90} is used as a proxy level for the L_{Aeq}. This is because the L_{Aeq} is more susceptible to influence by non-WTN sounds in the environment, and WTN is generally relatively steady in level, compared with many other environmental noise sources. Other percentile levels such as L_{01}, L_{10}, L_{50}, L_{99} etc. can be used in various types of noise assessment. As an RMS SPL-based statistical level, the percentile measures should normally also have the time weighting included in the descriptor, as well as the time period of the measurement, e.g. $L_{AF90,10min}$.
Level Difference ΔL	In the context of amplitude modulation, the level difference expresses the difference in level between the highest and lowest amplitudes in the signal, and is also called the peak-to-trough level, or '*modulation depth*'. The level difference is related to the modulation factor m (see '*amplitude modulation factor*') by the expression $\Delta L = 20\log_{10}[(1 + m)/(1 - m)]$. A difference in sound levels is expressed in terms of dB. See the Concept Diagrams for an illustration.
Level Envelope	The envelope of a signal describes its variation in amplitude over time, and 'encloses' the signal levels.
Longitudinal and Cross-Sectional Studies	A longitudinal study is conducted by making observations from the same sample at more than one point in time. A cross-sectional study examines results observed from a sample at a single point in time (or cross-section).
Masking Noise	The human perception of a sound is affected by the presence of other audible sounds. Noise can provide masking for sounds that would otherwise be more clearly perceived. A masked sound may appear less distinct or may even not be detectable at all by a listener when a masking noise is present. In some situations, such as wind farms with residential neighbours, some masking noise (such as wind blowing through local vegetation) may be desirable.
Modulation Frequency / Period	The frequency of modulation is the number of times within a second that the amplitude fluctuates over the observed cycle, i.e. from maximum to minimum and back to maximum. The period of modulation is the reciprocal of frequency, i.e. the length of time between two amplitude peaks in a modulation cycle. See the Concepts Diagrams for an illustration.
Octave Band or Third Octave Band	A sound consisting of more than one frequency can be described using a frequency spectrum, which shows the relative magnitude of the energy in the different frequencies within it. The possible range of frequencies is continuous, but can be split up into discrete bands, often an octave or third-octave in width. Each band is referred to by its centre frequency, e.g. (for octave bands) 63 Hz, 125 Hz, 250 Hz, 500 Hz, 1 kHz etc. Separation of the spectrum in this way is typically implemented via band-pass filters.
Periodicity	A sound wave with a repeating form can be described as periodic. The level of a sound with periodic amplitude displays a regular fluctuation, although the peaks and troughs in the level may still vary.

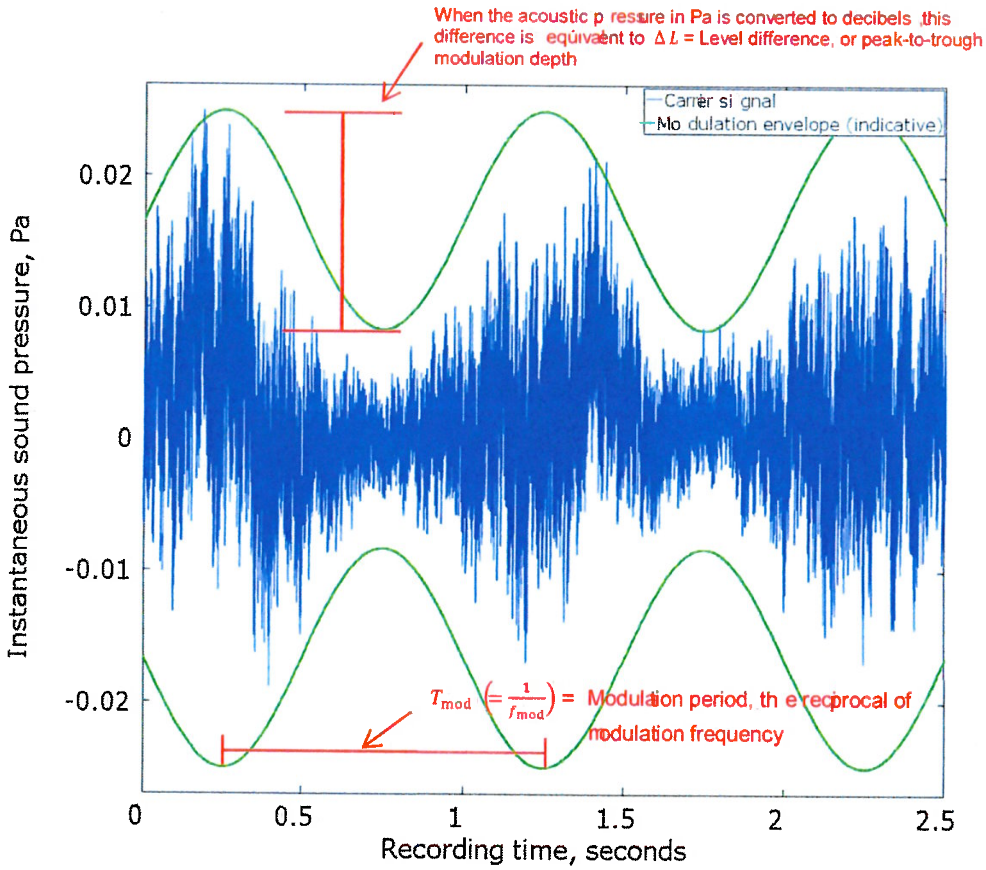
GLOSSARY

Term	Description
Pink Noise	Noise in theoretical acoustic terms is sound energy with random variation. 'White' noise has equal sound energy at every frequency; 'pink' noise has a sound energy that is inversely proportional to frequency, which results in a more low frequency sound compared with white noise.
RMS/root-mean-square sound (acoustic) pressure	Acoustic pressure waves comprise perturbations of air pressure, and the instantaneous pressure values at any given point in space therefore take positive and negative values around the mean, which is the steady local atmospheric pressure. In order to represent a meaningful amplitude, it is necessary to square the values (to make all values positive), calculate the mean (over some time interval), and take the square root of the result. The acoustic energy (or power, for finite signals) can be described by the mean-square of the pressure amplitude. The square root reduces the mean-square value to linear (amplitude), rather than squared, units.
Sound Pressure Level (SPL)	The Sound Pressure Level has units of decibels, and compares the level of a sound to the smallest sound pressure generally perceptible by the human ear, or the reference pressure. It is defined as follows: SPL (dB) = $10 \text{ Log}_{10}(P/P_{ref})^2$ Where P = root-mean-square (see '*RMS*') sound pressure (in Pa) P_{ref} = Reference pressure 2×10^{-5} Pa An SPL of 0 dB suggests the sound pressure is equal to the reference pressure. This is the approximate threshold of normal hearing. An SPL of 140 dB represents the approximate threshold of pain. SPL is also often denoted as 'L_p'.
Spectral content	Sounds are typically made up of acoustic energy present in many frequencies of the audible spectrum. The frequency spectrum describes this signal 'content'.

CO NCEPT DIAG RAMS



The RMS sound pressure level shown in the above diagram is evaluated over a (short) averaging time and therefore represents the 'level envelope' of the signal rather than instantaneous sound pressure values. The envelope concept is also illustrated below, related to instantaneous acoustic pressure.



The diagram above shows a pink noise carrier signal modulated in level by a sine wave.
NB: Concept plots show simulated signals and do not display real wind turbine noise data.

Appendix B

FULL LIST OF PUBLICATIONS

AUTHOR	YEAR	TITLE	PUBLICATION	STATUS	CATEGORY
Abbasi, M, et al.	2015	Impact of Wind Turbine sound on general health, sleep disturbance + annoyance of Workers - a pilot Study in ManjilWind Farm ,Iran	Journal of Environmental Health, Science and Engineering	[black]	2d
Abbasi, M, et al.	2015	Effect of Wind Turbine Noise on Workers' Sleep Disorder: A Case Study of ManjilWind Farm in Northern Iran	Fluctuation and Noise Letters	[black]	2d
Aslund,ML Wet a l	2013	Projected contributions of future wind farm development to community noise + annoyance levels in Ontario, Canada	Energy Policy	[black]	2e
Bakker,RH et al	2012	Impact of wind turbine sound on annoyance, self-reported sleep disturbance + psychological stress	Science of the Total Environment	[black]	2d
Bauer,M et al	2015	Investigation of perception at infrasound frequencies by functional magnetic resonance imaging fMRI and magnetoencephalography (MEG)	International Congress on Sound and Vibration	[grey]	2e
Bengtsson,J et al	2004	Sound characteristics in low frequency noise + their relevance for the perception of pleasantness	Acta Acustica united with Acustica	[black]	2c
Berger,RG et al	2015	Health-based audible noise guidelines account for infrasound + low-frequency noise produced by wind turbines	Frontiers in Public Health	[black]	2d
Bockstael ,Aet al	2012	Reduction of wind turbine noise annoyance- an operational approach	Acta Acustica united with Acustica	[black]	1
Bockstael A et al	2011	Wind turbine noise - annoyance + alternative exposure indicators	Forum Acusticum	[grey]	1
Bolin,K	2007	Investigating the audibility of wind turbines in the presence of vegetation noise	International Meeting on Wind Turbine Noise	[grey]	2e
Bradley,JS	1994	Annoyance caused by constant-amplitude and amplitude-modulated sounds containin grumble	Noise Control Engineering Journal	[black]	2c
Brink,M et al	2010	Field study of the exposure-annoyance relationship of military shooting noise	Journal of the Acoustical Society of America	[black]	2c

AUTHOR	YEAR	TITLE	PUBLICATION	STATUS	CATEGORY
Bullmore, A et al	2011	Wind turbine amplitude Modulation- Research to Improve Understanding as to its Cause & Effect	International Meeting on Wind Turbine Noise	[grey]	2a
Bunk,O	2009	Investigation of day-/nighttime differences in sound emissions of high wind energy systems	Euronoise	[grey]	2e
Cand,M et al	2015	Practical Investigations of AM Mitigation	Acoustics 2015	[grey]	2b
Cand,M et al	2015	Measurements demonstrating mitigation of far-field AM from wind turbines	International Meeting on Wind Turbine Noise	[grey]	2b
Cand,M et al	2015	Understanding amplitude modulation of noise from wind turbines- causes and mitigation	Acoustics in Practice	[grey]	2b
Cassidy,M et al	2015	Addressing the Issue of Amplitude Modulation- A Developer's Perspective	International Meeting on Wind Turbine Noise	[grey]	2f
Council of Canadian Academies	2015	Understanding the evidence - wind turbine noise	Independent report	[black]	2d
Cowen,R	2015	INWG Work package 6.1A- Legal issues - the control of excessive amplitude modulation from wind turbines	Independent report	[grey]	2f
Cowen,R	2015	INWG Work Package 6.1A – Legal Issues: the Control of Excessive Amplitude Modulation from Wind Turbines Supplementary Paper	Independent report	[grey]	2f
Cox,R	2015	INWG Work Package 8 - Review of Institute of Acoustics Amplitude Modulation Study and Methodology	Independent report	[grey]	2f
Cox,R et al,	2015	INWG Work Package 2.1 - Review of reference literature	Independent report	[grey]	2e
Crichton, F et al	2015	Health complaints + wind turbines-the efficacy of explaining the nocebo response to reduce symptom reporting	Environmental Research	[black]	2d

AUTHOR	YEAR	TITLE	PUBLICATION	STATUS	CATEGORY
Crichton,F et al	2015	Framing sound- using expectations to reduce environmental noise annoyance	Environmental Research	[black]	2e
Cummings, J	2013	The Variability Factor in Wind Turbine Noise	International Conference on Wind Turbine Noise	[grey]	2f
Davis, J et al	2007	Noise Pollution From Wind Turbines - Living with amplitude with modulation, lower frequency emissions and sleep deprivation	International Meeting on Wind Turbine Noise	[grey]	2e
DEFRA	2008	Research into improvement of management of helicopter noise - nanr235-project report	Independent report	[grey]	2e
Di Napoli,C	2009	Case study- wind turbine noise in a small+ quiet community in Finland	International Meeting on Wind Turbine Noise	[grey]	2b
Di Napoli,C	2011	Wind turbine noise assessment in a small and quiet community in Finland	Noise Control Engineering Journal	[black]	2b
Di Napoli,C et al	2015	Current challenges of assessing excess amplitude modulation character in wind turbine noise during EIA/planning phase	International Meeting on Wind Turbine Noise	[grey]	2f
Dittrich,K et al	2009	Comparison of the temporal weighting of annoyance + loudness	Journal of the Acoustical Society of America	[black]	2c
Falourd,X et al	2015	Low Frequency Amplitude Modulation related to Doppler frequency shift: an experimental study of a 101m diameter wind turbine in a swiss valley	International Meeting on Wind Turbine Noise	[grey]	2e
Fastl,H et al	2013	Psychoacoustic aspects of noise from wind turbines	Inter-noise	[grey]	2a
Feder,K et al	2014	An assessment of quality of life using the WHOQOL-BREF among participants living in the vicinity of wind turbines.	Environmental Research	[black]	2d
Fredianelli,F et al	2014	Looking for a wind turbine noise legislation paying attention to annoyance: which metric?	International Congress on Noise as a Public Health Problem	[grey]	2f
Gabriel,J et al	2013	Amplitude Modulation and Complaints about Wind Turbine Noise	International Conference on Wind Turbine Noise	[grey]	2b

AUTHOR	YEAR	TITLE	PUBLICATION	STATUS	CATEGORY
Gray,B	2015	INWG Work package 6.2-Control of AM noise without an AM planning condition using Statutory Nuisance	Independent report	[grey]	2f
Gray,B	2015	INWG Work Package 9 – The Cotton Farm Monitor Experience	Independent report	[grey]	2e
Hanning,C et al	2011	Selection of outcome measures in assessing sleep disturbance from wind turbine noise	International Meeting on Wind Turbine Noise	[grey]	2d
Hanning,CD	2015	INWG Work package 3.2-Excess amplitude modulation, wind turbine noise, sleep and health	Independent report	[grey]	2d
Hansen, KL et al	2015	Quantifying the character of wind farm noise	International Congress on Sound and Vibration	[grey]	2b
Health Canada	2014	Wind Turbine Noise and Health Study- Summary of results [online]	Independent report	[grey]	2d
Health Canada	2014	Health impacts and exposure to sound from wind turbines - Updated research design + sound exposure assessment [online]	Independent report	[grey]	2d
Hulme,M	2015	INWG Work Package 4 - Den Brook	Independent report	[grey]	2e
Inagaki,T et al	2015	Analysis of aerodynamic sound noise generated by a large-scaled wind turbine and its physiological evaluation	International Journal of Environmental Science and Technology	[black]	2a
Jabben,J et al	2012	Options for assessment and regulation of low-frequency noise	International Meeting on Low Frequency Noise and Vibration	[grey]	2e
Janssen,SA et al	2011	A comparison between exposure-response relationships for wind turbine annoyance and annoyance due to other noise sources	Journal of the Acoustical Society of America	[black]	2d

AUTHOR	YEAR	TITLE	PUBLICATION	STATUS	CATEGORY
Janssen,SA et al	2009	Exposure-response relationships for annoyance by wind turbine noise: a comparison with other statio narysources	Euronoise	[grey]	2d
Jeffery, RDet al	2014	Industrial wind turbines and adverse health effects.	Canadian Journal of Rural Medicine	[black]	2d
Kaczmarek, Tet al	2010	Annoyance of time-varying road-traffic noise	Archivesof Acoustics	[black]	2c
Kageyama,T et al	2014	Exposure-response relationship of wind turbine noise with subjective symptoms on sleep and health: a nationwide socio-acoustic surv eyin Japan	In ternational Congress on Noise as a Public Health Problem	[grey]	2d
Kantarelis,C et al	1988	Ide ntification+subjective effect of AM in diesel engine exhaust noise	Journal of Sound and Vibration	[black]	2c
Kelby,ND et al	1985	Acoustic noise associated with the MOD-1 wind turbine- its source, impact and control	Independent report	[grey]	2a
Klen, A et al	2015	Spectral + modulation i ndices for annoyance-relevant features of urban road single-vehicle pass-by noises	Journal of the Acoustical Society of America	[black]	2c
Kropper, LD et al	2011	Health effects and wind turbines- a review of the literature	Environmental Health	[black]	2d
Knopper, LD et al	2014	Wind turbines and human health	Frontiers in Public Health	[black]	2d
Kugler,K et al	2014	Low-frequency sound affects active micromechanics in the human inner ear	Royal Society Open Science	[black]	2e
Kurpas,D et al	2013	Health impact of wind farms	Annals ofAgricultural and Environmental Medicine	[black]	2d
Kuwano, S et al	2014	Social survey on wind turbine noise in Japan	Noise Control Engineering Journal	[black]	2d

AUTHOR	YEAR	TITLE	PUBLICATION	STATUS	CATEGORY
Kuwano, S et al	1999	Loudness, annoyance + unpleasantness of amplitude modulated sounds	Inter-noise	[grey]	2c
Large, S et al	2015	INWG WP5- Towards AM planning condition	INWG	[grey]	2f
Large, S et al	2014	Noise characteristics of 'compliant' wind farms that adversely affect its neighbours	Inter-noise	[grey]	2b
Large,S	2015	INWG Work Package 2.2 - AM Evidence Review	Independent report	[grey]	2e
Laszlo, HE et al	2012	Annoyance and other reaction measures to changes in noise exposure: a review	Science of the Total Environment	[black]	2e
Lee,S et al	2011	Annoyance caused by amplitude modulation of wind turbine noise	Noise Control Engineering Journal	[black]	1
Lee,S et al	2009	An estimation method of the amplitude modulation in wind turbine noise for community response assessment	International Meeting on Wind Turbine Noise	[black]	1
Legarth,SV	2007	Auralization + assessments of annoyance from wind turbines	International Meeting on Wind Turbine Noise	[grey]	2a
Lenchine,VV	2009	Amplitude modulation in wind turbine noise	Acoustics 2009	[grey]	2a
Lichtenhan,J et al	2013	Amplitude modulation of audible sounds by non-audible sounds - understanding the effects of wind turbine noise	International Congress on Acoustics	[grey]	2a
Magari,SR et al	2014	Evaluation of community response to wind turbine-related noise in Western New York State	Noise and Health	[black]	2d
Marshall Day Acoustics	2013	Examination of the significance of noise in relation to onshore wind farms	Independent report	[grey]	2e
Matsuda,H et al	2012	Measurement of Psychological Response and Evaluation of Task Performance on Low-frequency Sound	International Meeting on Low Frequency Noise and Vibration	[grey]	2c
McCunney,RJ et al	2014	Wind Turbines and Health A Critical Review of the Scientific Literature	Journal of Occupational and Environmental Medicine	[black]	2d

AUTHOR	YEAR	TITLE	PUBLICATION	STATUS	CATEGORY
Merlin, T et al	2013	Systematic review of the human health effects of wind farms	Independent report	[black]	2d
Michaud,DS et al	2015	Effects of Wind Turbine Noise on Self-Reported and Objective Measures of Sleep	Sleep	[black]	2d
Michaud,DS et al	2013	Self-reported and Objectively Measured Health Indicators Among a Sample of Canadians Living Within the Vicinity of Industrial Wind Turbines: Social Survey and Sound Level Modelling Methodology	Noise News International	[grey]	2d
Moorhouse, AT et al	2009	A procedure for the assessment of low-frequency noise complaints	Journal of the Acoustical Society of America	[black]	2c
Moorhouse, AT et al	2007	The effect of fluctuations on the perception of low frequency sound	Journal of Low Frequency Noise, Vibration and Active Control	[black]	2c
Nissenbaum, M et al	2011	Adverse health effects of industrial wind turbines: a preliminary report	International Congress on Noise as a Public Health Problem	[grey]	2d
Nissenbaum, MA et al	2012	Effects of industrial wind turbine noise on sleep and health	Noise and Health	[black]	2d
Nobbs,B et al	2012	Characterisation of noise in homes affected by wind turbine noise	Acoustics 2012	[black]	1
Onakpoya,IJ et al	2015	The effectof wind turbine noise on sleep and quality of life: A systematic review and meta-analysis of observational studies	Environment International	[black]	2d
Pawlaczyk-Luszczynsk,M et al	2014	Evaluation of annoyance from the wind turbine noise: A pilot study	International Journal of Occupational Medicine and Environmental Health	[black]	2d
Pawlaczyk-Luszczynsk,M et al	2013	Assessment of annoyance due to wind turbine noise	Meetings on Acoustics	[grey]	2d

AUTHOR	YEAR	TITLE	PUBLICATION	STATUS	CATEGORY
Pedersen, E	2011	Health aspects associated with wind turbine noise: results from three field studies	Noise Control Engineering Journal	[black]	2d
Pedersen,CS et al	2012	Low-frequency noise from large wind turbines-additional data+assessment of Danish regulations	International Meeting on Low Frequency Noise and Vibration	[grey]	2f
Pedersen,E et al	2004	Perception + annoyance due to wind turbine noise- a dose-response relationship	Journal of the Acoustical Society of America	[black]	2d
Pedersen,E et al	2010	Can road traffic mask sound from wind turbines - response to wind turbine sound at different levels of road traffic sound	Energy Policy	[black]	2d
Pedersen,E et al	2009	Response to noise from modern wind farms in the Netherlands	Journal of the Acoustical Society of America	[black]	2d
Pedersen,E et al	2009	Wind turbine sound – how often is it heard by residents living nearby?	Euronoise	[grey]	2e
Pedersen,E et al	2007	Wind turbine noise, annoyance and self-reported health and well-being in different living environments.	Occupational and Environmental Medicine	[black]	2d
Pedersen,E et al	2005	Human response to wind turbine noise – annoyance and moderating factors	International Meeting on Wind Turbine Noise	[grey]	2d
Persson Waye, K	2004	Effects of low-frequency noise on sleep	Noise and Health	[black]	2f
Persson Waye, K et al	2002	Psycho-acoustic characters of relevance for annoyance of wind turbine noise	Journal of Sound and Vibration	[black]	2a
Persson Waye, K et al	2001	The prevalence of annoyance + effects after long-term exposure to low-frequency noise	Journal of Sound and Vibration	[black]	2e
Renewable UK	2013	Template planning condition on amplitude modulation	Independent report	[grey]	2f
Renewable UK	2013	Development of a penalty scheme for amplitude modulated wind farm noise	Independent report	[grey]	1

AUTHOR	YEAR	TITLE	PUBLICATION	STATUS	CATEGORY
Rennies,J et al	2015	Spectro-temporal characteristics affecting the loudness of technical sounds- data + model predictions	Acta Acustica united with Acustica	[black]	2c
Roberts, M et al	2009	Evaluation of the scientific literature on the health effects associated with wind turbines and low frequency sound	Independent report	[grey]	2d
RSG et al	2016	Massachusetts study on wind turbine acoustics	Independent report	[grey]	2a
Salt, AN et al	2010	Responses of the ear to low frequency sounds, infrasound + wind turbines	Hearing Research	[black]	2e
Schmidt, JH et al	2014	Health Effects Related to Wind Turbine Noise Exposure: A Systematic Review	PLOS One	[black]	2d
Seong,Y et al	2013	An experimental study on rating scale for annoyance due to wind turbine noise	Inter-noise	[grey]	1
Seong,Y et al	2013	An experimental study on annoyance scale for assessment of wind turbine noise	Journal of Renewable and Sustainable Energy	[black]	1
Shepherd, D et al	2011	Evaluating the impact of wind turbine noise on health-related quality of life.	Noise and Health	[black]	2d
Sherman, T	2015	INWG Work Package 3.1 - Study of Noise and Amplitude Modulation Complaints Received by Local Planning Authorities in England	Independent report	[grey]	2e
SRL & Hoare Lea	2015	Wind farm impacts study	Independent report	[grey]	2a
Stelling,K	2015	Infrasound-low frequency noise and wind turbines	Independent report	[grey]	2e
Stigwood,M et al	2013	Audible amplitude modulation - results of field measurements and investigations compared to psychoacoustical assessment and theoretical research	International Conference on Wind Turbine Noise	[grey]	2e

AUTHOR	YEAR	TITLE	PUBLICATION	STATUS	CATEGORY
Stigwood,M et al	2014	Initial findings of the UK Cotton Farm Wind Farm long term community noise monitoring project	Inter-noise	[grey]	2b
Tachibana,H et al	2014	Outcome of systematic research on wind turbine noise in Japan	Inter-noise	[grey]	2a
Tachibana,H et al	2014	Nationwide field measurements of wind turbine noise in Japan	Noise Control Engineering Journal	[black]	1
Takahashi,Y	2013	Present situation + research task on the assessment of psychological effects caused by low-frequency noise	Japanese Journal of Hygiene	[black]	2e
Thorne,R	2014	The perception and effect of wind farm noise at two Victorian wind farms	Independent report	[grey]	2d
Thorne,R	2007	Assessing intrusive noise and low amplitude sound	Independent report	[black]	2e
van den Berg,F	2011	Wind Turbine Noise Chapter 6 - Effects of sound on People	Wind Farm Noise Book	[grey]	2a
van den Berg,F	2013	Wind turbine noise- an overview of acoustical performance + effects on residents	Acoustics 2013	[grey]	2a
van den Berg,F	2009	Why is wind turbine noise noisier than other noise?	Euronoise	[grey]	2a
van den Berg,GP	2004	Do wind turbines produce significant low frequency sound levels	International Meeting on Low Frequency Noise and Vibration	[grey]	2e
van den Berg,GP	2004	The beat is getting stronger - the effect of atmospheric stability on low frequency modulated sound of wind turbines	Noise Notes	[grey]	2a

AUTHOR	YEAR	TITLE	PUBLICATION	STATUS	CATEGORY
van den Berg ,GP	2005	The beat is getting stronger - the effect of atmospheric stability on low frequency modulated sound of wind turbines	Journal of Low Frequency Noise, Vibration and Active Control	[grey]	2a
van Renterghem,T et al	2013	Annoyance, detection and recognition of wind turbine noise	Science of the Total Environment	[black]	2d
von Hünerbein et al	2015	Affect iveResponse to Amplitude Modulated Wind Turbine Noise	International Meeting on Wind Turbine Noise	[grey]	1
von Hünerbein et al	2013	Wind Turbine Amplitude Modulation- Research to Improve Understanding as to its Cause & Effect. Work Package B(2)- Development of an AM Dose-Response Relationshi p	Independent report	[grey]	1
Vos,J et al	2010	Analysis of wind turbine sound recordings	Independent report	[grey]	2a
Vos,J et al	2010	Annoyance caused by low frequency sounds- spectral + tem poral effects	Inter-noise	[grey]	2c
Yano et al	2013	Dose-response relationships for wind turbine noise in Japan	Inter-noise	[grey]	2d
Yano, T et al	1990	Assessing intrusive noise and low amplitude sound	Environment International	[black]	2c
Yeland,J	2015	INWG Work Package 1 – The Fundamentals of Amplitude Modulation of Wind Turbine Noise	Independent report	[grey]	2e
Yokoyama et al	2015	Subjective experiments on the auditory impression of the amplitude modulation sound contained in wind turbine noise	International Meeting on Wind Turbine Noise	[grey]	1
Yokoyama et al	2014	Perception of low frequency components in wind turbine noise	Noise Control Engineering Journal	[black]	1
Yokoyama et al	2014	Audibility of low frequency components in wind turbine noise	Forum Acusticum	[grey]	1

AUTHOR	YEAR	TITLE	PUBLICATION	STATUS	CATEGORY
Yokoyama et al	2013	Study on the amplitude modulation of wind turbine noise part 2- auditory experiments	Inter-noise	[grey]	1

Appendix C

REVIEW RESPONSE CATEGORIES

REVIEW RESPONSE CATEGORIES

Noise source	[Describe the noise stimuli and applicability/similarity to WTN AM]
Exposure-response	[If applicable, describe the exposure-response approach and scale used, e.g. reported complaints/annoyance, 11-point annoyance scale, etc.]
Main scope of work	[Outline the scope]
Conclusions of paper	[Summarise the relevant conclusions]
Quality, robustness and relevance of work, risk of bias	[Overall comments]
Independently peer-reviewed	[Yes or no, plus details if important]
Funding source	[Public/private/mixed/unstated]
Lab or field study	
Lab exposure method	[e.g. loudspeakers or headphones]
Sample size and response rate	
Exposure	[Measured/calculated/estimated]
Response	[e.g. specify type and scale used]
Robustness	Exposure [Comments] Response [Comments]
Reviewer weighting 0-9	[Attach a subjective importance weighting to the paper/study based on the previous box, referring back to the study aims. Conflicts will be resolved by discussion]
Newcastle-Ottawa Scale overall rating	[if relevant, score according to the NOS manual and checklist, max overall score 9]
GSR checked?	[confirm Y if relevant and checked; otherwise INDEPENDENT REPORT]

Newcastle-Ottawa Score Table

Selection	[max 4 stars]
Comparability	[max 2 stars]
Outcome	[max 3 stars]

ANNEX 1

CATEGORY 1 STUDY F

Title: Effect of modulation depth, frequency, and intermittence on wind turbine noise annoyance

Authors: Ioannidou, C., Santurette, S, & Jeong, C-H.

Institution: Technical University of Denmark

Publication: Journal of the Acoustical Society of America 139(3) pp1241-1251

Publication date: 23rd March 2016

Details

This laboratory study comprised three listening test-based experiments with 10, 14 and 13 participants respectively (aged 23-28 years).

The subjects were presented with a range of WTN recordings, synthesised stimuli and combinations via headphones, in the subjective context of garden relaxation. They were asked to rate annoyance felt after presentation of 30-second samples on an 11-point scale.

The experiments were designed to investigate the effect on annoyance of i) modulation depth; ii) modulation frequency; iii) temporal variation in AM depth.

Results

The results of experiment one showed a significant association between increasing mean modulation depth[65] and rated annoyance.

The results of experiment two indicated a trend but statistically insignificant relationship between modulation frequencies over the range 0.5 to 2 Hz and rated annoyance.

The results of experiment three suggested that the 'baseline' modulation depth outside intermittent periods of increased depth may dictate the rated annoyance, i.e. shorter periods of increased AM do not necessarily lead to increased annoyance.

Implications

The results of experiment one suggest a slightly stronger influence of modulation depth on annoyance than is clear from the Category 1 studies examined in the main report. This lends additional support to the proposed use of a sliding scale for rating AM, rather than a stepped scale approach.

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[65] Modulation depth in this study was defined as the mean depth over the frequency range of the 'modulation depth spectrum', established using the same Fourier process established by the Seoul University study group discussed under 'Study A' in the main report. These modulation depths cannot therefore be compared directly with AM depths defined in a different way – see Appendix A .

The results of experiment two indicate that, over the turbine rotation speed range addressed in the main report, i.e. up to 32 RPM, there is no strong need to directly consider modulation frequency as a modifying factor in determining a rating for AM (assuming a 3-bladed turbine), given that some uncertainty 'headroom' within the penalty magnitude has been included for this purpose. The results do appear to exhibit the expected relationship for modulated noise, i.e. that perceptual sensitivity increases steadily from 0 Hz, and on this rationale the trend could probably be extrapolated up to around 4 Hz, which would be the expected peak sensitivity (further increases in modulation frequency would then be expected to show decline in sensitivity). In the absence of further research aimed at establishing equivalent perceptual responses corresponding to higher modulation frequencies, the condition as proposed should be limited to the advised upper frequency limit, i.e. approximately 1.6 Hz.

The results of experiment three suggest that short periods of higher AM are probably not as annoying as a sustained period of reduced AM depth.

Limitations

The main limitations of the study are the small sample size and limited age group, the artificiality of the exposure (laboratory, headphones) and the short exposure periods.

The results address laboratory ratings of absolute annoyance; these should not be interpreted as directly indicative of responses in real field situations.

Conclusion

The outputs of this study appear to support the planning control approach proposed in the main report.

ANNEX 2

CATEGORY 1 STUDY G

Title:	Short-term annoyance reactions to stationary and time-varying wind turbine and road traffic noise: a laboratory study
Authors:	Schäffer, B., Schlittmeier, S.J., Pieren, R., Heutschi, K., Brink, M., Graf, R. & Hellbrück, J.
Institution:	Empa / Catholic University of Eichstätt-Ingolstadt / Federal Office for the Environment (CH)
Publication:	Journal of the Acoustical Society of America 139(5) pp2949-2963
Publication date:	May 2016

Details

This laboratory study included a sample of 60 participants aged 18-60 years (median: 35 yrs).

The study objective was to compare rated annoyance responses to WTN and road traffic noise (RTN) stimuli, presented in controlled listening tests.

The subjects were presented with synthesised WTN stimuli and edited recordings of RTN via loudspeakers. They were asked to rate their annoyance to the 25s samples on an 11-point scale.

The AM component in the WTN stimuli set was introduced in two ways: periodic fluctuations, and random. The periodic AM had a 3 dB standard deviation in the level fluctuation, and a modulation frequency of 0.75 Hz. The random AM had the same standard deviation in the level fluctuation, and a varying modulation frequency of 0.3-1.1 Hz. The maximum WTN modulation depths shown in the $L_{pA,F}$ signals appeared to be in the range 7-10 dB.

Results

The results indicated that:

→ For similar time-average levels, subjects typically rated WTN more annoying than RTN (replicating results known from field studies); and were slightly quicker to assign a rating to WTN than to RTN;

→ The ratings indicated a difference (in the time-averaged level) of around 4-5 dB for equivalent annoyance between WTN and RTN;

→ Periodicity in the AM of the WTN did not appear to have more of an influence on the ratings of annoyance than random AM;

→ A linear mixed effects model was developed from the data, indicating the relationship between the annoyance ratings and the time-averaged level for each sample type. This suggested that the AM WTN samples could elicit the same annoyance rating at around 1-2 dB lower L_{Aeq} than a WTN sample with no AM.

→ A logistic regression model was also developed from the data, to enable a relationship between the 'Probability of High Annoyance' (pHA) and the time-averaged level to be estimated for each sample type. This model suggested that the maximum difference in the time-averaged level for equivalent pHA between the WTN samples without AM, and those with AM (whether periodic or random, as the models were very similar), was around 2.5 dB.

Implications

The authors conclude that the results suggest the increased annoyance associated with WTN (compared with RTN) is not caused by the periodicity in the fluctuations, as might be thought, but instead appears more likely to be due to its modulation frequency, which is closer to that of expected human peak sensitivity (~4Hz).

The results suggest that the equivalence in annoyance due to the AM component in WTN may be smaller than the proposed penalty rating system, in the order of around 1-3 dB, rather than the 3-5 dB proposed. However, the modulation frequency range employed (up to around 1 Hz), does not cover the full range of potential modulation the control is designed to address, and equivalent annoyance at higher modulation frequencies (up to 1.6 Hz) would be expected to be higher than the study results suggest.

Limitations

The sample size for this laboratory study (60) was unusually large compared with the other lab studies examined. There was also a range of age groups represented and an almost even gender split. The authors acknowledge however that the sample represents a limited geographic region and are mainly drawn from research institutions, and no residents affected by wind farm noise were recruited.

The authors also enter into a detailed discussion of the differences between the type of 'annoyance' being rated in the laboratory and the annoyance experience by people in field situations, pointing out that these differences limit the comparability of the results. They conclude that the study addresses only 'short-term annoyance' and applicability to long-term exposure would need to be validated (e.g. by further field investigations).

Conclusion

The outputs of this study appear to support the planning control approach proposed in the main report.

ANNEX 3

HEALTH CANADA COMMUNITY NOISE AND HEALTH STUDY LITERATURE

AUTHOR	YEAR	TITLE	PUBLICATION	STATUS
Feder, K et al.	2015	An assessment of quality of life using the WHOQOL-BREF among participants living in the vicinity of wind turbines	Environmental Research	[black]
Michaud, D et al.	2016	Effects of wind turbine noise on self-reported and objective measures of sleep	Sleep	[black]
Michaud, D et al.	2016	Exposure to wind turbine noise: perceptual responses and reported health effects	Journal of the Acoustical Society of America	[black]
Michaud, D et al.	2016	Self-reported and measured stress related responses associated with exposure to wind turbine noise	Journal of the Acoustical Society of America	[black]
Michaud, D et al.	2016	Personal and situational variables associated with wind turbine noise annoyance	Journal of the Acoustical Society of America	[black]
Voicescu, S.A. et al	2016	Estimating annoyance to calculated wind turbine shadow flicker is improved when variables associated with wind turbine noise exposure are considered	Journal of the Acoustical Society of America	[black]

Jennifer Sherry

From: procbordemail
Sent: Tuesday 30 January 2018 12:01
To: Jennifer Sherry
Subject: FW: Email 3 of 3 - Your ref: PL 04.248152 (244439) PA Reg Ref: 14/557 & Your ref: PL 04.248153 (245824) PA Reg Ref: 14/6760
Attachments: i) DB09-Acoustics Bulletin November-December 2017.pdf; j) DB10-2015 Programme v4.xls.pdf; k) DB11-R243630 Ardglass Inspectors Report.pdf; l) DB12-Marshall Day Report.pdf; m) ETSU-R-97.pdf

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From: Bord
Sent: Tuesday 30 January 2018 09:26
To: procbordemail <procbordemail@pleanala.ie>
Subject: FW: Email 3 of 3 - Your ref: PL 04.248152 (244439) PA Reg Ref: 14/557 & Your ref: PL 04.248153 (245824) PA Reg Ref: 14/6760

From: Joe Noonan [mailto:jnoonan@nlcc.ie]
Sent: Monday 29 January 2018 16:49
To: Bord <bord@pleanala.ie>
Cc: Pippa Willows - Legal Secretary, Noonan Linehan Carroll Coffey <pippawillows@nlcc.ie>
Subject: Email 3 of 3 - Your ref: PL 04.248152 (244439) PA Reg Ref: 14/557 & Your ref: PL 04.248153 (245824) PA Reg Ref: 14/6760

Noonan Linehan Carroll Coffey
SOLICITORS
www.nlcc.ie

TO: An Bord Pleanála

FROM:

Joe Noonan
NOONAN LINEHAN CARROLL COFFEY
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54 North Main Street
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[Evolve:61b27260-f28e-4f62-802a-72941a978040]

An Bord Pleanála

Inspector's Report

Proposed Development: Permission is sought for a 10 year planning permission to construct a wind farm consisting of 11 no. turbines (each with a maximum tip height of 156.5m), a sub-station including 1no. control building and associated internal equipment, septic tank and percolation area, 3no. borrow pits, a meteorological mast, new internal access roads, upgrading of existing internal access roads, underground cables and ancillary works, all within the townlands of Peafield, Portavarrig, Oldcourt, Ballynona North, Walshtown More (West) and Ballyogaha West Midleton, Co.Cork

The application was accompanied by an Environmental Impact Statement and a Natura Impact Statement

Planning Application

Planning Authority: Cork County Council

Planning Authority Reg. Ref.: 13/04959

Applicant: Ardglass Windfarm Ltd.

Type of application:	Permission
Planning Authority Decision:	Refuse permission

Planning Appeal

Appellants:	Ardglass Windfarm Ltd.
Observers:	1. Ardglass Wind Turbine Action Awareness Group 2. Cork Renewable Energy Group 3. Castlelyons Development 4. Seamus & Breda Sexton 5. Don Sheehan 6. Dr. Sharon McKenna & Malachy Ward 7. Andrew Ennis & Susan Liddy 8. Sharon Guiry & Others 9. James & Anne Cagney 10. Christy O'Mahony 11. Ricky Galvin 12. Margaret Galvin

Type of appeal:	First Party against refusal
Site Inspection:	7th & 8th October, 2014
Inspector:	**A. Considine**

Table of Contents

1.0 THE SITE

1.1 The proposed development is for the construction of 11 no. wind turbines and associated ancillary works all in the townlands of Peafield, Portavarrig, Oldcourt, Ballynona North, Walshtown More (West) and Ballyogaha West Midleton, Co.Cork. The site is located approximately 3km to the north-east of Ballincurrig, 5km to the north west of Dungourney, 7.5km to the south east of Rathcormac and approximately 13km to south west of Tallow. Middleton is located approximately 9km to the south. The site of the identified study boundary appears to have been delineated by the existing road network in the vicinity of the proposed development site.

1.2 The elevation of the subject site, which can be considered in two sections with a local road dissecting the site, is identified at +220m OD in the northern area and 150m OD in the southern area of the site. The site is essentially bound by local and county roads along the western and eastern boundaries, with a further county road dissecting the site almost in the middle, running west to east. In addition, there is a further county road which affects the site at the south eastern area. The site boundaries of the proposed development follows the line of the access roads, the areas of the proposed turbines and the other essential work areas. Although the area is considered quite rural in nature, the Board will note that there is a population visibly present in clusters of houses along the access roads and in the vicinity of the site. There are a number of houses located within 1km of the proposed turbines. In addition, while the presence of the IDL Maturation Plant can be considered as reinforcing the presence of development and people in the proximity of the proposed development site, the Board will note that this development is not very prominent in the landscape from the public roads in the vicinity of the site.

1.3 The site has a stated area of 83.42ha, and the total footprint of the development will cover 6.25ha. The site covers land in the ownership of a number of different people. For the purposes of the EIS submitted, the study area extends beyond the site area and looks at an area covering 957ha, of which approximately 501ha is in the ownership of Coilte. From the information provided in the EIS, it is noted that three of the proposed wind turbines and the smallest borrow pit will be located in the northern area of the site with the remaining eight turbines, two larger borrow pits and permanent meteorological mast will be located to the south. The proposed substation will also be located towards the south of the overall site, in the vicinity of T1 and T2 and will be accessible from the lower county road at the south eastern area of the site directly. The proposed temporary compound to facilitate the proposed development is to be located along the county road which dissects the site centrally.

1.4 Much of the site is located within a heavily forested upland plateau area which is both open and exposed within a primarily lowlying rolling landscape. The River Bride is located to the north of the site and runs in a west to east direction. In addition to the River Bride, there are a number of smaller rivers and streams including the Dungourney and Kiltha Rivers affecting the area. Much of the subject site is forested and a stated area of 36.8ha will be required to be felled to accommodate the proposed turbines and associated tracks. The clearing will include a 30m corridor along all access roads and a 70m radius around each turbine.

2.0 PROPOSED DEVELOPMENT

2.1 The proposed development, as per the public notice, is described as follows:

Permission is sought for a 10 year planning permission to construct a wind farm consisting of 11 no. turbines (each with a maximum tip height of 156.5m), a sub-station including 1no. control building and associated internal equipment, septic tank and percolation area, 3no. borrow pits, a meteorological mast, new internal access roads, upgrading of existing internal access roads, underground cables and ancillary works, all within the townlands of Peafield, Portavarrig, Oldcourt, Ballynona North, Walshtown More (West) and Ballyogaha West Midleton, Co.Cork

The application was accompanied by an Environmental Impact Statement.

2.2 The proposed wind farm consists of eleven wind turbines of tip height up to 156.5 metres, a substation, a meteorological mast, three borrow pits, the construction of approximately 2.7 km of new site tracks and the upgrading of approximately 6.6 km of existing tracks and associated site development works. It is stated that the proposed turbines will be connected to the national grid at the Midleton 110kv substation at Carrigogna. The precise route of the of the underground grid connection has not as yet been determined.

2.3 6 of the proposed turbines will be located within the forested area while the remaining 5 will be located on open farmland. The turbines located to the south of the site are to be constructed around two hills where the elevations have been indicated at +210m and 217m OD respectfully. The smaller cluster of 3 turbines located to the north of the L7612 is located on lands where the elevations are indicated at +190m to 210m OD. The turbines are laid out in an irregular pattern with a minimum separation distance of 600 metres between turbines.

2.4 As part of the overall development, a substation and meteorlogical mast are also proposed. Both of these elements are to be located in the southern area of the overall site in the vicinity of T1, T2 and T3. Two of the proposed borrow pits are also to be located in this area while the third is to be located in the northern area of the overall site. The information provided indicates that the overall site area is comprised of parts of four landholdings. It is also indicated that the developers propose to set up a Community Investment Scheme to assist local community schemes subject to a number of criteria which include that projects being supported must be environmentally friendly, must promote energy efficiency and must benefit a large number of people and which beings the community closer to the wind farm. An initial €150,000 contribution is proposed with subsequent payments over 19 years of approximately €30,000 per annum.

3.0 ENVIRONMENTAL IMPACT STATEMENT

3.1 Legislative Context:

The proposed development falls within the scope of Part 2, Schedule 5 Development for the purposes of Part 10 (Environmental Impact Assessment) of the 2001, Planning & Development Regulations. As stated above, an Environmental Impact Statement was submitted with the planning application, and is presented in four volumes which includes appendices and photomontages. The EIS provides a non-technical summary, details of the environmental report including all environmental matters associated with the proposed development, and relevant appendices to the main statement. I have read this EIS in its entirety. The EIS provides a non-technical summary as well as a reasoning for the EIS, including its scope and the structure and methodology of same. The EIS submitted provides information in relation to a number environmental aspects and describes the potential affects the development will have on the receiving environment. It is also to be noted that the EIS is also advertised in the public notices pertaining to the development.

The following is a summary of the issues arising:

3.2 Volume 1 - Non-Technical Summary:

The EIS provides a Non-Technical Summary associated with the main EIS document. This NTS is presented in accordance with the legal requirements for the preparation of an EIS in that it clearly presents information relating to the development in clear and non-technical language. The project is described, as is the site selection process, the need and justification for the project, the methodology employed in the preparation of the EIS, consultations undertaken and alternatives, including sites, and design, considered. The NTS also provides an assessment of the environmental impacts associated with the relevant aspects of the environment.

3.3 Volume 2 - EIS:

3.3.1 The main body of the EIS submitted in support of the planning application consists of 15 chapters, which consider the potential impacts of the proposed wind farm on the receiving environment. The EIS submits that the construction phase of the project will be approximately 12 months and will generate jobs for up to 20 technical consultants, contractors and maintenances staff during the design construction and operation of the proposed wind farm. It is indicated that the wind farm will be part of the Gate 3 grid connection process and will utilise the capacity of the grid connection offer. The installed capacity of the wind farm will be +20MW, in order to satisfy the grid connection offer secured.

Each chapter of the EIS deals with a specific element of environmental impact as follows:

1. Introduction
2. Existing site setting
3. Description of development
4. Policy & legislation
5. EIS Scoping: The key issues
6. Ecology
7. Geology, Hydrogeology and slope stability
8. Hydrology and Water Quality
9. Landscape and Visual
10. Noise
11. Human Environment
12. Cultural Heritage
13. Telecommunications and Aviation
14. Air and Climate
15. Interaction of the Foregoing.

The following is a summary of the main impacts identified:

3.3.2 Ecology:

Chapter 6 of the EIS deals with Ecology and the information provided details the methodology employed in the preparation of this chapter. The EIS identifies seven designated sites within 10km of the site of which three are Natura 2000 sites. There are no designated sites identified within 3km. Fehily Timoney & Co. were commissioned to prepared an Appropriate Assessment Screening Report and this report is presented in Appendix D, Volume 3 of the EIS. The EIS notes that a number of organisations were consulted in the preparation of the Ecology chapter of the EIS. A habitat survey was undertaken, to include specific species and bird surveys, and a habitat map was prepared. The EIS provides a description of the receiving environment and provides an evaluation of ecological importance of the ecological features present on the site.

The EIS notes that the nearest pNHA is located approximately 6.1km to the south west of the study area being Ballynaclashy House which is identified as a nursery colony of the whiskered bat and is of national importance. Leamlara Wood, pNHA is located 6.3km also to the south west of the site and is identified for the presence of semi-natural oak woodland in east Cork. The nearest SAC is located 3.1km to the north of the site, being the Blackwater River, so designated for alluvial wet woodlands and Yew wood, both of which are priority habitats. There are a number of other Annex I habitats present in the SAC including floating river vegetation, estuaries, tidal mudflats, *Salicornia* mudflats, Atlantic salt meadows, Mediterranean salt meadows, perennial vegetation of stony banks and old Oak woodlands. This SAC supports a variety of Annex II species including Sea Lamprey, River Lamprey, Brook Lamprey, Freshwater Pearl Mussel, Crayfish, Twaite Shad, Atlantic Salmon, Otter and the Killarney Fern. The River Blackwater is also noted for its high conservation value for the populations of bird species. Cork Harbour SPA and Great Island Channel SAC and pNHA are located 9.1km to the south of the site, which are hydrologically linked to the subject site.

Screening for Appropriate Assessment was undertaken (appendix D of Volume 3 of the EIS). It is noted that the River Blackwater (Cork/Waterford) SAC, Site Code 002170, was not assessed within this report as it is upstream of the proposed development and is not within the likely zone of impact of the proposed wind farm. It was determined that a full AA was not required, due to the distance of the proposed development from Cork Harbour and the dilution effects of the marine environment. The AA Screening Report concludes that no significant impact on designated habitats is expected to occur. Details of habitat types and their associated values are provided for within the EIS, and in chapter 6.

The EIS also presents details of a mammal survey and a bat survey where the following protected species were recorded – fox, rabbit, Irish Hare, Fallow Deer, American Mink, Irish Stoat and red squirrel. The mammal survey also notes that it is possible that Otter may be present due to the proximity of the Dungourney River, but it is submitted that as the river is small in the vicinity of the site, it is unlikely to support breeding otters. In terms of bats, the Common Pipistrelle and the Soprano Pipistelle both of which are listed on the Annex IV of the EU Habitats Directive were found to be present on the site during the survey, but the EIS notes that activity levels were low.

The Birds Survey was carried out over the summer and winter periods, using on site surveys and counts. The survey concluded that the only Bird Watch Ireland amber listed species recorded on the site was the kestrel and it is concluded that it is unlikely that this species breed within or close by the subject site. The Red-Listed Yellowhammer and Golden Plover, also an Annex I species under the EU Birds Directive, were also noted on the site during the March vantage points watch in 2012. Overall it is concluded that due to the low biodiversity of the site, the limited range of flora and fauna and the habitats present being common, and the lack of evidence of breeding of protected bird species, the ecological value of the site is described as being of moderate local value.

The EIS describes the potential impacts associated with the proposed development in terms of the construction, operational and decommissioning phase, as well as providing a small assessment on the cumulative impacts associated with other developments in the area. Mitigation measures are considered. In terms of mitigation, Chapter 6 of the EIS refers the reader to the mitigation measures presented in chapters 7 and 8 and advises that with the implementation of mitigation measures, the proposed development adequately considers the ecological issues in its design and will therefore result in an overall neutral and imperceptible residual impact.

3.3.3 Geology, Hydrogeology and Slope Stability:

The EIS presents chapter 7 in order to provide information with regard to the environmental at the location of the proposed development works in terms of geology, hydrogeology and slope stability and seeks to describe same. The report discusses the potential impacts that the construction and operation of the proposed development may have on them and mitigation measures are proposed where necessary. The assessment was carried out through a desk top study, field visits and site investigations and extends to advising that the site walkover did not find any evidence of peat on the site. In this regard, it was concluded that a Peat Stability Assessment was unnecessary.

The EIS considers that the risk to ground waters is generally negligible and that surface water is the main sensitive receptor which is dealt with in chapter 8 of the EIS. The potential impacts associated with the proposed development in terms of ground water are considered in the document and the risk of pollution from hydrocarbon spills, leakages at borrow pits and from the waste water treatment system are identified as the primary risks. In terms of potential impacts associated with the proposed development, the EIS identifies the impacts associated with the construction and decommissioning activities at the site. Chapter 7 of the EIS concludes that submitted to mitigation measures, the construction, operation and decommissioning of the windfarm will have an negligible impact in terms of geology, hydrogeology and slope stability.

3.3.4 Hydrology & Water Quality:

Chapter 8 of the EIS describes the aspects of the hydrogeological environment that could be affected by the activities associated with the construction of the wind farm. An impact assessment was carried out to determine whether the project poses a significant impact to the hydrology and water qualtiy aspects of the environment, with mitigation measures proposed to reduce any potential negative impacts associated with the wind farm. The assessment describes the methodology employed for the impact assessment presented.

In terms of hydrology, the EIS identifies the prominent hydrological features, including all rivers and drainage features on and in the vicinity of the subject site, as well as providing information with regard to flooding events in the area. The chapter also discusses issues relating to the existing water quality and the Water Framework Directive (WFD). The EIS acknowledges that the water quality in the existing environment, and particularly the Dungourney River is considered to be mostly satisfactory with Good Ecological Quality, but poor quality further downstream in Middleton, with a Q value of 4.

Section 8.3 of the EIS deals with the proposed surface water management. The findings of the assessment suggest that there will be a negligible increase in impervious area as a result of the construction. The EIS notes that there are two existing watercourse crossings of significant tributaries on the site and the development will also require the provision of one new culvert. A small catchment is drained by rivulets above the rise of a tributary of the Dungourney River along the proposed access track between T1 and T2 and it is proposed to provide a series of 4no. 450mm diameter pipes to allow continuation of the natural flow regime in this area.

Potential risks are identified with regard to the construction, operational and decommissioning phases of the development, noting that the construction phase and decommissioning phases are likely to present the highest risk of impacts. Oil spills and increased runoff are identified as possible impacts arising from the operation of the wind farm. Mitigation measures are identified in section 8.5 of this chapter of the EIS. It is concluded that based on the measures identified to prevent the release of silt laden runoff from the site, a high degree of confidence can be assured in the mitigation measures proposed for hydrology and water quality and that any effects on the receiving environment will be of low significance.

3.3.5 Landscape & Visual:

The EIS presents a landscape and visual impact assessment report, in accordance with the various guidelines, in support of the proposed development. The assessment was carried out by MosArt Landscape Architects and Chapter 9 of the EIS provides details of the assessment methodology employed in the preparation of the Landscape and Visual Impact Assessment. The assessment was prepared using both a desk top study as well as site surveys and includes a number of photomontages. These photomontages are presented in Volume 4 of the submitted EIS. The landscape character of and in the vicinity of the identified study area is indicated, under the Draft Landscape Strategy for Cork, as a Landscape Type 10b: *Fissured Fertile Middleground (Rylane East to Waterford),* with the following values:

Landscape Value:	Medium
Landscape Sensitivity:	High
Landscape Importance:	County

The Type 10b landscape is described as 'an elevated landscape which is fissured by fairly gentle slopes, with reasonably fertile agricultural land comprising a mosaic of small to medium sized fields with broadleaf hedgerows', and a landscape character that 'has characteristics of both flatter fertile farmland areas and the higher marginal hilly farmland'. The EIS notes that the medium value landscapes are defined as 'landscapes with positive characters and with local or county importance', whilst high sensitivity landscapes are considered to be 'vulnerable landscapes with the ability to accommodate limited development pressure. To the north of the site, the landscape is indicated as Landscape Character Type 6c – *Broad Fertile Lowlands.*

The EIS presents a Zone of Theoretical Visibility as part of the overall visual impact assessment, which represents the area over which the proposed development can theoretically be seen. The submitted ZTV represents the worst case scenario and the methodology employed in the assessment is described within Chapter 9 of the EIS. A ZTV map was prepared as part of the visual assessment and is identified as figure 9.4, using a radius of 20km.

In terms of the visual assessment presented, the EIS notes that the visual impact assessment, and associated photomontages, is based on a turbine with an overall height of 156.5m to blade tip, with a maximum hub of 100m with a rotor diameter of 113m. 17 no photomontages are provided as part of the EIS, Volume 4, and a written description is provided in relation to each. The identified 17 locations are indicated as being within 15.6km of the subject site. The EIS, considers the cumulative impact associated with the proposed development and existing features in the vicinity and concludes that 'given the highly visible nature of commercial wind energy developments, it is not generally feasible to screen them from view using on site measures'. The EIS states that 'the visual impact of the combined development is the same as the impact of the proposed wind farm on its own and there is no significant cumulative impact'.

Overall, it is consider that the significance of impact on the landscape is deemed to be moderate. In terms of visual impacts, it is concluded that the relative visual dominance of the scheme from each VRP is strongly related to viewing distance. From the majority of the VRPs, the magnitude of the visual impact is considered to be medium or low. In only two instances, the magnitude is deemed to be high. Overall, the EIS concludes that the although the study area is not currently a landscape characterised by the view of wind farms, it is not a landscape that is sensitive to such development or where this would be an unexpected feature. The impacts identified are considered to be acceptable and do not coincide with any particularly sensitive receptor.

3.3.6 Noise:

Chapter 10 of the EIS deals with noise and the EIS describes the methodology employed in the assessment of noise associated with the proposed development as is the potential impacts of noise. Vibration associated with wind farms is also discussed in this chapter. The existing noise environment was determined by means of a background noise survey at three identified noise sensitive locations where the ambient noise levels in the area were recorded. The three identified locations are within 1km of the turbines and represent 7 houses.

The EIS notes the operational compliance of the turbines with the daytime fixed limit of 45dB(A). Non-compliance with the night time limit of 43dB(A) is noted at three receivers with wind speeds of +6 to 7m/s, notably when the wind is from an easterly direction. The EIS concludes that the noise modelling used for the construction phase of the development shows that it is unlikely that the construction phase will cause significant nuisance. A number of mitigation measures are proposed to mitigate against the impact of noise in this phase. No vibration impact is expected from the operating turbines and no mitigation measures are considered necessary.

3.3.7 Human Environment:

Notwithstanding visual, landscape and noise impacts which are addressed in separate chapters, the EIS considers the potential impacts of the development on the human environment, which includes a consideration of mitigation measures, where they are deemed appropriate, in Chapter 11 of the EIS. The document describes the existing environment, identifying the main land uses within the study area as well as discussing the potential impacts on recreation and amenity, including tourism, associated with wind farms. In addition, the chapter provides details relating to socio economics, including property prices, material assets, roads and transport property values and the impacts of shadow flicker. A house survey carried out identified that there are 15 existing and permitted dwellings within the study boundary of the proposed wind farm with the closest house being 510m from the nearest turbine, T7.

Shadow flicker is a term used to describe the shadows cast by rotating blades of a wind turbine. The shadows cast are intermittent and results in a 'flicker' effect. The EIS submitted refers to the appropriate guidelines pertaining to shadow flicker, which provides that *shadow flicker at neighbouring dwellings within 500m should not exceed 30 hours per year or 30 minutes per day*. The EIS notes that there are no houses located within the 500m limit. The Shadow Flicker Assessment which was carried out identified 45 buildings within 10 rotor diameters (1,130m) of the proposed turbines. The results of the modelling notes that the DoEHLG total annual guideline limit of 30 hours is predicted to be exceeded at 22 locations assuming 100% sunshine. When 40% sunshine limit is applied, this figure is reduced to 3 locations, all of whom are contributing landowners participating in the proposed project. In terms of mitigation it is submitted that mitigation measures will be assessed and a procedure of evaluation of the existing screening, window orientation and the periods of shadow flicker actually occurring will be undertaken in consultation with any relevant land owner.

In terms of Material Assets, the EPA notes that material assets are *resources of intrinsic value which may be of either natural or human origin.* The EIS sets out issues associated with material assets in Chapter 11 and includes assets such as non renewable resources, renewable resources and utilities infrastructure. In light of the above, it is submitted that there will be potential impacts due to quarry and mine activities but notes that most of the material required by the development will be sourced within the site and that existing tracks are to be used. Due to the requirement to fell trees, there will be a negligible impact on this renewable forestry resource. It is submitted that the area felled will be replanted therefore, the overall impact on renewable resources will be neutral. With regard to utilities, it is submitted that the proposed development will contribute to the electricity network. There will be no impacts to the Bord Gais Transmission Pipeline and conditions requested by the company will be complied with.

In terms of roads & transport, the EIS notes the intended access route from Middleton. The purpose of this section of the EIS is to assess the traffic impact on the additional traffic movements that will be generated by the proposed wind farm development during both the construction and operational phases of the development. The EIS notes the requirements of the NRA document 'Guidelines for Traffic & Transport Assessments', and concludes that as the development will represent an annual increase of 3.9% over current traffic on the R626, ant that this is below the 10% NRA threshold, a Transport Assessment is not required.

The EIS deals only with the delivery of the turbines and it is estimated that during the construction phase a total of 40 trips will be made by employees, with a further 49 HGV trips. During operation, the wind farm will generate very little traffic movements. Mitigation measures are proposed as part of the EIS to include the preparation of a traffic management plan.

The EIS considers the likely effects of the proposed development on all aspects of the human environment, concluding that, following the temporary disturbances associated with the construction phase, for which there are mitigation measures proposed, it will have a small positive impact on both the socio economics associated with the construction of the wind farm together with the community benefit scheme proposed by the company, which will support local environmental improvement and recreational, social or community amenities and initiatives in the locality.

3.3.8 Cultural Heritage:

Chapter 12 of the submitted EIS seeks to address any potential issues arising in relation to the proposed development and impacts on the cultural heritage of the study area. An archaeological and cultural heritage impact assessment was undertaken as part of the EIS by Annette Quinn and Miriam Carroll of Tobar Archaeological Services. The assessment included both a desk top study and a field inspection of the proposed development area. The report details the legal framework and requirements regarding the protection of archaeological monuments and architectural heritage, and identifies the information sources employed in the desk top study of the site. The EIS identified 10 archaeological monuments within the study boundary all of which are Recorded Monuments, with an additional 80 monuments identified within 2km of the site. Of the 90 monuments identified, 37 no longer have above ground expression with a further 10 which are no longer accessible or visible in the landscape due to the forestry. No new archaeological monuments were discovered in the course of this assessment.

In terms of Architectural and Cultural Heritage, the EIS notes that there are no protected structures within the study area, and two within 2km of the site, both of which are thatched houses, refs RPS 80 and 773. One house is included in the NIAH, ref no. 20905406. This is a 19th C farm house located at Monalyre Cross Roads and at 670m from T3. There are a further 6 NIAH structures located in the wider area. A number of Cultural heritage features were identified in this assessment including a limekiln, four bridges, enclosed field and field boundaries and small 19thC settlements / farmsteads.

Mitigation measures have been considered in this chapter including the recommendations as follows:

- Pre development testing of T7 turbine base and other bases and hardstands on greenfield areas.
- Establishment of a 30m buffer zone around RMs CO054-142001 and 002
- Monitoring of all ground works to be carried out under licence.
- that the derelict stone house at Ballynona North be preserved in situ and avoided as part of the development.

In terms of the proposed development, the EIS acknowledges that archaeological remains may appear due to earth movements associated with the development. It is submitted that there will be potential impacts associated with the construction of T7 given the proximity of two fulachta fia, one being located within the boundary area associated with same. The

EIS submits that all construction works will be monitored under archaeological licence, and in consultation with the relevant authorities.

3.3.9 Telecommunications & Aviation:

Chapter 13 of the EIS deals with telecommunications and aviation. Potential impacts are described as possible electro-magnetic interference with radio navigation signals. Cork Airport is approximately 33km south west of the site. Given the distance, the IAA has confirmed that a radar assessment will not be required. In terms of impacts on telecommunications, interference can occur in two ways including signal scattering and signal obstruction. In terms of mitigation, a protocol has been prepared between RTE and the developer which sets out the developers obligation to correct any deterioration in television and radio signal reception. All IAA lighting requirements will be complied with. In conclusion, it is submitted that the proposed development will not have any negative impact on aviation subject to compliance with the stated IAA requirements. Compliance with the protocol will ensure that there will be no negative impact on TV or radio reception.

3.3.10 Air & Climate:

Chapter 14 of the submitted EIS deals with Air and Climate.

Air: The site is located within an Air Quality Zone D and the assumption is that air quality is good and any potential impact on air quality as a result of the proposed development will be confined to the construction phase. Wind farm developments have no direct air emissions. Data in terms of existing air quality is provided from the 2000 monitoring period in Blackpool, Cork City, 1997, Heatherton Park, 2002 all zone B and Glashaboy, 1995 and Cork Harbour 2007-2008 both zone D. It is submitted that the limits provided are likely to be significantly higher than those at the subject site. The main potential air pollutants are identified as site machinery, vehicle exhaust emissions and dust during construction. It is considered that the development is unlikely to significantly increase levels of air pollutants or cause a breach of the air quality standards.

Climate: In considering the potential impact of the development on climate, the EIS cites the necessity to develop alternative energy sources and that the burning of fossil fuels is a known contributor to global warning. It is submitted that the proposed development will result in the production of energy from a renewable source which, once fed to the national grid, has the potential to avoid several thousand tonnes of carbon dioxide being released to the atmosphere. It is concluded that the development will have a negligible indirect positive effect on the climate.

3.3.11 Interactions of the foregoing:

Chapter 15 of the EIS addresses the interaction of the previous environmental aspects in accordance with the requirements of Schedule 6 of the Planning & Development Regulations, 2001 as amended. The chapter considers the interactions by means of a matrix, Table 15.1. The EIS identifies two types of potential inter-relationships and interactions, being positive and negative, and considers the proposed development during both the construction and operational phases of the development. The environmental interactions are identified under the following headings:

			Const. phase	**Operational**
1.	Ecology	-	Tree felling Traffic Excavation Noise	Noise Visual Energy Output Drainage Traffic Change in land use
2.	Hydrology & Water Quality	-	Tree felling Traffic Excavation	Drainage Traffic Change in land use
3.	Geology & Hydrogeology	-	Tree felling Traffic Excavation	Drainage Geotechnical Change in land use
4.	Landscape	-	Tree felling Traffic Excavation Noise	Visual Change in land use

5.	Human Environment	-	**Const. phase** Tree felling Traffic Excavation Noise	**Operational** Noise Visual Energy Output Drainage Shadow Flicker Traffic Change in land use
6.	Archaeology & Cultural Heritage	-	**Const. phase** Tree felling Excavation	**Operational** Visual Change in land use
7.	Air & Climate	-	**Const. phase** Tree felling Traffic Excavation	**Operational** Energy Output Traffic Change in land use

3.4 Volume 3 - Appendices:

The EIS notes 10 no. appendices associated with the EIS and application. The detail of the appendices include as follows:

Appendix A: Consultation Correspondence
Appendix B: ESB Document on Turbine Transformers
Appendix C: Alternative Layouts
Appendix D: Ecology - Appropriate Assessment Screening Report
Appendix E: Geology & Hydrogeology
Appendix F: Hydrology
Appendix G: Noise
Appendix H: Human Environment
Appendix I: Cultural Heritage
Appendix J: Site Suitability Assessment

3.5 Volume 4 - Photomontages:

Volume 4 provides details of the visual impact assessment associated with the proposed development in the form of the photomontages.

4.0 REPORTS ON PLANNING FILE

4.1 The PAs report notes that two pre planning meetings were held between the Planning Authority personnel and representatives of the developers, in relation to this development.

4.2 There are 244 submissions noted on the planning file from third parties. I have read the content of all submissions. The issues raised in the objections are summarised as follows:

- Inadequacy of the submitted E.I.S., notably in relation to the consideration of alternative sites
- Unacceptable visual impact
- Noise implications
- Health implications
- Impacts on persons with existing medical conditions including Autism and Asperger's Syndrome
- Impact of shadow flicker on adjacent properties
- Lack of adequate pre planning consultations with the local community
- The site is not located in an area identified as being a Strategic Search Area in the Co. Development Plan 2009,
- Impact of the development on livestock and farming
- Safety implications of siting a wind farm in proximity to the permitted Midleton Distillery Maturation Plant and to a Bord Gas underground pipeline
- Impact of the development on property values in the area
- Impact on the ecology, amenity and tourism potential of the area
- Impact on the road network in the area
- Impact of the development on ground water.

4.3 Three submissions from elected representatives were received from the following:

- Cllr. Barbara Murray
- Cllr. Noel Collins &
- David Stanton. T.D

4.4 7 no. external reports were submitted to the Planning Authority in relation to the proposed development:

Felling Section, Forest Service, Department of Agriculture, Food and Marine: Report outlines information that should be included in an E.I.S in relation to wind farm development on forested land. The report notes that the developer must obtain a Felling Licence for the Department before trees are felled or removed.

An Taisce: Report states that an evaluation on ecological, amenity and landscape impact grounds is required.

Development Applications Unit, Department of Arts, Heritage and the Gaeltacht: Report notes no objection and recommends conditions be included should planning permission be granted.

Inland Fisheries Ireland: Report recommends that should permission be granted, include 3 no. conditions.

Bord Gas Networks: E-mail sent to CCC with accompanying documentation, advising no objection in principle to the proposed development subject to 1 no. condition being attached to any planning permission granted.

Health Service Executive: Report comments on seven issues related to the proposed development.

Health & Safety Authority: On the basis of the information provided, the Authority does not advise against the granting of permission in the context of Major Accident Hazard but notes that developments around Seveso establishments may have a potential impact on the future expansion of those establishments.

4.5 There are 6 no. reports noted from internal County Council Departments on the Planning Officers report from the following:

Road Design Officer: No comments or objections to make.

Area Engineer: Discusses issues relating to roads and surface water and provides for a number of conditions to be included in any grant of planning permission, including conditions relating to the repair of public roads.

Environment Section: Notes no objection to the proposed development, subject to compliance with 8 conditions.

Subsequent report dated 8/7/13 recommends that additional information be sought from the developers in relation to 10 issues relating to noise implications of the proposed development.

Ecologist: The report from the CCC Ecologist considers that there is insufficient information to complete Habitats Directive Assessment or to complete an assessment of impacts of the proposed development on the ecology of the proposed development site. The report concludes that additional ecological information and surveys are required under 7 headings.

Archaeologist: The report considers the proposed development in terms of the County Development Plan and the policy requirements contained therein. The report considers the direct and indirect impacts, architecture and cultural heritage and concludes that while there will be some indirect visual impacts associated with the proposed development, overall, there is no objection to the proposed development, subject to compliance with 3 conditions.

O'Callaghan and Moran Consultants (OMC): A report was prepared on behalf of Cork Co Council by OMC to address the geological, hydrogeological, hydrological and slope stability implications of the proposed development. This report, dated 1/7/13 considers the proposed development under the following headings:

- Geotechnical stability
- Borrow pits
- Dewatering
- Noise
- Mitigation measures

The report concludes by recommending that additional information be sought.

4.6 The Planning Authority considered the proposed development together with the information submitted in support of the proposal against the requirements of the County Development Plan and National Policy pertaining to Wind energy projects. The Senior Executive Planning Officers report also had regard to the many submissions made in relation to the proposed development as well as reports received from internal departments with the Planning Authority and from prescribed bodies. A number of concerns were raised in the report regarding the proposed development and potential impacts on the receiving landscape were raised. In addition, issues were considered in terms of hydrology, hydrogeology, geology and slope stability, ecology, shadow flicker, archaeological impacts, fire safety, turbine failure stability, cumulative impacts in relation to the permitted IDL Maturation Plant, noise, traffic and road safety issues and the consideration of alternative sites. The report concludes that there are a number of issues arising in relation to the proposed development and that further information is required.

4.7 Further information was sought in relation to 29 stated items.

4.8 A request from the developers sought an additional period of time in order to fully reply to the FI request. Three months was granted by the PA. A substantial response to the further information request was submitted to the PA on the 22nd April, 2014. The response deals with each issue raised in the FI request and provides for a number of appendices. On the 30th April, 2014, the development was re-advertised in local press. The response dealt with each item under nine headings with the response summarised as follows:

- Economics:
  The proposal is to install 11 no. 2.3MW turbines with the maximum potential power generation of 25.3MW. The developer has a grid connection offer of 21.6MW, but as the Commissioner of Energy Regulation allows the installation of up to 120% of the maximum export capacity, of the grid offer, which would be 25.92MW, the proposal is acceptable.

  The proposed development could provide sufficient electricity to power over 11,645 homes, contributing to the significant demand in Co. Cork.

  The wind farm could potentially avoid over 28,560 tonnes of CO_2 per year, and over 714,000 tonnes over the lifetime of the wind farm. The power output per year is estimated to be approximately 58,411 MWh per year and in terms of the tonne of oil equivalent (TOE), the development would avoid over 5,000 toe per year, or 125,000 toe over the lifetime of the project.

- Alternative Locations:
  Appendix B of the response provides the response to this issue, prepared by McCarthy Keville O'Sullivan, Planning & Environmental Consultants. The document presents the existing planning policy context and in terms of justification for the subject site, it is submitted that the areas identified Strategic Search Areas in the vicinity, they are fragmented and generally much smaller in nature than those identified within the other three SSA groupings. Due to the limited size and fragmented nature and local constraints, the SSA areas in this location limit the viability to provide for a significant wind farm development.

  A robust site selection process is demonstrated in the submission and notes the Draft Cork County Development Plan, 2013, noting that the subject site is entirely located within an area which is Open to Consideration.

  The site selection process was led by a detailed review of all relevant project constraints and facilitators from the outset as follows:

  Proximity to grid: Having regard to the node assignment and grid offer at Carrigogna sub-station, potential sites were focused within 15km of the node connection point. The total land area amounts to 70,500 ha which represents a significant initial search area.

  Wind farm format: Several wind farm formats were considered and using a single site to accommodate the required grid capacity was deemed to consolidate the visual extent of the turbines and would be preferable to providing a number of smaller wind farms at various locations.

  Three areas in this area of Co. Cork were considered in terms of alternative locations for the wind farm and these are presented in Figure 2.1 of the FI response. The response provides for an analysis of each of these alternative sites considered. The report concludes that while the site selection process identified the subject site as the optimal location for the development, the development, if permitted, will not preclude or compromise the other wind energy developments within any of the other areas identified in the Strategic Search Area in the County Development Plan.

- Cumulative Impact:
  The response to the FI request considers that the proposed wind farm will contribute to an increased intensity of build development in combination with the maturation warehouse development. The character of this landscape has been that of a low intensity upland rural landscape with some remoteness and tranquillity. This is changing slightly towards a landscape of rural industry as a result of the distillery buildings. The wind farm will contribute to this change but is more typical of emerging trends in upland rural landscape than the distillery is. As the distillery is highly screened by conifer plantations from all directions except the south, there is little potential for significant cumulative visual impacts to occur.

- Visual Impact:
  A revised Zone of Theoretical Visibility at a scale of 1:50,000, as well as photomontages were submitted as requested in items 4 and 5 of the FI request. In terms of item 6 of the FI request, 6 additional photomontages were submitted and described.

- Borrow Pit:
  In response to item 7 of the FI request, the applicant refers to the content of the EIS and the findings of the trial pits that were undertaken on the site in August 2012.

  In response to item 8, which requested a materials balance calculation to confirm that the borrow pits as proposed are required and where the excess materials to reinstate them will be sourced, the applicant advises that the three borrow pits have a maximum potential excavation volume of 41,400m^3. The estimated volume of material to be excavated to facilitate the proposed development is approximately 29,900m^3. There will be no need to source surplus material to reinstate the borrow pits.

  Item 9 if the FI request sought an assessment of the need to dewater the borrow pit, and if required, an assessment of the impact on the surface water drainage system and / or associated flood risk. In response, the applicant submits that the trial pits encountered groundwater seepage within two of the three borrow pits locations at depths of 2.3m and 2.5m at borrow pits 1 and 3 respectively. Preliminary indications suggest that some drainage may be required during excavations, including pumping. Large scale dewatering is unlikely. A more detailed assessment of the need for dewatering will be made as part of the detailed design stage.

Item 29 of the FI request sought a detailed investigation to determine the suitability and availability of site stone material for the site access roads and hard standing. The response notes that the testing of materials will require rotary core drilling and associated lab testing which will be undertaken at detailed design stage. The existing tracks at the site were constructed using materials excavated on site.

- CEMP:
  An outline Construction and Environmental Management Plan has been prepared and is included in appendix I of the response to the FI request. It is submitted that this plan will be further developed by the contractor at the construction stage of the development.

- Deforestation:
  In terms of proposed replanting the applicant submits that a felling licence application will be made to the Forestry Service and under such licence, there will be a requirement to replant on other lands to compensate. A felling licence much be accompanied by a grant of planning permission and therefore follows once the planning process is complete.

- Noise:
  Items 12 to 21 for the further information request dealt with noise. The response to these issues are presented in the FI response document and appendix J which comprises a very comprehensive report from AWN Consulting. This report notes the issuing of a new document from the Institute of Acoustics (IoA), *"Institute of Acoustics Good Practice Guide to the Application of ETSU-R-97 for the Assessment and Rating of Wind Turbine Noise"*, (May 2013), and advises that the noise assessment presented in the EIS has been revised to reflect this

current best practice in terms of noise predictions, etc.

- Ecology:
  Items 22 to 27 of the further information request dealt with issues of ecology. The response notes that further surveys were carried out in order to address the issues raised by the PA. The results of the survey recorded an additional six avian species, which included the Sparrowhawk which is an amber listed species. A peregrine falcon was recorded offsite in December, 2013 during the winter vantage point surveys, as was the Lesser Black-bearded Gull. The Golden Plover appears to remain the most active red listed and Annex I species using the site with significant activity noted to the south of the site and in the western area of the application site. The report submits that overwintering birds may be subject to temporary disturbance during the construction phase of the project, but that the impacts will not be significant due to the widespread availability of suitable alternative habitat in the wider area. No hen harrier was observed at the site.

  A revised AA report has been prepared to address the issues raised in the FI request and a comprehensive habitat map is provided. A further Bat survey was carried out in September, 2013 where higher levels of activity were recorded. The Common Pipistrelle and the Soprano Pipistrelle were recorded but no roosts were found within the EIA study area. Mitigation measures are proposed to minimise bat collision. The removal of small areas of hedgerow and treelines will lead to a loss of foraging habitat for bats, but it is submitted that the removal will be on a small scale and the impact is not considered to be significant. Additional planting will compensate for the removal of habitats within the development footprint.

  The Annex I habitat, *Marsh Fritillary* was not recorded at the site.

4.9 Following receipt of the response to the further information request, there were a further 210 submissions noted on the planning file from third parties. I have read the content of all submissions. The issues raised in the objections are summarised as follows:

- The response to the issues raised in FI has not allayed concerns.
- Unacceptable visual impact

- Noise implications
- Health implications
- Impact of shadow flicker
- Lack of adequate pre planning consultations with the local community
- The site is not located in an area identified as being a Strategic Search Area in the Co. Development Plan 2009,
- Impact of the development on livestock and farming
- Safety implications of siting a wind farm in proximity to the permitted Midleton Distillery Maturation Plant and to a Bord Gas underground pipeline
- Impact of the development on property values in the area
- Impact on the ecology, amenity and tourism potential of the area
- Impact on the road network in the area
- Impact of the development on ground water.

4.10 Following receipt of the response to the further information request, there was a further submission from Cllr. Noel Collins.

4.11 Following receipt of the response to the further information request, there were a further 4 no. external reports were submitted to the Planning Authority in relation to the proposed development:

Geological Survey of Ireland: the submission details the available online information. It further requests that data collected during the EIA would be welcome as well as a copy of reports detailing any site investigations carried out.

Bord Gas Networks: No further comments to make.
Waterford County Council: Advises that details have been referred to the Senior Planner. A further submission advises that it is noted that the development will have a considerable zone of theoretic visibility extending as far as the Banks of the River Blackwater at Tallowbridge and to the south west of Lismore. On balance, there is no objection to the proposed development.

Inland Fisheries Ireland: Report requests that the original comments made be given full consideration. The report adds that specifically in relation to the crossing of spur road to T7, the IFI should be consulted in relation to the design and construction of this crossing point.

4.12 Following receipt of the response to the further information request, there were a further 4 no. reports noted from internal County Council Departments on the Planning Officers report from the following:

Area Engineer: No objection subject to compliance with 5 conditions. Second report seeks the inclusion of a condition requiring a development contribution of €23,000.

Environment Section: Following the consideration of the response to the further information request, the report concludes that clarification is required in relation to a number of matters before a decision issues. The final conclusion however is that the development should be refused for the following reason:

'It has not been demonstrated on the basis of the information submitted that the proposed development and operation thereof, would not, by reasons of noise and nuisance, injure the amenities of noise sensitive locations in the vicinity.'

Ecologist: The second report from the CCC Ecologist following receipt of the response to the further information request notes that concern remains with regard to a number issues and it is recommended that planning permission be refused on the basis that the information provided does not facilitate the PA to complete EIA and Screening for AA. Issues relate to the management of surface waters, impacts on species of birds of high conservation value and impacts on bats.

4.13 The SEP prepared a report following the submission of the response to the Planning Authority's further information request and deals with each issue in turn. The report concludes that, in accordance with the requirements of the CDP, the local visual impacts are an important consideration in the assessment of new proposed wind energy projects. In addition, the Draft CDP, 2013 is cited whereby the emerging policy includes an assessment in areas 'open for consideration' of residential amenity in relation to noise, shadow flicker and visual impact and can avoid adverse impacts on visual quality of the landscape and the degree to which impacts are highly visible over wider areas. In this regard, the consideration of visual impact is also considered in relation to residential amenity. The report concludes that the scale of the proposed windfarm development is not justified at this location. In addition to the visual impact, it is considered that the development, if permitted, will set a precedent for further wind farm developments of this scale in the area. It is recommended that permission be refused for the proposed development.

4.14 The Senior Planner also prepared a report in relation to the proposed development and noted the other reports from the Senior Executive Planner, third party submissions and other reports prepared in relation to the development. The report notes that key outstanding issues relate to the following:

1. Ecology (including AA)
2. Noise
3. Hydrology / hydrogeology
4. Visual impacts
5. Cumulative impacts

The report considers that, while a number of the issues raised might be dealt with by way of condition, when taken together, it has not been demonstrated that the development is acceptable in relation to environmental impacts. In terms EIA, it is noted that while the EIS is acceptable in relation to the scope of issues addressed, it is concluded that it has not been shown that the proposal would not have a significant negative impact on the environment. It is considered that the potential impacts on relevant sites have been screened out and therefore AA screening cannot be completed. The report concurs with the SEP that there are issues in relation to the visual impacts associated with the proposed development. The SP considers that the proposal is acceptable in overall visual terms. The critical visual impact relates to a number of houses in the vicinity of the site where the development as proposed will have an unduly negative impact on residential amenity, the possible mitigation of which cannot be dealt with by condition.

The report concludes as follows:

- The submitted documentation is unsatisfactory by reference to ecological, noise and hydrogeological impacts;

- The EIS is not satisfactory in this regard and it has not been shown that the proposal would not have a significant negative impact on the Environment;
- It is not considered that the potential impacts on relevant sites have been screened out and therefore AA screening cannot be completed;
- The proposal is acceptable in terms of overall visual impacts including impacts on scenic route. There are localised visual impacts which is considered will have localised negative impacts in terms of residential / visual amenity.

Refusal is recommended for two reasons.

5.0 DECISION OF THE PLANNING AUTHORITY

The Planning Authority refused planning permission for the proposed development for the following 2 no. reasons:

1 Having regard to the submissions made in connection with the application by reference to ecological, noise and hydrological/hydrogeological impacts (which is considered deficient) the planning authority are not satisfied that the proposed development would not have a significant and adverse impact on the amenities and environment of the area including significant adverse impacts on:

- noise sensitive locations in the vicinity,
- water quality and hydrology/hydrogeology of area, and,
- ecology of the area including protected species and sites.

The proposed development would therefore be contrary to the provisions of The Wind Energy Guidelines for Planning Authorities issued by the DoEHLG in June 2006 and would be contrary to the proper planning and development of the area.

2 Having regard to the number of residential properties in the vicinity of the site and notwithstanding the proposed mitigation measures contained in the submitted Environmental Impact Assessment and noting the deficiencies in submitted noise assessment it is

considered that the proposed development would adversely impact upon the existing residential amenities of a number of houses in the vicinity by reason of visual intrusion and noise. The proposed development would therefore be contrary to the proper planning and sustainable development of the area.

6.0 RELEVANT PLANNING HISTORY

6.1 There is no specific planning history associated with the subject site with regard to a wind energy project.

6.2 IDL Maturation Plant located 400m to the south of the subject site:
PA ref 10/8481: Permission was granted for the development of warehousing at the IDL Maturation Plant consisting of 40 warehouse structures (bulk flammable storage) each with a floor area of 1600 sq metres and a height of 11.5 metres was permitted on a 36.6 hectare site under planning permission 10/8481 and is currently under construction. The Board will note that there is a submission to the current application / appeal on behalf of the Midleton Distillery which outlines that company's long term proposals for the expansion of their permitted maturation plant at this location. It is also noted that the maturation facility is a Tier One Seveso Establishment.

6.3 In addition to the above, the Board will note that a number of planning permissions have been granted in the wider area and in proximity to the subject site for a number of one off houses.

7.0 POLICY CONTEXT:

7.1 Cork County Development Plan 2009

7.1.1 Within the Cork County Development Plan 2009, Wind Energy is addressed in terms of policy on transport and infrastructure in chapter 6. Policy INF 7-2 commits the planning authority to support the National Climate Change Strategy in seeking to reduce the emission of greenhouse gases. Policy INF 7-3 is an objective generally to encourage the production of energy from renewable sources including wind energy subject to normal proper planning considerations, including in particular the impact on areas of environmental or landscape sensitivity.

7.1.2 In relation to wind energy, and following a study of wind speeds and the landscapes of the County on a broad level, the Plan identified in broad strategic terms, two specific areas with regard to the provision of wind energy developments, under objective INF 7-4 and Figure 6.3:

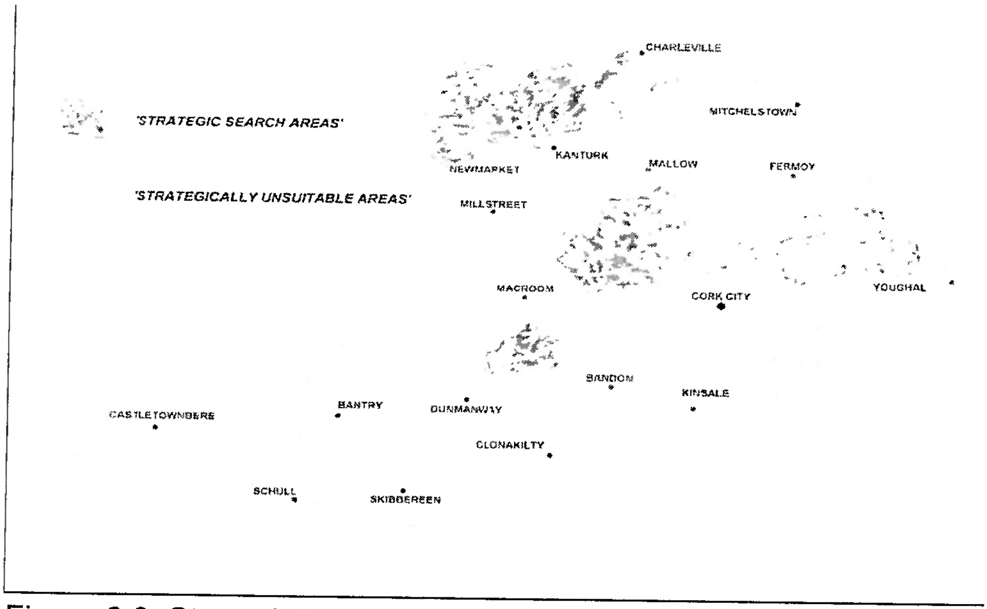


Figure 6.3: Strategic Wind Energy Areas

Strategic Search Areas: Areas which have both relatively high wind-speeds and relatively low landscape sensitivity to wind projects. Whilst not all locations within these areas would be suitable for wind projects they do give a strategic representation of generally preferred areas.

Strategically Unsuitable Areas. Areas which because of high landscape sensitivity, are considered generally to be unsuitable for wind energy projects. The Board will note that the subject site lies in neither described area.

7.1.3 The Plan also sets out that the identification of these areas does not give any certainty about the outcome of any particular wind energy proposal and, even within the strategic search areas, there will be particular constraints at individual sites. For example, within the identified search areas, important breeding and feeding grounds for rare and protected hen harriers can be found and these can be damaged or destroyed by inappropriate development.

7.1.4 INF 7-4 is the objective to encourage prospective wind energy businesses and industries. INF 7-4 deals specifically with Wind Energy Projects and provides that it is an objective of the council to encourage wind energy projects while avoiding strategically unsuitable areas identified in the plan. Part (c) of this policy deals with those areas that are identified as neither strategic search areas nor strategically unsuitable areas and provides that it is an objective in such areas to consider new, or the expansion of existing, wind energy projects on their merits having regard to normal planning criteria. The policy, provided in full in the appendix to this report, cites a number of planning criteria to be considered in this regard. Objective INF 7-5 deals with overhead power lines which are also considered relevant.

7.1.4 Chapter 7 of the County Development Plan deals with Heritage and Environment and the following policies are relevant in relation to the subject proposed development:

ENV 1-5:	which deals with Natural Heritage Sites:
ENV 1-8:	which deals with Legally Protected Plant and Animal Species:
ENV 1-9	which deals with Features of Natural Interest:

7.1.5 In relation to Landscape issues, the following policies are considered relevant:

ENV 2-11:	which deals with Scenic Routes:
ENV 2-13:	which deals with Development on Scenic Routes

7.1.6 Section 7.3 of the County Development Plan deals with Archaeological Heritage, and the following policies are considered relevant:

ENV 3-1:	which deals with Sites, Features and Objects of Archaeological Interest:
ENV 3-2:	which deals with Newly Discovered Archaeological Sites:
ENV 3-3:	which deals with Zones of Archaeological Protection:
ENV 3-4:	which deals with Archaeology and Infrastructure Schemes:

7.2 National Policy

National policy on renewable energy has arisen primarily in response to international agreements, most particularly the UN Framework Convention on Climate Change and the Kyoto Protocol. Current government policy in relation to renewables is outlined in the National Climate Change Strategy 2007 – 2012 which highlights the need for a radical strategy to meet the climate change commitments made under Kyoto.

7.2.1 *Sustainable Development – A Strategy for Ireland*, includes emphasis on the use of renewable resources.

7.2.2 *The National Spatial Strategy 2002 – 2020,* states, "in economic development the environment provides a resource base that supports a wide range of activities that include agriculture, forestry, fishing, aqua-culture, mineral use, energy use, industry, services and tourism. For these activities, the aim should be to ensure that the resources are used in sustainable ways that put as much emphasis as possible on their renewability" (page 114).

7.2.3 *National Biodiversity Plan 2002,* was prepared in response to Article 6 of the Convention on Biological Diversity and 'pays special attention to the need for the integration of the conservation and sustainable use of biological diversity into all relevant sectors.'

7.2.4 *Guidelines for Planning Authorities on Wind Farm Development and Wind Energy Development* - Planning policy guidance is outlined in "Wind Farm Development: Guidelines for Planning Authorities", 2006. The guidelines offer advice on planning for wind energy through the development plan process and in determining applications for planning permission and are intended to ensure consistency of approach in the identification of suitable locations for wind energy developments and acknowledge that locational considerations are important. These considerations include ease of vehicular access and connection to the electricity grid. It is acknowledged that visual impact is amongst the more important issues to be taken into account when deciding a particular application.

Any wind farm proposal will require an assessment of the possible ecological effects. Consideration should also be given to sensitive habitats and species as well as possible risks to birds including migratory birds. Regard should be had to special areas of conservation and other designated sites. Rural land uses other than housing are generally unlikely to conflict with wind farm developments. Conditions will generally be required to provide for the decommissioning of wind farms and ancillary developments on site.

Chapter 5 of the guidelines refers to other environmental considerations, including the impact on habitats and bird species, noise and electro-magnetic interference. Section 5.3 states that a planning application must be accompanied by information on such issues as slope stability and an assessment of whether the development could create a hazard of bogburst or landslide.

Chapter 6 of the draft guidelines refers to the assessment of siting and location of such development in terms of aesthetic considerations, landscape sensitivity, spatial extent and cumulative effect, with regard to landscape character types including hilly and flat farmland, mountain moorland and transitional landscapes. The factors to be assessed comprise landscape sensitivity, visual presence of the wind farm, its aesthetic impact on the landscape and the significance of that impact.

7.2.5 *South West Regional Planning Guidelines 2010-2022*

The vision of the RPGs is stated as follows:

> "to maintain and develop a sustainable and competitive economy, optimise the quality of life of its residents and visitors, protect and enhance its unique environment, culture and heritage.
>
> By 2022, the South West Region will be realising its economic potential and providing a high quality of life for its people by meeting their employment and housing, educational and social needs in

sustainable communities. At the same time it will reduce its impact on climate change and the environment, including savings in energy and water use and by strengthening the environmental quality of the Region."

One of the key principles identified in the RPGs as underpinning this stated vision includes promoting the security of energy supply and the development of renewable energy in the region in a sustainable manner.

RKI-01 of the RPGs sets out the key planning and development issues facing the region, while Section 1.3.37 of the RPGs identifies that "wave and wind technologies are expected to play a significant part in meeting additional demand with excess renewably generated power being exported through an enhanced transmission grid to other regions within the State."

Section 5.6.21 of the RPGs acknowledges that there is a growing network of wind powered electricity generators in both Cork and Kerry and significant potential exists for additional electricity generation by sustainable wind, wave and tidal energy sources.

Objective RTS-09 Energy and Renewable Energy, promotes the development of renewable energy resources in a sustainable manner. In particular development of wind farms shall be subject to:

- the Wind Energy Planning Guidelines
- consistency with proper planning and sustainable development
- criteria such as design and landscape planning, natural heritage,
- environmental and amenity considerations.

Objective REAS-05 Flood Risk Management states that it is an objective to ensure that significant developments in upland areas, such as *inter alia* wind farm developments, provide sufficient storm water attenuation so as to avoid the occurrence of river erosion or flooding downstream.

7.3 Wind Turbines Bill, 2012.

In the interests of presenting a complete consideration of legislative requirements, and for information purposes, I would refer the Board members to the above Bill which is currently with the Houses of the Oireachtas. This Bill seeks to provide clear guidance with regard to the minimum separation distances between residential properties and wind turbine generators. The minimum separation distances are determined by way of the overall height of the proposed turbines as follows:

(4) If the height of the wind turbine generator is –
(a) greater than 25m, but does not exceed 50m, the minimum separation distance requirement is 500m;
(b) greater than 50m, but does not exceed 100m, the minimum separation distance requirement is 1,000m;
(c) greater than 100m, but does not exceed 150m, the minimum separation distance requirement is 1,500m;
(d) greater than 150m, the minimum separation distance requirement is 2,000m;

8.0 GROUNDS OF APPEAL

8.1 This is a first party appeal against the decision of Cork County Council to refuse planning permission for the proposed development. The comprehensive document provides an introduction and background to the development as well as providing a description of the development characteristics and issues pertaining to planning policy. The document seeks to address the reasons for refusal as presented in the Planning Authority decision pertaining to the development

The specific grounds of appeal with regard to the reasons for refusal are summarised as follows:

8.2 <u>Reason 1:</u>
Refusal reason 1 relates to the adverse impacts on the amenities of the environment of the area including on noise, water quality and ecology. The grounds of appeal are summarised as follows:

8.2.1 Noise:
AWN Consulting prepared a submission in order to address the issues relating to noise as referred to during the PAs assessment of the proposed development. The appeal document provides a copy of this report and also a summary of its content and findings as follows

- The development can be designed to comply with the relevant guidance

- Further updated baseline noise monitoring was commissioned and worst case noise criteria have been derived based on the guidance.
- In the limited instances where levels are exceeded, it has been demonstrated that the relevant noise criteria curves can be complied with

Based on the minimum curtailment requirements identified, the technologies available to the market have lower noise ratings with them than those considered for the assessment and the strong likelihood that the final selected turbine model will have lower noise emissions associated with it, it is likely that the requirement for any curtailment strategy will be removed from the site.

8.2.2 Water Quality and Hydrology / Hydrogeology:

It is submitted that OCM, consulting company used by Cork County Council to consider certain aspects of the proposed development, considered that matters of hydrology and water quality have been comprehensively addressed in the EIS.

In terms of geology, hydrogeology and slope stability, it is submitted that OCM agreed with the findings of the EIS. Further information was requested with regard to a number of issues with clarification recommended following the receipt of the response to the FI request. The appellant notes that OCM considered that said clarification may be obtained by way of planning conditions, yet the PA decided to refuse permission. It is submitted that the appellant is confident that the borrow pit material to be extracted will be suitable for the purposes required. The level of detail required prior to a grant of planning permission is considered to be unprecedented.

Three borrow pits are proposed on the site and trial pits were undertaken at these locations. It is expected that the borrow pits will be easily excavated and that blasting will not be required. It is further considered that the material extracted will be suitable as the existing tracks on the site were constructed using material excavated on site. In terms of groundwater and seepage, it is noted that OCM confirmed the conservative approach taken by the applicant.

8.2.3 Ecology:

The grounds of appeal in this regard seeks to address the individual items raised by the Heritage Officer of Cork County Council in relation to ecology. There are 4 areas of concern considered as follows:

- Birds
- Habitat Directive Screening Report
- Habitats and
- Bats

a. Birds:

Comprehensive bird surveys were carried out between March 2012 and March 2014 and comprised of a number of elements. Detailed data on breeding birds was provided in the EIS and the RFI response. Only one red-listed species was recorded being the Meadow Pipit. There is little evidence that wind farms affect bird populations following construction. The hen harrier was not recorded on the site.

The Golden Plover was recorded in low numbers at the site and it is believed that the species over-winter in the wider area. There were no breeding populations recoded during the bird surveys and while a number of flocks were noted over the site, the majority of activity was recorded outside the wind farm site boundary. It is concluded that disturbance displacement is not expected to have any long term impacts on wintering Golden Plover in the area.

Kestrel were recorded on the site three times during the surveys, twice during the winter and once during breeding season. It is considered that the Kestrel are unlikely to be impacted by collision at the proposed site.

A buzzard was recorded twice during all bird surveys at the site, in December, 2013. At both times, the Buzzard was flying at less than 30m and therefore it is considered unlikely that they will be significantly impacted from collision or disturbance / displacement. The Buzzard were not recorded during the breeding season.

Snipe were recorded on three occasions during 60 hours of VP watches, twice in December, 2013 and once in March 2013 with a total of 4 birds recorded. There are small areas of wet grassland at Peafield meadows and Portavarrig wetland which can be considered as suitable breeding ground for the Snipe and it is acknowledged that it may be at risk of collision during the breeding season.

Mitigation measures are indicated in the EIS and in the RFI response. In addition, it is proposed that additional trees and hedgerows will be planted along gaps in the existing hedgerows and treelines within the site in order to strengthen habitat areas and compensate for the removal of these habitats in other areas within the development footprint. In addition, the appellant commits to comply with the requirements of the Heritage Officer with regard to clearfelling and ground works to avoid the main breeding season.

b. Habitats Directive Screening Report:
The submitted AA Screening Report submitted to the PA described the Golden Plover recorded at Ardglass as over-wintering in the vicinity of the area and notes that this bird is widespread in Ireland during the winter months. It is considered unlikely that the birds recorded in the vicinity of the site commute to Cork Harbour, 9km from the site. It is further submitted that given that there is a low degree of interconnectivity between the Blackwater Callows and Cork Harbour and / or the Ardglass site, it is unlikely that the development will have a significant impact on the populations. Therefore, the findings of the AA Screening Report remain unchanged.

With regard to the impacts on water quality of the Great Island Channel SAC, it is submitted that extensive measures are detailed in the EIS dealing with potential surface water runoff and discharges such as the construction of swales, buffer zones, silt traps and settlement ponds. In addition, an outline Construction and Environmental Management Plan was submitted in response to the FI request response which included a drainage management plan and mitigation measures. It is concluded that it is not likely that there will be any impacts on the SAC, which lies 16.9km from the proposed site.

c. Habitats:
The response to the further information request detailed the extent of the semi-natural habitats to be removed as part of the proposed development. No natural habitats will be impacted. A total of approximately 570m of semi-natural habitats, or hedgerows and treelines are earmarked for removal to accommodate the development.

d. Bats:

Two bat surveys were carried out as part of the EIS in the summer of 2012 with two further surveys carried out in response to the further information request, in Autumn 2013 and Spring 2014. These surveys and findings were presented to the PA with mitigation measures detailed. With regard to the location of a small roost for Brown Long-Eared Bats in the vicinity of T2, mitigation measures include the monitoring of the roost prior to commencement of development to determine if the roost is still in use. If it is not a breeding roost, it is proposed to exclude and relocate the roost to a purpose built structure. If it is a breeding roost, the operations of T2 will be restricted during the active bat season.

In support of this appeal, it is now proposed to relocate the turbine, T2 to a location greater than 150m from the roost. Alternative location is presented on Figure 3.1 of this appeal submission.

8.2.4 <u>Reason 2:</u>

Refusal reason 2 relates to the adverse impacts on residential amenities, noting the number of residential properties in the vicinity of the site, notably in terms of visual intrusion and noise. The grounds of appeal are summarised as follows:

a: Shadow Flicker:

Results from model predict that there is potential for some shadow flicker to impact at some dwellings. Mitigation measures will ensure that shadow flicker remains below the recommended guideline limits. It is noted that the PA did not raise this issue as a concern.

b. Visual Amenity:

MosArt has prepared a response to the landscape and visual aspect of the reason for refusal and a number of photomontages have been presented in support of the proposed development. The submission notes that the PA considers that the proposed development will adversely impact on the existing residential amenity of a number of houses due to visual intrusion, it is considered that the level of impact on the landscape is not considered significant in EIA terms.

c. Noise:

A noise report has been submitted to address this issue. The submission seeks to deal with the issues raised in the Cork County Council Environmental Report, dated 19/06/2014, which contributed to the reason for refusal in terms of noise. The submission, appendix B in the appeal submission, deals with each issue raised in said report. The report provides an updated baseline noise monitoring and details the locations of the monitoring equipment, the instruments and procedures used. The document further provides an analysis of the results with an updated assessment of the predicted results.

The report submits that the conclusions presented in the original EIS have been confirmed in the updated assessment. In the limited instances where an exceedence is noted, it has been demonstrated through the consideration of wind directionality and the application of a curtailment programme the relevant noise criteria curves can be complied with in all instances. It is finally submitted that it is likely that the requirement for any curtailment strategy will be removed from the site.

This noise report provides a number of appendices as follows:

- Appendix A: Calibration Certificate
- Appendix B: IoA Article on Windscreens
- Appendix C: Directional Noise Contours
- Appendix D: Calibration Certificates (2014 Survey)
- Appendix E: Site Survey Log Sheets (2014 Survey)
- Appendix F: Directional Noise Predictions V Criteria Curves
- Appendix G: Siemens Technical Report
- Appendix H: Nordex Technical Report

9.0 OBSERVERS

There are 12 no observers noted in relation to this first party appeal as follows:

1. Ardglass Wind Turbine Action Awareness Group
2. Cork Renewable Energy Group
3. Castlelyons Development
4. Seamus & Breda Sexton
5. Don Sheehan

6. Dr. Sharon McKenna & Malachy Ward
7. Andrew Ennis & Susan Liddy
8. Sharon Guiry & Others
9. James & Anne Cagney
10. Christy O'Mahony
11. Ricky Galvin
12. Margaret Galvin

Two further observations were received but considered invalid.

The issues raised in the above observations are similar to those initial objections made to Cork County Council and are summarised as follows:

Ardglass Wind Turbine Action Awareness Group:
The submission presents observations under a number of headings and the main points are summarised as follows:

- Site selection has not been robustly justified and the consideration of alternative sites is inadequate in that the sole justification for the proposed site appears to be the securing of a grid connection.
- Visual impact assessment has a number of gaps in terms of the applied methodology which have the effect of distorting the degree of impact. A number of important view receptors have not received appropriate attention in this regard including scenic route no. 44, the National Primary Route and ACAs.
- The issue of noise has not been addressed appropriately and is noted as a reason for refusal by Cork County Council. The new noise data submitted by the first party as part of the appeal has been independently assessed and it is contended that the appellants assessment does not provide an appropriate description of the likely significant effects of the proposed project on the environment due to noise, nor does it address the requirements of the DoECLG guidelines in terms of ambient noise levels. It is considered that the site fails to meet the specified tests in the 2006 Guidelines by a large margin.
- It is submitted that issues relating to hydrology, hydrogeology and water quality have not been adequately addressed.
- Issues are raised regarding the ecology assessment presented in support of the proposed development and it is noted that the Council

has concerns in this regard. It is submitted that it is not possible for any competent authority to complete EIA and Screening for AA and the recent High Court Ruling in relation to Gaeltech Energy Developments Ltd., is cited.

- Cumulative impacts associated with other developments in the vicinity have not been accurately considered by the applicant, and reference is made to the permitted Midleton Distilleries development in the area.

There are a number of enclosures with this observation including:

- Appendix A: Site selection mapping
- Appendix B: Landscape & Visual Assessment
- Appendix C: Noise Assessment
- Appendix D: Ecology Assessment

Cork Renewable Energy Group:

The submission presents observations under a number of headings and the main points are summarised as follows:

- Environmental impacts
- Health & wellbeing
- Noise
- Private ownership v community development.
- Health & safety
- Economic justification
- Public Service Obligation
- Lack of current planning guidelines
- Tourism
- Flora & Fauna
- Alternative renewables are not being catered for in the County Plan
- Energy policy
- Aarhus Convention / Public Consultation
- Links to the grid and details of proposed connections
- Finance
- Planning policy
- Cumulative impact with the Irish Distillers development
- Impact on house prices
- Non-compliance with CDP policy

There are a number of enclosures with this observation including:

- References
- Rural Environment Protection Scheme 3
- Extracts from the Cork County Development Plan, 2009
- Cork Renewable Energy Groups response to the Green Paper on Energy Policy in Ireland, undated
- BW Energy, Evaluation of Grid Link Stage 1 report

Castlelyons Development:

Castlelyons Development is a voluntary Community group which formed in 2003 to discuss planning issues in the area. The observation includes two submissions made to Cork County Council during their assessment of the proposed development and the issues raised relate to the following topics:

- Impact on community and lack of consultation
- Noise and shadow flicker impacts
- Proximity to the gas line
- Visual impact on scenic area
- Impact on tourism industry
- Impact on existing businesses including horse training facility in the area.
- Impacts on Hogans Wood, a local amenity.

There are a number of enclosures with this observation including:

- Original submissions to Cork County Council

Seamus & Breda Sexton:

The submission presents observations under a number of headings and the main points are summarised as follows:

- Noise
- Visual impact
- Effects on wildlife
- Precedent
- Loss of amenity
- Lack of consultation
- Coiltes use of their lands goes against their stated core-purpose.
- Failure to consider alternatives
- Cumulative impacts

- Effects on local businesses / tourism
- Impact on health
- Lack of economic benefit to the local area
- Shadow flicker
- Lack of adequate guidelines / legislation.

Don Sheehan:

The submission presents observations under a number of headings and the main points are summarised as follows:

- Proximity of development to houses
- Noise
- Shadow flicker
- Visual impact
- Loss of amenity
- Lack of consultation
- Impact on property prices and the impact on property owners

Dr. Sharon McKenna & Malachy Ward:

The significant submission presents observations under a number of headings and the main points are summarised as follows:

- Noise and health
- Lack of consultation
- Safety issues
- Non-compliance with County Development Plan
- Loss of amenity
- Landscape destruction and visual impact
- Impacts on ecology
- Cumulative impacts
- Shadow flicker and inadequate assessment in the submitted EIS
- Lack of need for the development
- Failure to describe constructability, notably with regard to the use of the local road network and the proximity of houses.
- Disregard to the terms of the Aarhus Convention with regard to access to environmental information, public participation and access to justice.

There are a number of enclosures included with this submission including a recent editorial in the British Medical Journal, details of a study on proximity to buried infrastructure and details of wind turbine accidents

<u>Andrew Ennis & Susan Liddy:</u>

The submission presents observations under a number of headings and the main points are summarised as follows:

- No consultation
- Noise
- Shadow flicker
- Environmental impacts
- Visual impact
- Health impact

<u>Sharon Guiry & Others:</u>

The submission presents observations under a number of headings and the main points are summarised as follows:

- Noise
- Shadow flicker, including at night and the impacts on the night sky
- Visual impact raised and photomontages submitted are suboptimal
- Safety issues raised and lack of assessment and consideration given.
- Impacts on hydrology
- Impacts on ecology
- Other issues
    - Inadequate infrastructure to support the development
    - No details regarding dismantling
    - Impact of overdevelopment in rural area
    - Lack of consultation
    - Out of date guidelines

<u>James & Anne Cagney:</u>

The submission presents its objection relating to the proximity of a turbine to their home and the impact of noise and shadow flicker. It is further stated that there is concern for the impact the turbines will have on family health, the local environment and their enjoyment of it.

Christy O'Mahony:

The submission seeks to raise concerns regarding the impact of the proposed windfarm on his farm and livelihood.

Ricky Galvin

The submission presents observations under a number of headings and the main points are summarised as follows:

- Noise
- Shadow flicker
- Ice throw
- Impacts on the river. It is submitted that the mountain site for the development is peat and concerns are raised should there be a mudslide.
- Devaluation of property.
- Impact on farming and agriculture

Margaret Galvin:

This submission notes that planning permission has been granted for a house which is intended to be constructed so that the observer can return to her home farm.

10.0 RESPONSES

10.1 Planning Authority:

The Planning Authority has not responded to this appeal.

10.2 First Party Response to Observers:

The first party has not responded to the third party observations submitted.

11.0 ASSESSMENT:

Having regard to the nature of this appeal, and having undertaken a site visit, as well as considering the information submitted, I suggest that it is appropriate to assess the proposed development under the following headings:

- Compliance with policy
- Landscape/visual impact
- Residential Amenity
- Cultural Heritage Impacts
- Roads & Traffic
- Ecology
- Water Quality & Hydrogeology
- Adequacy of the EIS
- Other Issues

11.2 Compliance with policy

11.2.1 The Cork County Council County Development Plan 2009-2015 is the relevant policy document for the proposed development, and commits the planning authority to take a generally positive approach to wind energy developments. To this end, the Plan identifies two specific areas in relation to the development of wind energy projects, being strategic search areas and strategically unsuitable areas, as set out in Figure 6.3 of the Plan. Under the current County Development Plan, the proposed development site is not located within either of these specific areas. That said, the Board will note that the draft Cork County Development Plan, 2013 has identified that the subject site is located within an area which has been identified as being in an area where wind farm developments are 'Open to Consideration'.

11.2.2 As the subject site is not located within either of the above identified areas, policy objective INF 7-4 of the Cork County Development Plan is relevant. This objective is generally supportive of wind energy businesses and industries sets out policy in relation to wind energy. In assessing potentially suitable locations for projects, potential wind farm developers should focus on the strategic search areas identified in the Plan and generally avoid the identified strategically unsuitable areas. This policy also provides for the consideration of wind projects in areas that are identified as neither strategic search areas nor strategically unsuitable areas on their merits having regard to normal planning criteria. In addition, Objective ENV 2-6 is considered relevant whereby it is a requirement to protect the visual and scenic amenities of County Cork's built and natural environment.

11.2.3 In order to determine compliance with local policies, normal planning issues must be considered, as required in objective INF 7-4 is, and in particular, Part (c) of this policy, which deals with those areas that are identified as neither strategic search areas nor strategically unsuitable areas. It is an objective in such areas to consider new, or the expansion of existing, wind energy projects on their merits having regard to normal planning criteria. Normal planning criteria include a variety of issues which will be dealt with further in this assessment below. Having considered the proposed development and having read all of the information provided in support of the proposed wind farm, including the EIS, together with all of the local authority reports and third party submission, I would advise at this point in my assessment that I have concerns, particularly in relation to the scale and layout of the development together with what I consider to be excessive turbine height in this undulating rural landscape, the proximity to private houses and public roads and having regard to the inadequacy of certain details and assessments of impacts. In addition, I have concerns regarding the visual impacts and potential for operational noise associated with the turbines to affect the general amenities and the enjoyment of dwelling houses and of the surrounding rural environment of this area of Co. Cork.

11.2.4 All of my initial concerns as detailed above aside, I would consider that the development of a wind energy development can be considered as being potentially acceptable in principle on the application site.

11.3 Landscape/Visual Impact

11.3.1 There is no doubt that the visual impact of a wind turbine must be considered significant given the nature of the installation. Whether or not the impact is negative or positive is a matter of opinion. In terms of the potential visual impact in the subject landscape, having regard to the gentle hilly, low lying, open and exposed nature of the landscape, I consider that the turbines will be highly visible, particularly having regard to the proposed number, height and scale of the turbines proposed. That said, significance of the visual impact of the turbines needs to be considered in the context of the surrounding landscape and the existing development it supports. The Board will note from the submitted and attached photographs, that this area of East Cork maintains its open and rural landscape. It is noted that there are no significant developments in the area other than the IDL Maturation Plant which is located approximately 400m from the site. This plant is heavily screened with trees and as such, is not particularly prominent in this landscape, in my opinion.

11.3.2 The EIS presents a landscape and visual impact assessment report, in accordance with the various guidelines, in support of the proposed development. The assessment was carried out using both a desk top study as well as site surveys and includes a number of photomontages. The landscape character of and in the vicinity of the identified study area is indicated, under the Draft Landscape Strategy for Cork, as a Landscape Type 10b: *Fissured Fertile Middleground (Rylane East to Waterford),* with the following values:

Landscape Value:	Medium
Landscape Sensitivity:	High
Landscape Importance:	County

The Type 10b landscape is described as 'an elevated landscape which is fissured by fairly gentle slopes, with reasonably fertile agricultural land comprising a mosaic of small to medium sized fields with broadleaf hedgerows', and a landscape character that 'has characteristics of both flatter fertile farmland areas and the higher marginal hilly farmland'. The EIS notes that the medium value landscapes are defined as 'landscapes with positive characters and with local or county importance', whilst high sensitivity landscapes are considered to be 'vulnerable landscapes with the ability to accommodate limited development pressure. To the north of the site, the landscape is indicated as Landscape Character Type 6c – *Broad Fertile Lowlands.*

11.3.3 It is clear that the proposed development would be highly visible from a very wide and extended area and in particular, if permitted, the development would impart a notable change to landscape character at a very localised level. Overall, the EIS considers that the proposed development will have a moderate impact on the surrounding landscape. In terms of my consideration of the visual impact associated with the proposed development of a wind farm at this location, I am mindful that the applicant has already secured connection to the grid in proximity to the site. While I acknowledge this as a positive, it must be noted that the subject site is located within an area where there is a population of residents, and the visual impact of the proposed turbines will be present on the scenic routes in proximity to the site.

11.3.4 The EIS presents a Zone of Theoretical Visibility as part of the overall visual impact assessment, Figure 9.4, which represents the area over which the proposed development can theoretically be seen. A ZTV map has been prepared as part of the visual assessment. Overall the assessment as presented in the EIS, supplemented by the response to the further information request and appeal documents, considers that the development, in places, will represent an intrusion but not an obstruction in views across the landscape. It is concluded that visual impact associated with the proposed development fall within the range of effects which are typical arising for any commercial scale wind farm. In terms of the visual assessment presented, the EIS notes that the visual impact assessment, and associated photomontages, is based on a turbine with a maximum height of 131m. 17 no photomontages are provided as part of the EIS, with a further 13 provided in response to the FI request, and a written description is provided in relation to each. The identified locations are indicated as being within 20km of the subject site.

11.3.5 The EIS, considers the cumulative impact associated with the existing Middleton Distillery, and the associated permitted warehousing associated with same which is in the vicinity of the wind farm site. The applicant concludes that the proposed development will not result in a cumulative impact with the Midleton Distillery Maturation site, on the basis that the visual impact of the combined development is the same as the impact of the proposed wind farm on its own and there is not significant cumulative impact. It is further acknowledged that the development will contribute to a sense of increased intensity of built development. It is suggested that there is little potential for significant cumulative visual impacts to occur viewing both developments in combination. I also note the comments of the PA with regard to the quality of the information provided which does not accurately account for the additional features of windfarm developments including access roads, and the removal of tracts of existing conifer plantation. It is clear that the proposed development of a wind farm in any landscape will have a visual impact, however, I would concur with the concerns of the Planning Authority in terms of the current proposal.

11.3.6 There are a number of residential properties in the vicinity of the subject site. Having regard to the topography of the area, which might reasonably be considered flat and hilly farmland in terms of the 2006 Wind Energy Guidelines, where guidance is provided. In this regard, it is stated "that the essential key here is one of rational order and simplicity, as well as respect for scale and human activities." As such, due regard must be given to houses and farmsteads. The EIS, in my opinion, fails to really consider this potential of the visual impact to seriously affect the residential amenities of existing properties close to the site as required by the guidelines. I refer the Board to the EIS relating to the Human Environment which makes very little reference to the visual impacts associated with the development. That said, the visual aids provided facilitate some assessment of the visual impacts on the houses in the vicinity.

11.3.7 Further to the above, the guidelines, with regard to the height of the turbines, require "that turbines should relate in terms of scale to landscape elements and will therefore tend not to be tall. An exception can be considered on a high ridge or hilltop of relatively large scale." Having regard to the information provided together with the context of the subject site, I have serious reservations regarding the proposed scale of the turbines, which will rise to 156.5m in height. In terms of compliance with the guidelines, I would question whether adequate justification has been presented to consider an exception in this instance. The actual capacity of this gentle landscape to accommodate the proposed development of its scale is a concern, and it is clear, even from the information provided, that the development, if permitted will be highly visible over a large area, including adjacent counties. In the context of the wider East Cork area, I have a real concern that the introduction of such a significant industrial installation will dramatically alter the receiving wider landscape. Certainly at a more local level, the impact of the proposed development on the visual amenities of the area will be significant and negative in my opinion, and a grant of planning permission would set an undesirable precedent for similar type developments in the wider East Cork area.

11.3.8 Having undertaken a site inspection, I am of the opinion that there are a number of houses which have the potential to experience high adverse impacts associated with the proposed development. While I acknowledge the submission and conclusions of the first party, I would not agree that proposed development represents an acceptable level of landscape and visual impact across the study area. I concur with the concerns of the local residents who raise concerns in relation to the visual impacts associated with the wind farm. While in principle, I would not generally have an issue with the provision of the larger turbines as currently proposed, a grant of permission for same in this instance would significantly impact upon the existing visual and residential amenities of residents in the area, contrary to the proper planning and development of the area. The maximisation of energy output together with the existence of a connection offer, while important, should not be facilitated to the detriment of local residents or the protection of the landscape.

11.3.9 In terms of mitigation, the EIS refers only to design features of the turbines, including their colour, height, blade rotation and onsite landscaping of roads and structures associated with the proposed substation. In my opinion, and while these are appropriate mitigation measures associated with the overall visual impact of the proposed development, they fail to address the potential for the significant visual impact of the turbines at local residential properties, warranting real and genuine concern.

11.4 Residential Amenity

11.4.1 Noise

A: The general area of Killaveenoge West, Derreenaspeeg, Killaveenoge East, Curranashingane and Garranes, Drinagh and the adjacent townlands, can be accurately described as quiet and although rural, is well populated in the towns and villages of Ballincurrig 3km to the south west, Dungourney, 5km to the south east, Rathcormac, 7.5km to the north west and Tallow, 13km to the north, as well as other individual houses along the public roads. There is little noise generating activity in the vicinity and the main noise source is animal with some minimal traffic. On the dates of my inspection, I spent a lot of time walking the site and its environs in order to ascertain the existing noise levels associated with existing developments, including the Middleton Distillery which is located in close proximity to the site. The Board will note the submission of third parties supporting the Distillery and its proposed expansion. The Board will also note that the Planning Authority refused planning permission for the proposed development on the grounds that it was not satisfied that the proposed development would not unduly affect the amenities and the enjoyment of dwelling houses by virtue of excessive and continuous operational noise. It is also noted that the PA considered that the level of information provided in the EIS was limited.

B The provision of a wind turbine generates two types of noise, 1. the sound of the generator and 2. the 'swoosh' as the blades rotate through the air. The guidelines for wind energy provides information relating to the maximum permissible noise levels and the noise assessment submitted as part of the EIS identified 35 noise sensitive receptors within 1km of the site. The EIS concludes that the proposed development would meet noise criteria for residential properties in the area save for 3 identified houses, H44, H45 and H46. The Board will note that in response to the further information request from the PA, the first party has acknowledged a further 36 houses being located between 1-1.5km of the turbines, and a further 37 between 1.5-2km. As part of the appeal submission, the First Party has submitted that it has been proven that the development can be designed in order to comply with the guidance in the Wind Energy Development Guidelines, 2006 and that it is likely that the requirements for any curtailment strategy will be removed from the site.

C. Mitigation is discussed in the EIS, at section 10.5, where it is submitted that there are 3no locations highlighted where the proposed development exceeds the adopted day or night time noise criteria at wind speeds of 6-7m/s, and generally relate to turbines 7 and 11. All three properties are landowners who have given consent for the development and that they are aware of the potential minor inconveniences arising. Therefore, no mitigation measures are required. In terms of the appeal documentation, the Board will note that the number of properties where there will be exceedances in the worst case scenario has increased from 3 to 6. To this end, an updated potential curtailment matrix has been prepared, page 27 of Appendix B of the appeal documentation.

D: As part of the appeal, further noise measurements were undertaken in the vicinity of the site at 4 locations. As part of the submission, the first party has presented a worst case envelope based on the lowest average levels at the various wind speeds which range from 24.1dB $L_{A90,T,}$ at 4m/s wind speeds to 34.6dB $L_{A90,T,}$ at 12m/s wind speed during the day time and 19.7dB $L_{A90,T,}$ at 4m/s to 32.6dB $L_{A90,T,}$ at 12m/s at night time. The information submitted in support of the appeal indicates that the updated background noise survey was undertaken over a two week period in July, 2014, and the document provides details of the equipment used to take the measurements as well as locations of equipment and results of the surveys undertaken. I accept the methods and software used in the calculation of noise in the vicinity of the site as part of this assessment. I note the results and conclusions of the assessment, which suggests that the development if permitted will result in a change in noise level across the majority of the development will be a maximum of 1.5dB(A), at a wind speed of 7m/s.

E: The Wind Energy Guidelines, 2006, with regards to the setting of limits for noise emissions provides that:
"in general, a lower fixed limit of 45dB(A) or a maximum increase of 5dB(A) above background noise at nearby noise sensitive locations is considered appropriate to provide protection to wind energy development neighbours............Instead, in low noise environments where background noise is less than 30dB(A), it is recommended that the daytime level of the LA90 10 min of the wind energy noise be limited to an absolute level with the range of 35 to 40dB(A).

As such, and given fact that the Planning Authority has considered the level of information provided in the EIS is limited warranting a refusal of planning permission, it may be considered that there is a concern arising in this regard. Notwithstanding all of the information now at the disposal of the Board, I share the same concerns. In particular, the Board will note that the appellant has applied the upper limits for the assessment of this proposed wind farm, and not the +5dB(A) which I would consider to be more appropriate given that the updated baseline noise curves suggest that the existing environment enjoys noise levels in the region of 28.8dB at wind speeds of 7m/s during the day and 25.2dB at night time for the same wind speeds.

F: In terms of the potential for estimated noise levels associated with the proposed development having the potential to represent nuisance for residents in the area, I refer to the guidelines which suggest a *maximum increase of 5dB(A) above background noise at nearby noise sensitive locations is considered appropriate to provide protection to wind energy development neighbours.* At an increase of 5dB(A), the increase in noise levels is perceptible. In terms of the information provided as part of the appeal documents, and just by way of example of my concerns, taking one house, H47, which lies in proximity to the measuring equipment used at location identified NSLA, and at a wind speed of 7m/s, the baseline noise in this area has been recorded at 28.8dB $L_{A90,\ 10min}$ during the day and 25.2dB $L_{A90,\ 10min}$ at night. The predicted noise associated with the development is indicated at 40.7dB $L_{A90,\ 10min}$ which represents a potential increase in noise at this location of between +11.9 – 15.5 dB $L_{A90,\ 10min}$. To apply the higher noise levels in this environment, while ensuring that the wind farm might comply in the main with the requirements, would have a significant and negative impact on the existing residential amenities of the area.

11.4.2 Shadow Flicker

A: In terms of shadow flicker, the applicant submitted an assessment which was carried out using the ReSoft Windfarm software programme. The phenomenon of shadow flicker requires that a number of specific criteria occur simultaneously, including the sun is shining and is at a low angle (after dawn and before sunset), and the turbine is directly between the sun and the affected property, and there is enough wind energy to ensure that the turbine blades are moving. It is contended by the applicant that the likelihood of all criteria occurring simultaneously is minimal.

B: The Wind Energy Development Guidelines, 2006 note that shadow flicker is not usually critical, but in *circumstances where the calculations indicate that occupied dwelling houses would be significantly affected, a condition requiring the non-operation of turbines at times when predicted shadow flicker might adversely impact on any inhabited dwelling within 500m of a turbine may be appropriate.* The guidelines also specify requirements in relation to quantifying the effect and where appropriate, measures to be taken to prevent or ameliorate the potential effect.

C: While the Guidelines recommend that shadow flicker should not exceed 30 hours per year or 30 minutes per day at any dwelling within 500m, the EIS submits that there are no dwellings located within 500m of a turbine. The assessment carried out for all houses located within 10 rotor diameters, and within 1,130m of the proposed development. 45 buildings houses in total have been identified as potentially being affected by shadow flicker using this criteria. The EIS suggests that 27 houses could be subject to shadow flicker in excess of 30 minutes per day with 22 houses being subject to shadow flicker in excess of 30 hours per year. These figures assume 100% sunshine and when the regional sunshine data is taken into account, and assumes 40% sunshine, these numbers are reduced to 3 houses being affected per year, H44, H45 and H46, all of which belong to participating landowners.

D: Mitigation is not explicitly proposed and the EIS suggests that where an issue arises, mitigation requirements will be assessed by way of a procedure of evaluation of the existing screening, window orientation and the periods of shadow flicker actually occurring and will be carried out in consultation with the relevant landowner. The EIS submits the following possible options, landscape screening, the installation of blinds or curtains or turbine control. The wind turbine control system could include the shutting down of particular turbines at specific times of specific days of the year. I accept the premise for the above conclusions, and I consider that the proposed development is acceptable in terms of the shadow flicker potential. However, and should the Board be minded to grant permission in this instance, a condition should be attached requiring the non-operation of the turbines at times when the predicted shadow flicker might occur, adversely affecting the adjacent houses.

11.4.3 Other Issues

While the issue of visual impact has been discussed above, I would wish to state at this point that, notwithstanding the potential impact of the proposed development on the general visual impact of the area, it is my opinion that a number of the proposed turbines, if permitted, have the potential to have a significant visual impact on a number of houses in the vicinity of the site. It is generally considered by the first party, that while a certain level of visual intrusion at a small number of properties will occur, the benefits from the project will further reduce the national reliance on fossil fuels. In addition, it is submitted that the wind farm should be allowed to maximise output which would be facilitated by the larger turbines. While it is appropriate and relevant to give weight to this issue, I consider that the proposed provision of 11 no. turbines in this area, rising to a height of 156.5m, will significantly and adversely impact upon the existing residential amenities of a large number of houses and properties in this area.

11.5 Cultural Heritage Impacts

11.5.1 The EIS notes that there are 10no. recorded archaeological sites within the identified study area, all of which are recorded monuments, with a further 80 recorded monuments identified within a 2km radius of the site. Of the 90 monuments identified, 37 no longer have above ground expression while a further 10 were no longer accessible or visible due to forestry. No new sites were identified.

11.5.2 In terms of the proposed development, the EIS acknowledges that archaeological remains may appear due to earth movements associated with the development. It is submitted that there will be potential impacts associated with the construction of T7 given the proximity of two fulachta fia, one being located within the identified boundary area associated with same. The EIS submits that all construction works will be monitored under archaeological licence, and in consultation with the relevant authorities. In terms of a recommendation in this regard, I consider it reasonable that a condition requiring monitoring and protection of archaeology in the vicinity be attached to any grant of planning permission.

11.5.3 In terms of Architectural and Cultural Heritage, the EIS notes that there are no protected structures within the study area, and two within 2km of the site, both of which are thatched houses, refs RPS 80 and 773. One house is included in the NIAH, ref no. 20905406. This is a 19^{th} C farm house located at Monalyre Cross Roads and at 670m from T3. There are a further 6 NIAH structures located in the wider area. A number of Cultural heritage features were identified in this assessment including a limekiln, four bridges, enclosed field and field boundaries and small 19^{th}C settlements / farmsteads.

11.5.4 The EIS provides a number of mitigation measures but ultimately concludes that there will be no direct impacts on the recorded monuments that have been identified. It is noted that while some turbines may be visible from archaeological monuments within the 2km study area, the overall impact is considered to be slight given their distances from same. In terms of impacts on architectural and cultural heritage, the EIS submits that as the nearest NIAH structure is located over 670m from the nearest turbine, together with the presence of coniferous forestry, there are no impacts on the house anticipated. The two farmsteads identified during the field work associated with this assessment noted that one stone building is located within 45-50m of T2. This building is to be preserved in situ and there will be impacts associated with the proposed development in terms of visual impact. The EIS submits that the landscape in this area has already been altered through the afforestation of the area. Residual impacts associated with the proposed development are considered to be low to medium subject to the implementation of the recommended mitigation measures.

11.5.5 The Board will note the comments of the Cork County Archaeologist with regard to the proposed development, and I would agree, that subject to the implementation of mitigation measures and appropriate conditions, the proposed development can be considered acceptable.

11.6 Roads & Traffic

11.6.1 Given the nature of the proposed development, it is clear that there will be disruption to existing traffic and road users in the construction phase of the development, and that the local road network will experience some additional volume. I would note that the construction phase is a temporary phase, and any disruption will not continue once the development is complete. Roads & Traffic & is dealt with under Chapter 11 of the EIS, which deals with Human Environment, where Section 11.1.7 describes roads and transport in the existing environment. Section 11.2.7 examines the potential impact of the development on the local road network. The assessment considers the impact of construction traffic in terms of the delivery of the turbines and the construction phase.

11.6.2 The Board will note that it has been determined by the applicant that given the estimated increase of 3.9% over current traffic on the R626 due to the construction phase of the development, there is no requirement for a traffic assessment as part of an environmental impact assessment. Based on the

NRA document Traffic & Transport Assessment Guidelines, it was considered that the proposed development does not require a Transport Assessment. It is estimated that during the construction phase of the development, approximately 49 traffic movements will be generated from HGVs and 40 movements by employees, amounting to a maximum of 89 movements daily in total. The construction phase is estimated last for 12 months.

11.6.3 In terms of mitigation, a transport management plan will be submitted to Cork County Council for discussion prior to the commencement of construction and which will address general construction traffic, oversized loads and emergency access. It is also noted that the junction at Peafield Crossroads will have to be widened to facilitate the delivery of the turbine components. No details in this regard have been provided and it is unclear from the information provided whether the relevant consents and permission has been secured to carry out said works. I note at page 195 of 246 of the EIS indicates that such permission has been given but no written evidence has been provided. It is further noted that tree canopies and hedges will require to be trimmed along the route which will be undertaken in consultation with Cork County Council.

11.6.4 The EIS identifies the possible route and public roads to be used in order to access the site. The EIS concludes that during the peak construction phase, "there will be a small increase in local traffic" but "it will not create any traffic congestion". Once constructed, the impact of traffic movements associated with the wind farm will be negligible. The impact of the development on the road network will be felt during the construction phase and then, only for a limited number of days.

11.6.5 In relation to the roads issues, the Board will note that the PA has raised no objections to the proposed development. I have real concerns that a full assessment of the proposed development, in particular the construction phase of the development, has not been undertaken and while it is implied that the level of additional traffic movements is estimated to amount to 3.9% of the current levels, given the nature of the proposed development, together with the quiet and very rural nature of the surrounding area, the impacts will be obvious and immediately felt. That said, and should the

Board be minded to grant planning permission in this instance, I consider that the issue of roads and access for delivery of equipment to the site will require the preparation of a full transportation plan where the schedules shall be agreed with the relevant engineer in the Roads Section of Cork County Council. Prior notification to local residents shall also be a requirement of this agreed schedule. The developer shall also be liable for any road repairs necessary following the completion of the development. As such, I consider that the temporary road and traffic impacts, which I consider will be significant, can be reasonably and appropriately mitigated.

11.7 Ecology:

Impacts on Habitats

11.7.1 There are no designated sites located within the proposed site boundary, although there are a number of habitats present on the site. There are seven designated sites however, within 10km of the proposed development site. The EIS notes that the nearest pNHA is located approximately 6.3km to the south of the study area, while the nearest SAC is located 3.1km to the north, being the Blackwater River (Cork / Waterford), Site Code 002170, so designated for alluvial wet woodlands and Taxas Baccata wood, both of which are priority habitats. The Great Island Chanel SAC, Site Code 001058 and designated for mudflats and sandflats not covered by seawater at low tide and Atlantic salt meadows, and Cork Harbour SPA, Site Code 004030, so designated for a number of species, are located approximately 9km to the south of the site. The EIS notes that screening for Appropriate Assessment was undertaken (appendix D of Volume 3 of EIS). It was determined that a full AA was not required, as the subject site is located downstream of the River Blackwater SAC and at a distance from the Cork Harbour SAC so that no significant impact on designated habitats in either Natura 2000 site is expected to occur. Details of habitat types and their associated values are provided for within the EIS, supplemented through the response to the further information request and the appeal submission.

11.7.2 The primary habitat within the study area is commercial conifer plantation (WD4) amounting to 50%+ of the overall site. This habitat is considered to be artificial and of low local value although it is acknowledged that the forest provides cover for a range of mammal species, and is used regularly by fallow deer. The second most prominent habitat comprises improved agricultural grassland (GA1), which is also generally considered to be of low ecological value save for the network of hedgerows (WL1) which comprises the field boundaries and which are considered to be of local ecological value. In addition there are a number of treelines (WL2) which are located along the existing forestry tracks and public roads. These areas are considered to be of local ecological and conservation value. Five biodiversity areas are identified within or adjacent to the EIA study area with the historical Ballynona Wood located to the south of the site, Peafield Meadow, Portavarrig Wetland, Rathorgan Wetland and Walshtownmore Wetland. These areas are identified as semi-natural habitats and are of local biodiversity value. A site inspection noted that the Rathorgan Wetland has been entirely removed due to construction activities by other parties.

11.7.3 The lands within the specific study area are identified and described in the EIS which uses the classification scheme outline in *A Guide to Habitats in Ireland* (Fossit, 2000), with 5 habitats included. The development will result in the loss of some land areas / habitat, but the EIS notes that none are protected. The EIS states that a desktop review and habitat survey was undertaken, to include specific bat and bird surveys. Screening for Appropriate Assessment was undertaken and initially it was determined that a full AA was not required, as the subject site is located at a distance from any designated sites. The findings of the assessment indicate that the proposal will not impact directly on qualifying habitats for designated sites in the vicinity of the subject site.

11.7.4 I have considered all of the information provided, including all reports and assessments, pertaining to the proposed development. I acknowledge the concerns of the County Council's Ecologist with regard to possibility of impact on on-site habitats which have been identified and are noted to support bat species in particular, and I also have had regard to the submissions of the first party and associated experts. In terms of the response to the FI request, I note the details provided in sections 10.3 which relates to the areas of habitat to be removed to accommodate the proposed development and in particular the potential impacts associated with the loss and the bats which use the site. I will discuss this issue further below. I note the concerns arising that there are gaps in the information provided to facilitate the Board in making a decision in relation to the proposed development and notable, in terms of the potential for impact on Natura 2000 sites in the vicinity of the site. It is to be noted that all the proposed turbines are located at least 50m from any streams or watercourses, except for T5 which is located within 45m of a small water body, and no construction (including borrow pits, sub-station and mast) will take place within this buffer zone apart from the proposed water crossings and associated road construction.

11.7.5 A Habitat Map, showing the development layout, was also submitted as part of the EIS, Figure 6.4, supplemented by Figure 10.6 of the response to the FI request. The First Party, through submissions, seeks to provide an evaluation of each habitat type recorded on the site and details of the areas of habitats that will be directly impacted upon due to the development. The information provided suggests that the entire footprint of the development will cover 6.25ha, of a total development site area of 83.42ha, and a study area of 957ha, amounting to 7.49% of the total subject development site area. All of the turbines are proposed to be constructed within the conifer plantation and on improved agricultural grasslands. While I acknowledge the submissions in support of the proposed development, I share the concerns of the Planning Authority, and the Ecologist, in terms of the details relating to the removal of hedge rows and tree lines to accommodate the proposed development. I would concur that clear information and maps should be provided to clearly depict the exact areas of hedgerows and trees to be removed in order to consider the impacts of the development on these habitats, and the species they support.

11.7.6 In terms of mitigation, I acknowledge that the design and layout of the proposed wind farm sought to avoid sensitive habitats identified on the site many of which are of high local importance. While the development will have localised impacts in respect of biodiversity and habitat loss, given the nature of the primary habitats to be affected, I am satisfied that the loss is not so significant as to warrant concern. The environmental benefits derived from the application of a renewable energy source might reasonably be considered to balance any negative impacts on a site, particular having regard to the prevalence of commercial forestry and degraded habitats in the area. In terms of the detail submitted however, I consider that the potential impact on the hedgerow and semi-natural habitats on the site is significant and that the level of information provided is inadequate to fully consider the potential for significant impacts on the species they support.

Impacts on Flora & Fauna

11.7.7 The EIS presents details of a mammal survey and a bat survey where the following species were recorded within study area, fox, rabbit, Irish Hare, Fallow Deer, American Mink, Irish Stoat and red squirrel. The mammal survey also notes that it is possible that Otter may be present due to the proximity of the Dungourney River, but as the scale of the river is small in proximity to the site, it is unlikely to support breeding otters. The EIS does not note rare or threatened mammal species confirmed on the site. In terms of bats, the EIS records the Common Pipistrelle and the Soprano Pipistelle, both of which are listed on the Annex IV of the EU Habitats Directive, were found to be present on the site. Following the submission of the response to the further information request, the Leisler Bat and the Brown Long-Eared bat were noted to be present on the site with a roost identified in proximity to proposed T2. The Board will note that there is no real acknowledgement or discussion in the body of the FI response in this regard, although there is a Bat Survey report provided at appendix M. Mitigation measures are presented as part of this survey and assessment.

11.7.8 <u>Birds:</u> The Birds Survey was carried out over the summer and winter periods, using a combination of on-site surveys and counts, as well as a desktop study. The Board will note that additional surveys were carried out in order to fully respond to the further information request issued by Cork County Council. The County Councils Ecologist advised that concern remained even after the additional surveys and assessment and submits that due to the lack of appropriate information, a full and considered EIA and AA could not be undertaken with regard to the proposed development.

11.7.9 The EIS concluded that of the Bird Watch Ireland red and amber listed species recorded on the site, or indeed the Annex I species, it is unlikely that any breed within or close by the subject site. The EIS concludes that the potential for the wind farm to impact on any bid species is low. The Planning Authority does not appear to accept this view and I refer the Board to the Ecologist Report dated 19/06/201 in this regard. As such, I am inclined to consider that based on the information available in the EIS, it is likely that in principle the development, if permitted, will not so significantly impact upon protected birds species in the area. However, I also acknowledge the expert opinion that additional information would be required to be conclusive in this regard.

11.7.10 Bats: Further to my comments above, I consider that the proposed development has the potential to impact upon the bat population of the area. This is due to the proximity of tree lines and hedgerows where the bat population may congregate, together with the findings of the site survey undertaken. While I would consider that in principle, the nature of the existing coniferous plantation is not generally preferred by bats, I have serious concerns that the EIS and indeed, the response to the further information request, failed to acknowledge the presence of the bat roost in the body of the report. I also note that the Bat survey which was carried out at this time, also noted that the site has potential to support two further rare bat species, Nathusius pipistrelle and Brandt's Bat, with the bat assessor certain that Natterer's Bat and the Whiskered Bat also occur on the site. I also concur with the findings of the Cork Co. Co. Ecologist that mitigation measures identified were not carried into the body of the response to the further information.

11.7.11 As part of the overall assessment, the Board will note that a Bat Survey & Assessment prepared, concluded that the risk to bats have to be acknowledged and that it is possible that some bat mortality may occur due to the proposed development. As such, mitigation measures are recommended to reduce the likelihood of such fatalities. These mitigation measures are detailed in the Bat Survey & Assessment and include acknowledging the presence of the roost in proximity to T2, buffer zones, retention of trees / removal of trees, lighting restrictions and bridges. Overall the report concludes that the favourable conservation status of the Leisler Bat should not be affected and that the development could provide an opportunity to gain baseline data on bat / turbine interaction. The board will note that the appeal documents provide a proposal for the relocation of T2, to a location greater than 150m from the roost. The author of the Bat Assessment report has advised that the relocation of T2 and the curtailment of its use during night hours within the peak period of bat activity during June and July it is now considered that the potential risk to the onsite bat colony will be substantially reduced or negated. Should the Board be minded to grant planning permission in this instance, it is recommended that these mitigation measures are clearly conditioned.

11.7.12 Badgers: No badgers were recorded during the mammal survey which was undertaken at the site although it is acknowledged that it is likely that this species forages in the area. The EIS notes that no setts were recorded during the site survey but notes that areas of the site were inaccessible so it is possible that badger setts are present in those area. Having regard to the information provided, I consider that it is likely that badgers occur at the site, most likely in the grassland habitats in the lower lying areas of the site. Badgers are a protected species under the Wildlife Acts 1976 and 2000. It is an offence to intentionally kill or injure a protected species or to willfully interfere with or destroy the breeding site or resting place of a protected wild animal. Should the Board be minded to grant planning permission in this instance, I consider it appropriate that appropriate conditions be included in the interests of protecting the badger in this area.

11.7.13 Others: The EIS identifies other mammals which are offered protection under the Wildlife Acts including Irish hare and the fox as being confirmed on the site. In addition, rabbit, red squirrel, stoat, fallow deer and American mink are also noted as being present on the site due to the presence of suitable habitat. The red squirrel is likely to be affected by clear felling of trees if these trees are being used by the animals. Any construction impacts on other mammals identified are, likely to be temporary in duration and I am otherwise satisfied that the proposed development would not undermine the habitat of protected species or other fauna in a substantive way, and that the species can adapt to changes where appropriate mitigation is put in place.

11.7.14 Mitigation measures are presented in the EIS with regard to any damage caused to habitats by the proposed development. The appeal submission, in relation to ecology, concludes that overall, the issues raised have been fully addressed. It is submitted that the site is not considered to sustain significant populations of birds of conservation concern and that the development is not considered to pose a risk to birds. In terms of habitats, it is submitted that mitigation measures have been presented to address the loss of 570m of hedgerows and tree lines which will result in the provision of a benefit to the biodiversity of the area post construction. T2 will be relocated in order to avoid the bat roost and restrictions on the timing of operations of this turbine will be applied to minimize the impact on the bat roost. I remain concerned that matters surrounding ecology contain a certain about of gaps in the information provided and as such, I consider it appropriate to err on the side of caution in this instance. I am not satisfied that it can be clearly determined that the development, if permitted will not have a significant impact on habitats, flora and fauna.

11.8 Water Quality & Hydrogeology

11.8.1 In terms of water quality, the EIS provides information regarding ground and surface water features and characteristics on and in the vicinity of the site. The EIS considers that the risk to ground waters is generally negligible and that surface water is the main sensitive receptor. The potential impacts associated with the proposed development in terms of ground water are considered in the document and the risk of pollution from hydrocarbon spills, leakages at borrow pits and from the waste water treatment system are identified as the primary risks. In terms of surface waters, the EIS acknowledges the sensitivity and quality of waters downstream of the site, including the Cork Harbour SPA and the Great Island Channel SAC. Potential risks are identified as surface runoff and the EIS provides an assessment of changes in site runoff volumes. It is concluded that the increase from the site post development will be negligible even before mitigation measures are put in place, providing no risk of flooding down gradient of the site.

11.8.2 The potential impacts on the hydrological and hydrogeological environments during the operational phase are also discussed in the EIS. In order to facilitate the proposed development, new roads, tracks, hard stands and turbine bases will be required which has the potential to affect surface water flow. The EIS concludes that subject to the implementation of mitigation measures, it is considered that the risks to geology and hydrogeology are considered to be negligible.

11.8.3 The development will include the felling of 36.8ha of commercial forestry and as such best practice Forestry Service Guidelines are relevant. Mitigation measures required in these guidelines should be applied to reduce the risk of entrainment of suspended solids and nutrient release in surface watercourses. Finally, the EIS discusses the potential for cumulative impacts associated with the proposed development as well as residual impacts and monitoring. Should the Board be minded to grant planning permission in this instance, I am satisfied that issues relating to water quality protection can be appropriately dealt with by way of condition.

11.9 Adequacy of the EIS

The nature of the development the subject of this planning application requires an EIS to be prepared under the EIA Directive. The EIS has been prepared in support of the planning application and has been advertised in the public notices submitted with the application to Cork County Council. The content of the EIS is summarised above in section 3 of this report, while section 12 below provides an assessment of impacts of the development on the receiving environment.

While I consider that the EIS originally submitted with this application generally presents the potential issues arising from the development and might reasonably be considered as being in accordance with the requirements of Schedule 6 of the Planning & Development Regulations, 2001, I have some reservations as to the lack of information provided with regard to the assessment of the issues and how the conclusions were reached.

The Board will note the extensive further information request that issued from Cork County Council which was responded to on 22nd April, 2014. In addition, I would refer the Board to the comments of Cork County Councils Ecologist who has considered the proposed development and the information provided in support of same but who, even after the receipt of the further information request response, remains of the opinion that 'insufficient information has been provided to complete EIA and screening for Appropriate Assessment.' The Appeal submission provides for additional information which is to be considered.

11.10 Other Issues

11.10.1 Interference with Telecommunications

It is a common submission that wind energy development may have a negative impact on TV reception in the area of such developments. The Frequency Planning and Coverage Department of RTE Transmission Network Ltd requires proposed wind farm applicants to sign a protocol document to ensure remedial measures are implemented to rectify any interference should it arise. It is normal for RTE to monitor such potential interferences and if detected, will investigate and report where necessary to the wind farm operator if it determines that the interference is attributable in whole or in part to the wind farm development. I am satisfied that this is acceptable.

11.10.2 Access to National Grid

The ultimate decision with regard to connection lies with the ESB, who will not usually consider a grid connection offer until permission has been granted for a wind farm. Connections to the grid are usually made through a 20kV or 38kV line. In this instance, the Board will note that the applicant already has secured a Gate 3 grid connection offer to connect the wind farm to the national electricity grid at the existing 110ikV Midleton substation at Carrigogna via an underground cable. The first party has submitted that the precise route of the underground grid connection is not confirmed at this point. The location of the sub-station is not clearly identified in the submitted documentation but the Board is advised that it is located approximately 8km to the south, south west of the site. I'm satisfied that this is acceptable.

11.10.3 Impact on Recreation, Amenity & Tourism

It is a requirement of policy INF 7-4 of the Cork County Development Plan, to have regard to a number of criteria in the consideration of a proposed wind energy project including those which might reasonably be considered as important in relation to the tourism draw of a particular location. Such criteria include:

- *The sensitivity of the landscape and of adjoining landscapes to wind energy projects;*
- *The scale, size and layout of the project, any cumulative effects due to other projects, and the degree to which impacts are highly visible over vast areas;*
- *The visual impact of the project on protected views and prospects, and designated scenic landscapes as well as local visual impacts;*
- *The impact of the project on nature conservation, archaeology and historic structures;*

The EIS notes that the main tourist attractions in the vicinity of the site are an open farm near Dungourney, 4.5km south west of the site and the Jameson Experience in Midleton, approximately 9km to the south of the site. While no key identified tourist attractions pertaining to the site have been identified, the EIS notes that Coilte has an open forest policy which means that their sites are generally accessible for people on foot. The EIS concludes that it is not considered that the proposed development would have an adverse impact on recreation and amenity, including tourism.

While there is no 'obvious' tourist attraction in this area, it is in fact, the area, its local towns and villages, and the landscape that is the draw for many tourists in this area of Cork. It is also to be noted that the issue of wind turbines and their attractiveness is a wholly subjective issue. The Board will also note the distinct lack of turbines in this area of Co. Cork. The applicant seeks to suggest that due to the presence of the distillation plant in the area, together with the maturation warehousing that is currently under construction, there is change to the character of this landscape, which "has been that of low intensity upland rural landscape with some remoteness and tranquillity". It is suggested this is "changing slightly towards a landscape of rural industry" and that "the wind farm will contribute to this change but is more typical of emerging trends in upland rural landscapes than a distillery is." I would not agree with this statement and I refer to my consideration of the visual impacts associated with the development as proposed above in section 11.3 of this report.

12.0 ENVIRONMENTAL IMPACT ASSESSMENT:

12.1 In accordance with the requirements of Article 3 of the European Directive, Directive 85/337/EEC, as amended by Council Directive 97/11/EC of 3rd March 1997, by Directive 2003/35/EC of the European Parliament and of the Council of 26th May 2003, and Section 171A of the Planning & Development Act 2000-2010, the environmental impact statement submitted by the applicant is required to be assessed by An Bord Pleanala, as the competent authority. It is a requirement that the direct and indirect effects of the proposed project are identified, described and assessed in an appropriate manner, in accordance with Articles 4 to 11 of the Environmental Impact Assessment Directive. As indicated above in section 3.0 of this report, the EIS submitted in support of this proposed development is made up of four volumes including a Non-Technical Summary, Main Report, Appendices and Photomontages, where the potential impacts of the proposed development on the environment are detailed.

The Board will note at this point that the information submitted in response to the further information request from the Planning Authority is also considered in my EIA. The following is an assessment of the main impacts identified, and which I consider to be most relevant to the subject site and development and I would advise that I have concerns with regard to a number of issues including noise, visual impact, the water environment and ecology, notably in terms of the information and evidence provided, as well as the conclusions of no significant impacts on the environment contained in the EIS.

12.2 Category 3(i) of schedule 5 of Part 2 of The Planning and Development Regulations 2001, provides that an Environmental Impact Statement shall be prepared in respect of a planning application for the following development:

"Installations for the harnessing of wind power for energy production (wind farms) with more than 5 turbines or having a total output greater than 5 megawatts."

As the application involves a wind farm of 11 turbines with a rated electrical output of approximately 25.3MW, the proposed development is subject to mandatory EIA. Grid connection has been secured for a capacity of 21.6MW.

12.3 The Environmental Impact Statement submitted with the application, dated January 2013 is in 4 volumes as described above and is in the grouped format structure. In general, I consider that the EIS, supplemented by further information response, while providing an appropriate level of detail and scientific evidence with regard to a number of environmental aspects, fails with regard to others. I will discuss these below. I will also have regard to the specialist reports prepared both in support of the proposed development and those from the Planning Authority in this regard.

12.4 I consider that the EIS seeks to compliance with Articles 94 and 111 of the Planning and Development Regulations, 2001, as amended. In this regard, it is notable that the EIS contains the information specified in paragraph 1 of Schedule 6 of the Regulations. The EIS seeks to -

- Describe the proposal, including the site and the development's design and size;
- Describe the measures envisaged to avoid, reduce and, if possible, remedy significant adverse effects;

- Provide the data necessary to identify and assess the main effects the project is likely to have on the environment;
- Outline the main alternatives studied and the main reasons for the choice of site and development, taking into account the effects on the environment.

The EIS, supplemented by the further information response, seeks to provide the relevant information specified in paragraph 2 of Schedule 6 of the Regulations. This includes-

- A description of the physical characteristics of the project and its land use requirements;
- The main characteristics of the wind energy process to be pursued;
- The emissions arising resulting from the operation of the proposed development;
- A description of the aspects of the environment likely to be significantly affected by the proposal;
- A description of the likely significant effects on the environment resulting from the development's existence, the development's use of natural resources, the emission of pollutants and creation of nuisances, and
- A description of the forecasting methods used; and
- Provision of an indication of any difficulties encountered in compiling information.

There is an adequate summary of the EIS in non-technical language, although I would suggest that certain information is lacking in this summary.

12.5 Issues arising with regard to the adequacy of the EIS are detailed in a number of Cork County Council internal engineering reports, notably with regard to noise, the water environment and ecology. I also note the credentials of the consultants who prepared the sections of the EIS in relation to these matters, but I would concur with the Planning Authority that there are a number of concerns arising.

In addition, I note the concerns of the SEP in terms of visual impact and amenity but I accept that the information is provided in order to determine impacts, so in this regard, I consider that the EIS, supplemented with the response to Further Information, is acceptable with regard to the visual impact assessment. I also note the comments of the Senior Planner in terms of EIA Report / NIS, who states that "the EIS is acceptable in relation to the scope of issues addressed having regard to reports on file (Noise, Hydrology / Hydrogeology and Ecological Issues) I conclude that it has not been shown that the proposal would not have a significant negative impact on the Environment. Having regard to the Ecologists / Hydrologists report and Habitats Directive requirements I do not consider that the potential impacts on relevant sites have been screened out and therefore AA screening cannot be completed."

12.6 The EIS considered the main likely significant direct and indirect effects arising from the proposed development. The main likely receptors and effects are presented in the Summary of Interactions of the Main Environmental Effects, Figure 15.1 of EIS as follows:

1.	Ecology	-	**Const. phase** Tree felling Traffic Excavation Noise	**Operational** Noise Visual Energy Output Drainage Traffic Change in land use
2.	Hydrology & Water Quality	-	**Const. phase** Tree felling Traffic Excavation	**Operational** Drainage Traffic Change in land use
3.	Geology & Hydrogeology	-	**Const. phase** Tree felling Traffic Excavation	**Operational** Drainage Geotechnical Change in land use
4.	Landscape	-	**Const. phase** Tree felling Traffic Excavation	**Operational** Visual Change in land use

			Noise	
5.	Human Environment	-	**Const. phase** Tree felling Traffic Excavation Noise	**Operational** Noise Visual Energy Output Drainage Shadow Flicker Traffic Change in land use
6.	Archaeology & Cultural Heritage	-	**Const. phase** Tree felling Excavation	**Operational** Visual Change in land use
7.	Air & Climate	-	**Const. phase** Tree felling Traffic Excavation	**Operational** Energy Output Traffic Change in land use

12.7 Description of the likely significant effects of the proposed development on the environment:

The likely effects arising from the development proceeding are anticipated to include the following-

12.7.1 Ecology:

Habitats: There are no designated sites located within 3km of the proposed site boundary. The Blackwater River (Cork / Waterford) SAC is located 3.1km to the north of the proposed development site. The Great Island Channel SAC and pNHA and Cork Harbour SPA are located 9.1km to the south of the site. These sites are connected to the subject site as tributaries of the Owenacurra and Dungourney Rivers rise in the site and flow south to the Natura 2000 sites. Impacts on water quality in the surface water bodies and rivers, has the potential to impact upon the designated sites, while impacts on the surface water system at the construction stage due to drainage and peat disturbance. No protected plant species, rare or protected species were recorded during the habitat and botanical surveys of the site.

Mitigation measures include: Buffer zones around water courses, detailed drainage arrangements; development footprint to be kept to a minimum including tree felling, general pollution protection, Environmental Management Plan;

Fauna: Impacts on birds, mammals and other fauna which use the site and adjoining watercourses. 6 protected species, under the Irish Wildlife Acts (1976-2012) were identified on the site and 4 species of bat with a Brown Long-eared bat roost was identified. In terms of birds, Annex I species Golden Plover and BWI red listed species Meadow Pipit were recorded within the proposed development site. In addition, there were recorded sightings of Kestrel, Buzzard and Snipe, but it is submitted that there is no indication that these species are breeding at the site and it is unlikely that the site is of importance to such species. Mitigation measures with regard to birds include the carrying out of works outside the breeding season and the planting of additional treesl and hedgerows along existing gaps

12.7.2 Human Environment:

Employment: 20 Short-term jobs at the construction stage, with no clear indication of the number of maintenance jobs during the operational phase.

Visual Impacts: This issue while acknowledged in the EIS is understated in my opinion.

Tourism: Visual and landscape impact distorting the natural tourism product. However, no significant negative impacts because of a generally positive attitude to wind energy and existing wind farms in the area.

Shadow Flicker: Shadow flicker may be cast on neighbouring residential properties. Shadow flicker was assessed in the EIS in relation to residential properties in the vicinity of the site and included total of 45 houses. The assessment concluded that shadow flicker is predicted to occur at 27 of the 45 houses and that DoEHLG guideline total values could be exceeded at 22 houses as a worst case scenario. When the regional sunshine data is considered, 3 houses are potentially affected, all of which belong to participating landowners.

Noise: Noise associated with the proposed operation of turbines is in two forms, the noise from the generator itself and the 'swoosh' noise as the blades move through the air. The submitted EIS figures would suggest that there will be an exceedence at one location but concludes that the proposed development can be designed so as to meet noise criteria for residential properties in the area, including the draft guideline of 40dB $_{LA90, T}$. Mitigation measures are advised in relation to construction noise, in line with best practice measures.

Traffic: Short term local community impact associated mainly with the construction phase of the development and the transportation of turbine elements and construction materials.

12.7.3 Soils, Hydrogeology and slope stability:

Peat stability: Potential of a peat slide from stored or disturbed peat is considered negligible.

Extraction of rock: Three borrow pits for rock extraction are proposed in order to provide for construction purposes.

Hydrogeology: Impact associated with the proposed necessary water crossings

12.7.4 Hydrology & Water Quality:

Effect on water quality: Changes in site run-off volumes, impacting on water chemistry for fish, siltation in streams.

Effect on important habitats located on site and downstream from the site.

12.7.5 Air & Climate:

Climate Change: Role of renewable energy and climate change.

Noise disturbance: Mechanical and aerodynamic noise impacts on residents.

Vibration

12.7.6 Landscape and Visual Impact:

Scale and height and extent of visibility: Intrusive visual effects on the wider area beyond the site.

Impact on landscape character: Distortion of the natural landscape character.

Impact on views: Potential incongruity with views into, across and beyond the site, notably from designated scenic route to the north.

12.7.7 Archaeology & Cultural Heritage:

Archaeology: Disturbance to or potential destruction of on-site archaeology, including newly discovered archaeology.

Cultural Heritage: visual impacts associated with development on protected structures.

12.7.8 Material Assets:

Road Network: The transportation of materials will have certain consequences for the structure and carrying capacity of the existing local roads at certain points along the proposed delivery route.

Telecommunications: Electromagnetic interference with telecommunications signals may occur.

Forestry: Clear-felling of commercial plantation to be undertaken on the site to facilitate the siting of the turbines and the provision of internal roads.

12.7.9 Interactions:

The effects of the interactions between humans and air quality, the visual landscape, flora & fauna and water and soils; and landscape and the natural environment are implicit in the range of preceding issues listed.

12.8 Assessment of the Likely Significant Effects Identified, having regard to the mitigation measures proposed:

The assessment contained in this report fully considers the range of relevant likely significant effects having regard to the information submitted with the planning application, together with all the comments and submissions made in relation to the proposed development. Mitigation measures proposed to be applied if the proposed development proceeds will be fully integrated to that assessment. Some of the more important mitigation measures proposed to be employed which are considered necessary to address the range of potential significant impacts arising from the proposed development include as follows:

12.8.1 Human Environment:

Shadow flicker: The EIS assessment concluded that shadow flicker is predicted to occur at 27 of the 45 houses and that DoEHLG guideline total values could be exceeded at 22 houses. When the regional sunshine data is taken into account, and assumes 40% sunshine, this number is reduced to 3 houses being affected per year, H44, H45 and H46, all of which belong to participating landowners. Mitigation is not explicitly proposed and the EIS suggests that where an issue arises, mitigation requirements will be assessed by way of a procedure of evaluation of the existing screening, window orientation and the periods of shadow flicker actually occurring and will be carried out in consultation with the relevant landowner. The wind turbine control system could include the shutting down of particular turbines at specific times of specific days of the year.

Noise: Noise mitigation measures were indicated as having been included as part of the overall design and layout of the proposed development. The EIS considers that the impact associated with noise is considered to be within the established parameters and guideline limits. I have advised my concerns in relation to noise associated with the proposed development and the potential impacts on the human environment in the vicinity of the site.

12.8.2 Flora & Fauna

Designated sites: Impacts on water quality in surface water bodies which feed Great Island Channel SAC and pNHA and Cork Harbour SPA are located 9.1km to the south of the site. These sites are connected to the subject site as tributaries of the Owenacurra and Dungourney Rivers rise in the site and flow south to the Natura 2000 sites.

Impacts on on-site habitats: Minimal loss of habitat

Species: Minimal reducing in the diversity of species.

Avifauna: Minimal impact for conservation species. I have advised my concerns in relation to the potential impacts on the birds using and in the vicinity of the site.

6.25ha (about 7.5%) of the entire site will be subject to development works. The amount of soil or rock to be disturbed is relatively limited.

The mitigation measures designed to limit silt/hydrocarbons moving into and down-stream/river systems are adequate.

The areas to be subject to construction works – existing roads/conifer plantations are not significant habitats for birds of conservation value and the proposed development will not negatively impact on species.

12.8.3 Soils & Hydrogeology

It is unlikely that the proposal will give rise to peat slides.

12.8.4 Hydrology & Water Quality

Water quality: Minimising run-off volumes, drainage design and control, Best practice methods during construction phase.

Natural water system: Maintaining routes of natural watercourses, avoiding natural watercourse crossings where possible.

Important habitats: It is suggested that there will be no direct discharge to any water body arising due to the proposed development.

The spatially limited extend of the works within the site, together with the mitigation measures proposed in the EIS and additional submissions to the planning authority and the Board should ensure against deterioration in water quality status.

12.8.5 Air, Climate

The proposed development will contribute to limiting CO_2 emissions.

12.8.6 Landscape and Visual Impact

Landscape character and important views: Separation distance from the public realm.

Cumulative impact: Not relevant.

The EIS submits that there will be minor and on-going visual intrusion from the proposed development but not sufficient as to seriously negatively impact on areas of special landscape importance or views or prospects which it is necessary to preserve. The matter of localised visual impact is considered in terms of residential amenity, which I consider to be significant and understated in the EIS.

12.8.7 Archaeology & Cultural Heritage

Archaeology: The identified archaeological remains on will be protected during construction by means of the application of buffer zones, and archaeological monitoring will be undertaken during the site preparation and construction phases.

Cultural Heritage: subject to the implementation of mitigation measures and appropriate conditions, the proposed development can be considered acceptable.

12.8.8 Material Assets

Road network: Heavy materials delivery and plant transportation with access junction improvements where necessary. The impacts on the local road network will be limited to the construction phase and will not permanently negatively impact on the local road network.

Telecommunications: Careful siting of turbines to minimise interference with existing telecommunications infrastructure. Adherence to protocol.

Aviation: Warning lights affixed to turbines. The impact on air navigation is not raised as a significant issue of concern.

12.9 Conclusions Regarding the Acceptability or Otherwise of the Likely Residual Effects Identified

The conclusions regarding the acceptability of the likely main residual effects of this proposal are clearly addressed under the various headings of the main assessment above. The principal areas of concern, in my opinion, focus on residential amenity, visual impacts, noise and ecology issues. In terms of the comments of the PA in relation to EIA, I do accept that there is somewhat limited information and assessment provided in support of the proposed development where there are outstanding issues particularly with regard to residential amenity and ecology which preclude me from determining that there will not be a significant environmental impact associated with the proposed development.

13.0 APPROPRIATE ASSESSMENT:

13.1 The obligation to undertake appropriate assessment derives from Article 6(3) and 6(4) of the Habitats Directive. Essentially it involves a case by case examination for Natura 2000 site and its conservation objectives. Appropriate Assessment involves consideration of whether the plan or project alone or in combination with other projects or plans will adversely affect the integrity of a European site in view of the site's conservation objectives and includes consideration of any mitigation measures to avoid reduce or offset negative effects. This determination must be carried out before a decision is made or consent given for the proposed plan or project. Consent can only be given after having determined that the proposed development would not adversely affect the integrity of a European Site in view of its conservation objectives.

13.2 The submitted EIS at Appendix D3, provides a Screening Report for AA prepared by Fehily Timoney & Company. This report identified three Natura 2000 sites within 10km of the subject site including

- Blackwater River (Cork / Waterford) SAC (Site Code 002170)
- Great Island Channel SAC (Site Code 001058)
- Cork Harbour SPA (Site Code 004030)

13.3 The Blackwater River (Cork / Waterford) SAC (Site Code 002170) is located 3.1km to the north of the site but it is submitted that it is not hydrologically connected to the proposed development site and is therefore not potentially impacted upon by the proposed development. The report seeks to address the other identified Natura 2000 sites and identifies the qualifying interests associated with the sites as well as the conservation objectives afforded to same. The report submits that there will be no direct impacts on the Natura 2000 sites. It is not considered likely that there will be any indirect impacts on the Natura 2000 sites during the construction of the wind farm project or in conjunction with the development at the adjacent Distillery Storage house, due to the distance of the proposed development from Cork Harbour.

13.4 The Great Island Channel SAC (Site Code 001058) is located approximately 9km to the south of the subject site. This SAC is so designated for the following qualifying interests:

Estuaries [1130]
Mudflats and sandflats not covered by seawater at low tide [1140]
Spartina swards (Spartinion maritimae) [1320]
Atlantic salt meadows (Glauco-Puccinellietalia maritimae) [1330]

13.5 The Cork Harbour SPA is located approximately 9km to the south of the subject site. This SPA is so designated for the following qualifying interests:

Little Grebe (*Tachybaptus ruficollis*) [A004]
Great Crested Grebe (*Podiceps cristatus*) [A005]
Cormorant (*Phalacrocorax carbo*) [A017]
Grey Heron (*Ardea cinerea*) [A028]
Shelduck (*Tadorna tadorna*) [A048]
Wigeon (*Anas penelope*) [A050]
Teal (*Anas crecca*) [A052]
Pintail (*Anas acuta*) [A054]
Shoveler (*Anas clypeata*) [A056]
Red-breasted Merganser (*Mergus serrator*) [A069]
Oystercatcher (*Haematopus ostralegus*) [A130]
Golden Plover (*Pluvialis apricaria*) [A140]

Grey Plover (*Pluvialis squatarola*) [A141]
Lapwing (*Vanellus vanellus*) [A142]
Dunlin (*Calidris alpina*) [A149]
Black-tailed Godwit (*Limosa limosa*) [A156]
Bar-tailed Godwit (*Limosa lapponica*) [A157]
Curlew (*Numenius arquata*) [A160]
Redshank (*Tringa totanus*) [A162]
Black-headed Gull (*Chroicocephalus ridibundus*) [A179]
Common Gull (*Larus canus*) [A182]
Lesser Black-backed Gull (*Larus fuscus*) [A183]
Common Tern (*Sterna hirundo*) [A193]
Wetlands & Waterbirds [A999]

In terms of the above, the Board will note that the Golden Plover has been identified as frequenting the subject site.

13.6 In addition to the above identified Natura 2000 sites, the Board will note that the Blackwater Callows SPA is located approximately 11km to the north of the site. This SPA is so designated for the following qualifying interests

Whooper Swan (*Cygnus cygnus*) [A038]
Wigeon (*Anas penelope*) [A050]
Teal (*Anas crecca*) [A052]
Black-tailed Godwit (*Limosa limosa*) [A156]
Wetlands & Waterbirds [A999]

It is the stated objective to maintain or restore the favourable conservation condition of the bird species listed as Special Conservation Interests for the two identified SPAs. The AA Screening report submitted in support of the proposed development noted that the subject site may affect the flight path of a number of bird species travelling between the Cork Harbour SPA and the Blackwater Callows.

13.7 The site the subject of this appeal itself can be considered a commercial forest. However, given that there are Natura 2000 sites located within 15km of the site, the Board will be required to consider the potential effects of the proposed development on the identified SPAs and SACs.

The site must be subject to AA regarding its implications for the Natura 2000 site in view of the site's conservation objectives *"if it cannot be excluded, on the basis of objective information, that it will have a significant effect on that site, either individually or in combination with other plans or projects"* (EC, 2006). In other words, where doubt exists about the risk of a significant effect, an Appropriate Assessment must be carried out.

13.8 Having considered a number of potential significance indicators which have regard to any potential or likely effects of the proposed development on the on-site habitats, together with the habitats so protected under the designated SACs within 15km of the subject site, it is clear that the potential impact associated with the proposed development relates to the deterioration of water quality, which could have an indirect effect on the species and habitats that occur within the SACs. That said, I consider that, given the scale of the proposed development, together with the distance between the site and the SACs and the mitigation measures proposed in the EIS, the proposed development is unlikely to have an impact on the Natura 2000 sites within the 15km of the site. I am of the opinion therefore, that the development, if permitted, is likely to have little or no impact on the proximate Natura 2000 site. Invoking Article 28 and seeking the comments of the NPWS, is unnecessary in my opinion.

13.9 The EIS determined that a full AA was not required, as the subject site is located at a distance from any designated sites and that no significant impact on designated habitats is expected to occur. The Planning Authority have considered that due to inadequate information pertaining to protected species supported by the Natura 2000 sites, which were identified within the study area, AA could not be completed in this instance. The Board will note that a number of protected bird species were noted on and off site during the surveys, many of which are qualifying species associated with the Cork Harbour and Blackwater Callows SPAs.

13.10 The safeguards set out in Article 6(3) and (4) of the Habitats Directive are triggered not by certainty but by the possibility of significant effects. Thus, in line with the precautionary principle, it is unacceptable to fail to undertake an appropriate assessment on the basis that it is not certain that there are significant effects. Having regard to information provided, and in terms of screening for AA, I concur with the findings of the County Council Ecologist and suggest that there is no certainty that there will not be an impact associated with the proposed development on the protected bird species, supported by the Natura 2000 sites and which are known to frequent in and around the subject site. It is therefore, not appropriate to 'screen out' the potential for significant impacts affecting said species.

14.0 CONCLUSION & RECOMMENDATION

14.1 Conclusion:

14.1.1 Having regard to the information submitted in support of the application together with all reports and third party submissions, and the requirements of the Cork County Development Plan 2009-2015 and in particular, as it relates to the provision of wind energy projects, the Board will note that while the subject site is not located within a 'strategic search area', neither is it located within a 'strategically unsuitable area'.

14.1.2 As such, it is reasonable to consider the potential for the site with regards suitability for the proposed development of a wind energy project in terms of the criteria stipulated in objective INF 7-4 of the Plan which deals specifically with Wind Energy Projects, and in particular part (c) of same. In this regard, I am satisfied that, subject to the normal planning criteria identified, in principle, it can be considered that the subject proposed site is suitable for the proposed development, and as such, a grant of planning permission would not, in principle, constitute a material contravention of the Development Plan, contrary to the indication of same by the Planning Authority in its reasons for refusal.

14.1.3 In relation to the roads and traffic issues, I consider that at minimum, a schedule of traffic and potential movements, including possible routes through the area, should be provided for consideration. Given the nature of the proposed development, these proposals should also be considered by the Roads Section of the County Council for comment and recommendation of conditions. However, I do not consider that the long term impacts of the development on the local road network is so significant as to warrant refusal of planning permission in this instance.

14.1.4 I further consider that the proposed development, subject to the mitigation measures indicated, will not so significantly impact upon archaeology, water quality, geology and hydrogeology of the site or the immediate vicinity of the site, as to warrant refusal of planning permission.

14.1.5 Notwithstanding the above, I do have a real concern regarding the scale of the proposed wind energy project which would exist on this site given its rural, but well-populated, low lying location, particularly in terms of visual impact and certain residential amenity impacts. I consider that the development as proposed will give rise to significant impacts on existing residential amenity. I consider that the development of turbines which are 156.5m high would substantially dominate the surrounding landscape and in my opinion, would be contrary to the provisions of The Department of Environment Heritage and Local Government Planning Guidelines for Wind Energy (June 2006). In this regard, I consider that the proposed provision of 11 turbines of the height propose at this location would adversely impact upon the visual amenities of the area, warranting refusal.

14.1.6 I have also indicated concern regarding the potential impact of the development on the residential amenities of a significant number for of residences in the immediate vicinity of the subject site, notably in terms of visual impact arising from the development.

14.1.7 Further to the above, I have considered the potential impact of the development on the ecology of the site. As part of my EIA, I have concluded that inadequate information has been provided to determine that the development, if permitted, will not have a significant and negative impact on habitats and flora fauna on the site, notably with regard to birds and bats and the loss of extensive areas of hedgerows and tree lines. I would concede to the findings of the County Council Ecologist in this regard.

14.1.8 In relation to Appropriate Assessment (AA), should the Board be minded to grant planning permission for the proposed development, then full screening for AA would have to be carried out as part of that consideration.

14.2 Recommendation:

Having considered the contents of the application including the Environmental Impact Assessment and all specialist reports contained therein, the decision of the planning authority, the provisions of the Cork County Development Plan, the provisions of the Wind Energy Development Guidelines (DOEHLG 2006) the grounds of appeal and the responses thereto, the observations made to the Board, my site inspection and my assessment of the planning issues, I recommend that permission be refused for the reasons set out hereunder:

REASONS AND CONSIDERATIONS

1 Having regard to the information submissions made in connection with the application by reference to ecological and noise impacts (which is considered deficient) the planning authority are not satisfied that the proposed development would not have a significant and adverse impact on the amenities and environment of the area including significant adverse impacts on:

- Noise sensitive locations in the vicinity, and
- Ecology of the area including protected species and sites.

The proposed development would therefore be contrary to the provisions of The Wind Energy Guidelines for Planning Authorities issued by the DoEHLG in June 2006 and would be contrary to the proper planning and development of the area.

2. Having regard to the number, scale and height of the proposed turbines, the proximity of the proposed turbines to a number of residential properties in the vicinity and notwithstanding the proposed mitigation measures contained in the submitted EIS, it is considered that that the proposed wind energy development, if permitted, would significantly and adversely impact upon the existing residential amenities of a number of houses in the vicinity by reason of visual impact and overbearing and noise impacts associated with the turbines considering the baseline noise levels identified in the EIS and supplementary documentation provided in

support of the proposed development. The development therefore, would seriously injure the existing residential amenities of the area and would be contrary to the proper planning and sustainable development of the area.

3. It is the stated objective of the current Cork County Development Plan, 2009, Objective INF 7-4, to consider the scale, size and layout of the wind farm and consider cumulative effects as well as local visual impacts. Having regard to the nature of the receiving low lying landscape and the open nature of the adjoining lands, it is considered that a wind farm development of the scale proposed would create a significant visual intrusion in this landscape by reason of the height and spatial extent of the proposed turbines which would be excessively dominant and visually obtrusive in the receiving landscape and when viewed from the surrounding countryside and villages. The proposed wind energy development would, therefore, seriously injure the visual amenities of the area, would be contrary to the provisions of The Department of Environment Heritage and Local Government Planning Guidelines for Wind Energy (June 2006), the objectives of the County Development Plan, 2009 and would be contrary to the proper planning and sustainable development of the area.

____

A. Considine,
Planning Inspector.
21st October 2014.

◀ P54

and velocity, v(f) and * signifies the complex conjugate. It is plotted in dB in figure 5 along with the two idealised lumped-parameter impedances of $i\omega m$ and $\rho c_L S$. It can be seen that while peaks in the spectrum reach the upper $i\omega m$ curve, at most frequencies the curve is closer to the lower $\rho c_L S$.

Figure 6 shows the velocity transmissibility of the bearings along with the SDOF transmissibility curve. Figure 6 shows, in 1/3 octave bands, the velocity transmissibility relative to the base velocity of the building with the bearings in place, and Figure 7 is the velocity transmissibility relative to the base velocity of the building with rigid support so that it takes account of the effect of the bearings on the source below as well as the structure above. Of particular note is the absence of a peak at the SDOF bearing natural frequency, and the presence of two coupled peaks, one above and the other below the SDOF natural frequency, resulting from the coupling between the structure above the bearings and the foundations below. Comparison of Figure 7 with Figure 6 shows that when the change in the foundation velocity is taken into account, the actual transmissibility more closely resembles that predicted using the driving point impedance of an infinite column than a lumped mass.

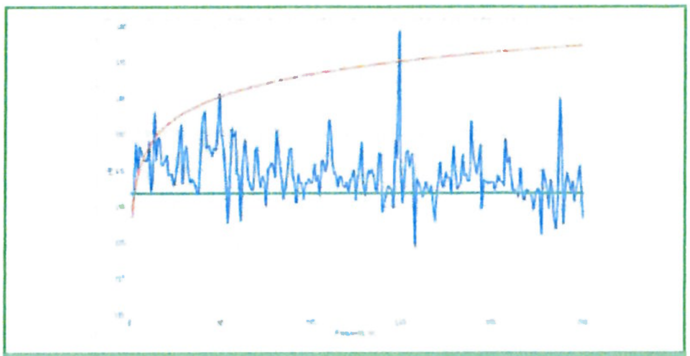


Figure 5. Driving point impedance of (1) column above bearing (middle curve) together with (2) an equivalent lumped mass (upper curve) and (3) an infinite column

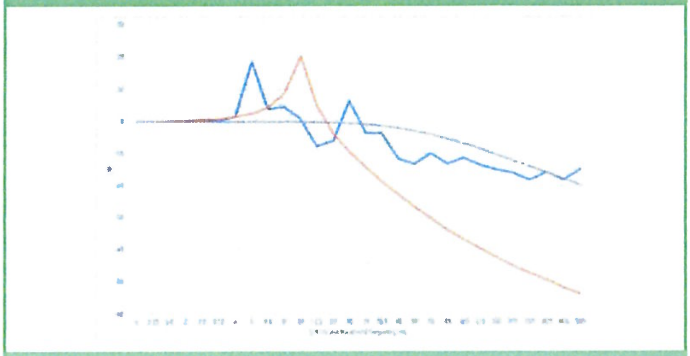


Figure 6. Velocity transmissibility of the 10Hz bearings (1) from the FDTD model (middle curve) together with (2) an equivalent lumped mass (lower curve) and (3) an infinite column (upper curve)

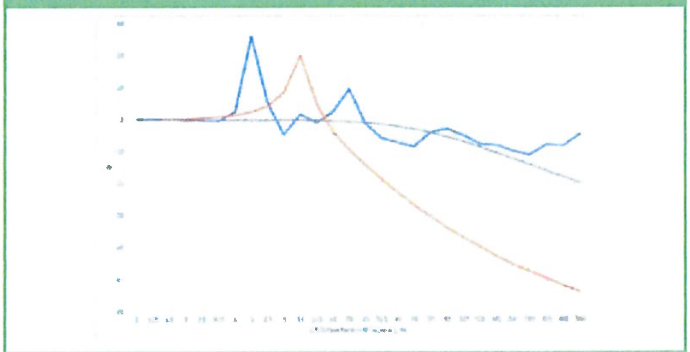


Figure 7. Velocity transmissibility of the 10Hz bearings relative to the base in the unisolated building(1) from the FDTD model (middle curve) together with (2) an equivalent lumped mass (lower curve) and (3) an infinite column (upper curve)

Conclusions

It can be concluded the predicting the performance of a base-isolation system over the frequency range relevant to the reduction of groundborne noise using a SDOF model is likely to lead to an over-optimistic result is the base of large, tall or complex buildings. The reasons for this have been discussed and primarily relate to the dynamic response of such buildings which will limit the driving point impedance of the structure "seen" by the top of the bearings. The additional degrees of freedom of a lumped mass are only a partial explanation. Additionally, the use of a simple velocity transmissibility equation can be misleading, as the velocity of the base is affected by the insertion of the bearings. The SDOF model also fails to allow for coupling between the mass-on-a-spring of the building and its bearings and the mass and spring system which exists in the foundation.

Numerical modelling is capable of taking all these matters into account, and provides the most detailed method of predicting the performance of base isolation systems.

__Rupert Thornely-Taylor__ began working in acoustics in 1964 and has run his own practice since 1968. A former member of the Noise Advisory Council, he was also a member of the Scott Committee which drafted the basis of the noise section of the Control of Pollution Act 1974.

References are available from the Editor at **ioa@ioa.org.uk**

A planning condition for wind turbines

This article has been contributed to by Andy McKenzie, Matthew Cand, Dick Bowdler, Mark Jiggins, Gavin Irvine, Michael Reid, Richard Perkins, Michael Lotinga, Malcolm Hayes and Andrew Bullmore

Introduction

This article sets out a proposed wording for a planning condition on noise for wind farms or individual wind turbines.

Whilst local authorities and developers have waited for a planning condition that could be applied to newly consented wind farms, or to those already consented but with a suspensive condition, the report Wind Turbine AM Review (WTAMR) by WSP/Parsons Brinckerhoff for DECC arguably did not provide that. In addition there have been a number of comments on WTAMR that we consider should be addressed. The introductory sections and the conditions text represent the broad consensus view of those whose names appear below, following a period of discussion, compromise and agreement. This approach is proposed based on the current state of understanding, but may be subject to modification in light of new research and further robust information.

Copies of the condition only in Word format are available from the following websites:

- **www.hayesmckenzie.co.uk/uploads/A_Planning_Condition_for_Wind_Turbines_Sept_2017.docx**
- **www.dickbowdler.co.uk/content/publications/**

Proposed wording condition

The annex contains the condition wording which takes fairly typical wording for a planning condition on wind farm noise, including adjustments for tonal penalties if relevant, and adds a mechanism for adding a penalty for AM. Consistent with the recommendations of the WTAMR, the AM penalty is applied in addition to the tonality penalty. But how to calculate an AM penalty in practice is not clear from the WTAMR report.

WSP researchers in their subsequent *Acoustic Bulletin* article have discussed this aspect further: the penalty "should be applied to each

P58 ▶

◀ P56

individual 10-minute period assessed, and the rated levels separated into wind speed integer 'bins' for the purposes of comparison with the condition limits". They explain that to "aggregate the AM penalty" values would give an equivalent result to adding the penalty to each 10 minute period and then averaging the resulting "rated" levels, which is our experience in practice. In contrast, as they note, averaging the AM ratings and deriving an AM penalty on that basis would in many cases lead to different results.

The proposed condition has therefore been drafted on the basis of aggregating the AM penalties obtained, and applying this to the overall noise levels. This is considered to be a pragmatic way to represent the frequency/intensity of AM typically observed in relevant weather conditions. The condition explains that this averaging should only be done in relevant subsets of conditions which are determined in each case based on the observed complaints (if relevant), data analysis results or practitioner judgment. Analysis in wind direction bins, or plotting the amplitude modulation as a polar plot may be important in determining the appropriate subset. An example is shown in Fig 1 which is a polar plot of AM values as a function of wind direction and speed.

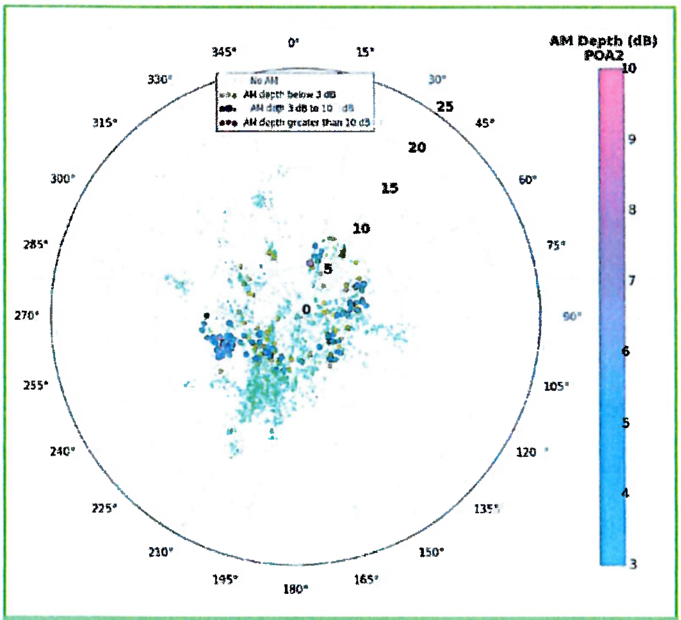


Fig 1 - plot of calculated AM ratings (dots) as a function of wind direction (circular direction) and wind speed (radial direction).

AM penalty – general aspects

As various people before us have discovered, the derivation of a penalty is not easy. There is not sufficient reliable research to be confident that a penalty system would always provide a fair indication of the impact of AM. However, to do nothing would be unfair on those wind farm neighbours adversely affected by AM and, in any case, there seems to be general agreement amongst many stakeholders on all sides of the debate that a robust condition including AM is required.

There are a significant number of people who have reservations about the penalty scheme proposed in the WTAMR report and this has been discussed in some detail by interested parties. The conclusion is that the penalty graph needs further research to establish whether it should be amended to take account of rotational speed and the difference between Leq and L90 (which increases as AM increases) and that this should be progressed as soon as possible. Meanwhile we have included the WTAMR graph in this condition. It is intended for medium to large scale turbines with a rotational speed up to 32 rpm.

A note on the night time limit

There has been criticism from some quarters of the method the WTAMR report proposed for an additional penalty to be applied at night to take account of the difference between the night-time and day-time limits; specifically where the night-time limits are higher. With a few exceptions (where suspensive conditions for AM have been applied, typically as a scheme to be agreed) the condition we are discussing here applies only to new consents. That means that, in the majority of cases, it will be applied as part of a complete set of noise limits. In such cases, the night-time and day-time limits can be set appropriately in accordance with the circumstances of the case. It should be noted that, if the night time limit is higher than the day time limit this could mean that an AM penalty would take the wind farm over the limit during the day but not at night. Where a suspensive condition for AM has been applied, the AM penalty would have to be tailored to the individual case unless an application were made to amend the conditions as a whole.

Annex

Proposed planning conditions on noise for ** Wind Farm**

The rating level of noise immissions from the combined effects of the wind turbines hereby permitted (including the application of any tonal penalty and amplitude modulation (AM) penalty), when determined in accordance with the attached guidance notes, shall not exceed the values for the relevant integer wind speed set out in or derived from Table 1 attached to these conditions and:

A) Within 21 days from receipt of a written request of the planning authority, following a complaint to it alleging noise disturbance at a dwelling, the wind farm operator shall, at its expense, employ an independent consultant and provide a written protocol to be approved by the planning authority. The protocol shall describe the procedure to assess the level and character of noise immissions from the wind farm at the complainant's property in accordance with the procedures described in the attached guidance notes. The written request from the planning authority shall set out as far as possible the time or meteorological conditions to which the complaint relates and time or conditions relating to tonal noise or AM if applicable. Measurements to assess compliance with the noise limits shall be undertaken in accordance with the assessment protocol which shall be approved in writing by the planning authority.

B) The wind farm operator shall provide to the planning authority the independent consultant's assessment of the rating level of noise immissions undertaken in accordance with the protocol within two months of the date of the approval of the protocol by the local authority unless otherwise agreed by the planning authority. The assessment shall include all data collected for the purposes of undertaking the compliance measurements and analysis, such data to be provided in a format to be agreed with the planning authority. Certificates of calibration of the equipment shall be submitted to the planning authority with the report.

C) Where a further assessment of the rating level of noise immissions from the wind farm is required pursuant to Guidance Note 5 of the attached Guidance Notes, the wind farm operator shall submit a copy of the further assessment within 21 days of submission of the independent consultant's initial assessment unless otherwise agreed by the Planning Authority.

[It is acknowledged that there may be other parts of the current IOAGPG conditions which require inclusion here, such as the clause discussing limits which apply at non named locations etc. The text included above aims to show how rating of AM scheme fits within the normal WF compliance approach.]

(Insert here the table or tables relevant to the specific planning condition)

Guidance notes for noise condition

These notes are to be read with and form part of the planning condition on noise. The measured data is to be split into bins as described below. The rating level in each bin is the arithmetic sum of the wind farm noise level, any tonal penalty applied in accordance with Note 3 and any AM penalty applied in accordance with Note 4. Reference to ETSU-R-97 refers to the publication entitled "The Assessment and Rating of Noise from Wind Farms" (1997) published by the Energy Technology Support unit (ETSU) for the Department of Trade and Industry (DTI). IOAGPG is "A Good Practice Guide to the Application of ETSU-R-97 for the Assessment and Rating of Wind Turbine Noise" or any update of that report current at the time of measurement. The IOA Metric is "A Method for Rating Amplitude Modulation in Wind Turbine Noise" dated 9th August 2016 or any update of that current at the time of measurement.

P60 ▶

◀ P58

Note 1 – Data collection

A) Values of the LA90,10-minute noise index should be measured in accordance with the IOAGPG. Measurements shall be undertaken in such a manner to enable a tonal penalty to be calculated and to allow an AM penalty to be calculated for selected periods where a tonal or AM assessment is required.

B) To enable compliance with the conditions to be evaluated, the wind farm operator shall continuously log arithmetic mean wind speed in metres per second (m/s) and arithmetic mean wind direction in degrees from north in each successive 10-minutes period in a manner to be agreed in writing with the planning authority. The wind speed at turbine hub height shall be "standardised" to a reference height of 10 metres as described in ETSU-R-97 at page 120 using a reference roughness length of 0.05 metres. It is this standardised 10 metre height wind speed data which are correlated with the noise measurements determined as valid. The wind farm operator shall continuously log arithmetic mean nacelle anemometer wind speed, arithmetic mean nacelle orientation, arithmetic mean wind direction as measured at the nacelle, arithmetic mean rotor RPM and whether each wind turbine is running normally during each successive 10-minutes period for each wind turbine on the wind farm. All 10-minute periods shall commence on the hour and in 10-minute increments thereafter synchronised with Universal Time (UT).

Note 2 – Data analysis

A) The independent consultant shall identify a sub set of data having had regard to:-
- the conditions (including time of day and corresponding wind directions and speeds) at times in which complaints were recorded;
- the nature/description recorded in the complaints if available;
- information contained in the written request from the local planning authority;
- likely propagation effects (downwind conditions or otherwise);
- the results of the tonality/AM analysis where relevant.

In cases where it is possible to identify patterns of clearly different conditions in which complaints have arisen additional sub sets may be considered provided this does not introduce unreasonable complexity in the analysis and can be justified by the independent consultant.

B) Within each of the sub set(s) of data identified, data shall be placed into separate 1 m/s wide wind speed bins.

Note 3 – Tonal penalty

A) Where, in accordance with the protocol, the noise contains or is likely to contain a tonal component, a tonal audibility shall be calculated for each ten-minute period using the following procedure.

B) For each 10-minute period for which a tonal assessment is required this shall be performed on noise immissions during two minutes of each 10-minute period. The two-minute periods should be spaced at 10-minute intervals provided that uninterrupted uncorrupted data are available ("the standard procedure").

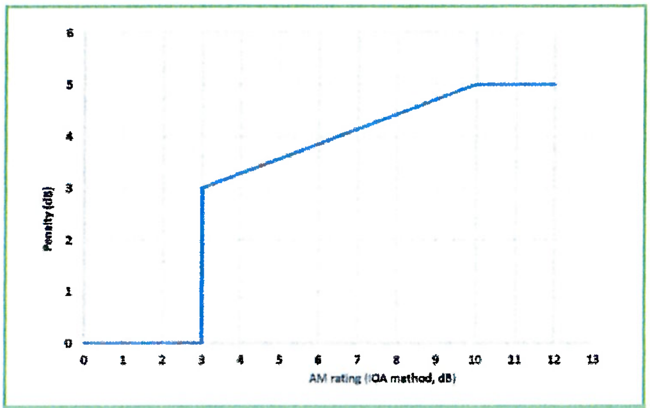
C) For each of the two-minute samples the tone level above audibility shall be calculated by comparison with the audibility criterion given in Section 2.1 on pages 104 -109 of ETSU-R-97. Samples for which the tones were below the audibility criterion or no tone was identified, a value of zero audibility shall be substituted. Where data for a ten-minute period are corrupted, that period shall be removed from the tonal analysis.

D) The tone level above audibility for each 10-minute period shall be placed in the appropriate data sub set and wind speed bin.

Note 4 – AM penalty

A) Where, in accordance with the protocol, the noise contains or is likely to contain AM, an AM penalty shall be calculated for each ten-minute period using the following procedure.

B) For each 10-minute interval for which an AM assessment is required this shall be performed in accordance with the IOA Metric. The value of AM for each ten-minute period shall be converted to a penalty in decibels in accordance with the graph below and the penalty shall be placed in the appropriate data sub set and wind speed bin. Where a penalty is zero it should be placed in the bin in the same way.



Penalty graph

Note 5 – Calculation of rating level

A) The LA90 sound pressure level for each data sub set and wind speed bin is the arithmetic mean of all the 10 minute sound pressure levels within that data sub set and wind speed bin except where data has been excluded for reasons which should be clearly identified by the independent consultant. The tonal penalty for each bin is the arithmetic mean of the separate 10 minute tonal audibility levels in the bin converted to a penalty in accordance with Fig 17 on page 104 of ETSU-R-97. The AM penalty for each bin is the arithmetic mean of the AM penalties in the bin. The assessment level in each bin is normally the arithmetic sum of the bin LA90, the bin tonal penalty and the bin AM penalty except where the AM penalty and the tonal penalty relate to the same characteristic (e.g. amplitude modulated tones) when the sum of both penalties may overly penalise the characteristics of the noise. Such cases should be identified and only the larger of the AM or tonal penalty should be applied.

B) If the assessment level in every bin lies at or below the values set out in the table(s) attached to the conditions then no further action is necessary. In the event that the assessment level is above the limit(s) set out in the tables attached to the noise conditions in any bin, the independent consultant shall undertake a further assessment of the rating level to correct for background noise so that the rating level relates to wind turbine noise immission only. Correction for background noise need only be undertaken for those wind speed bins where the assessment level is above the limit.

C) The wind farm operator shall ensure that all the wind turbines in the development are turned off for such periods as the independent consultant requires to undertake the further assessment. The further assessment shall be undertaken in accordance with the following steps:-

i. Repeating the steps in Note 1, with the wind farm switched off, and determining the background noise (L_3) in each bin as required in the protocol. At the discretion of the consultant and provided there is no reason to believe background noise would vary with wind direction, background noise in bins where there is insufficient data can be assumed to be the same as that in other bins at the same wind speed.

ii. The wind farm noise (L_1) in each bin shall then be calculated as follows where L_2 is the measured level with turbines running but without the addition of any tonal nor AM penalty:

$$L_1 = 10\log\left[10^{L_2/10} - 10^{L_3/10}\right]$$

iii. The rating level shall be calculated by adding the tonal and AM penalties to the derived wind farm noise L1 in that bin.

iv. If the rating level after adjustment for background noise contribution and adjustment for tonal and AM penalties in every bin lies at or below the values set out in the Tables attached to the condition at all wind speeds then no further action is necessary. If the rating level at any integer wind speed exceeds the values set out in the Table(s) attached to the condition then the development fails to comply with the planning condition in the circumstances represented by that bin.

INCEEUROPE

6th International Conference on Wind Turbine Noise

Glasgow, 20 - 23 April 2015

Overall Programme

Sunday 19th April	14:00 to 17:00	Registration
Monday 20th April	09:00	Registration and Refreshments
	11:00	Conference Opens - Oral Presentations
	17:00	Drinks Reception and Poster Inauguration
	19:00	Free Evening
Tuesday 21st April	08:00	Refreshments
	08:30	Oral Presentations
	16:50	Workshop - Experience with the implementation of IEC 61400-11 (Edition 3) - Contact Sylvia Broneske
	18:15	Whisky Tasting
	19:45	Free Evening
Wednesday 22nd April	08:00	Refreshments
	08:30	Oral Presentations
	17:30	Workshop - Measuring Modulation from Wind Turbines - Contact Matthew Cand
	19:30	Conference Dinner
Thursday 23rd April	08:00	Refreshments
	08:15	Oral Presentations
	16:00	Conference Ends

Please note that some of these times may change slightly

6th International Conference on Wind Turbine Noise

Poster Presentations

Group	Title	Author 1
A - Source Noise - Localisation	The DTU Wind Energy WTN Test Facility	Bradley
	Doppler analysis and processing for the localization of low frequency tonal sound sources on blades: An experimental approach	Falourd
	Observation of vibration velocity at many parts of wind turbine and relational analysis with propagated sound to surroundings	Iwase
	Sound source localization on wind turbines using a single acoustic vector sensor	Serraris
B - Source Noise - Measurement	Small Wind Turbines – Comparison of Acoustic Noise Measurements in Accordance with IEC 61400-11 Ed. 3 to BWEA Small Wind Turbine Guideline	Broneske
	A new method for determining the wind turbine noise based on the constant divergence of sound pressure level	Buzduga
	Field comparison of IEC 61400-11 Wind turbines - Part11: Acoustic noise measurement techniques: Edition 3.0 and Edition 2.1	Joswiak
C - Receiver - Sensitivity	Relationship between exposure to wind turbine noise and subjective and objective sleep disorder in southern part in Japan ……..	Morimatsu
	Wind turbines - A changed environment	Palmer
	Experimental study of relationship between amplitude modulation and detection threshold of wind turbine noise	Yoon
D – Receiver - Monitoring	Study of secondary wind shield performance in the field	Adcock
	Wind noise estimation functions for low frequency sound measurment in natural wind at different topography types	Kamiakito
	Investigation into the influence of windscreens during sound emission measurements in accordance with IEC 61400-11 ed. 3.0	Kaufmann
	Background noise assessment in Utrecht	Balkema
	Automated wind farm noise measurement systems with feature analysis	Jiggins
E - Low Frequency and Infrasound	A system for measuring wind turbine infrasound emissions	Annan
	Stationary wind turbine infrasound emissions and propagation loss measurements	Huson (1)
	Constraints imposed by and limitations of IEC 61672 for the measurement of wind farm sound emissions	Huson (2)
	Environmental Impact Assessment and Management Plan on Wind Turbine Noise in South Korea	Park
	Direct experience of low frequency noise and infrasound within a windfarm community	Swinbanks
	Measuring wind turbine coherent infrasound	Vanderkooy

6th International Conference on Wind Turbine Noise

Monday 20th April 2015 - Oral Presentations		
11:00	Opening	
	Sound Propagation 1 - Geoff Leventhall	
11:05	**PLENARY** - Wind turbine noise propagation - results of numerical modelling techniques to investigate specific scenarios	Sims
11:35	Modeling of ground and atmospheric effects on wind turbine noise	Tian
11:55	Metrological validation of the DIN ISO 9613-2 propagation model concerning wind turbine noise	Engelen
12:15	Prediction of variability in wind turbine noise calculations	Cotte
12:35	Discussion	
13:00	Lunch	
	Sound Propagation 2 - Sylvia Broneske	
14:00	Directivity noise attenuation values for large wind turbines - Research based on long term measurements	Coulon
14:20	Propagation of noise from wind farms according to the Institute of Acoustics' Good Practice Guide - a sensitivity analysis	Birchby
14:40	Low-Frequency acoustic near-field of wind-turbines	Richarz
15:00	Prediction of infrasound and low frequency noise propagation for modern wind turbines, a proposed supplement to ISO9613-2	Hansen
15:20	Discussion	
15:40	Break	
	Sound Propagation 3 - Dick Bowdler	
16:00	Influence of vertical temperature gradient on background noise and on long-range noise propagation from wind turbines	Bigot
16:20	Effects of built environment morphology in residential areas on resisting wind turbine noise on building façades	Qu
16:40	Discussion	
16:50	Session ends	

6th International Conference on Wind Turbine Noise

Tuesday 21st April 2015 - Oral Presentations		
	Health Effects and Annoyance - Matthew Cand	
08:30	**PLENARY** – Wind Turbine Noise and Health Study: Summary of Results	Michaud
09:10	Findings of the Council of Canadian Academies Expert Panel on Wind Turbine Noise and Human Health	Howe
09:30	Impact of windturbine noise on local residents in mountainous terrain at Lista Windfarm, South Norway	Vagene
09:50	Compliance isn't everything	Large
10:10	Noise from wind turbines and health effects - Investigation of wind turbine noise spectra	Sondergaard
10:30	Discussion	
10:50	Break	
	Regulations 1 - David Colby	
11:10	Comparative analysis of wind turbine noise assessment and rating procedures in the UK, France and the Netherlands	Goeme
11:30	The use of cumulative wind turbine noise related planning conditions	Mackay
11:50	State of the art and new perspectives for the development of noise regulation of wind farms	Schild
12:10	A history of wind turbine noise regulations in the Netherlands	van den Berg (GP)
12:30	Discussion	
12:55	Lunch	
	Receiving Environment - TBA	
13:55	From good practice guidance to solving amplitude modulation for wind turbine noise assessment in the UK	Perkins
14:15	Wind turbines - A changed environment	Palmer
14:35	Modelling of house filter for wind turbine noise	Tachibana
14:55	Discussion	
15:10	Break	
	Tonal noise - Jean Tourret	
15:30	Assessment of tonal components contained in wind turbine noise in immission areas	Kobayashi
15:50	Tonal noise from wind turbines	Evans
16:10	Reduction of tonalities in wind turbines by means of active vibration absorbers	Engelhardt
16:30	Discussion	
16:45	Presentations end	

6th International Conference on Wind Turbine Noise

Wednesday 22nd April 2015 - Oral Presentations - Hall 1		
	Aeroacoustic Noise Source 1 - Helge Madsen	
08:30	**PLENARY** - Basic principles and evidences of wind turbine noise generation mechanisms	Bertagnolio
09:05	**PLENARY** - Impact on flow topology of solid and permeable trailing edge serrations at incidence on cambered and symmetric airfoils	Arce
09:25	Aeroacoustic simulation of an airfoil in turbulent inflow	Illg
09:45	Displacement thickness evaluation for BPM-Type Airfoil-TE noise prediction model	Saab
10:05	Simulation of broadband trailing-edge noise - Influence of airfoil shape and flow characteristics	Rautmann
10:25	Discussion	
10:45	Break	
	Aeroacoustic Noise Source 2 - Brian Howe	
11:05	Numerical simulation of airfoil trailing edge serration noise	Zhu
11:25	On the measurement and prediction of wind-turbine trailing-edge noise	Stalnov
11:45	Development of a high-fidelity noise prediction and propagation model for noise generated from wind turbines	Debertshauser
12:05	On predicting wind turbine noise and amplitude modulation using Amiet's theory	Sinayako
12:25	Discussion	
12:45	Lunch	
	Aeroacoustic Noise Source 3 - Sabine von Hunerbein	
13:45	On the noise prediction of a serrated DU96 airfoil using the Lattice Boltzmann Method	van der Velden
14:05	An experimental and numerical parameter study on trailing edge blowing for reduced trailing edge noise	Gerhard
14:25	Aeroacoustic wind tunnel experiment for serration design optimisation and its application to a wind turbine rotor	Hurault
14:45	Icing of wind turbines and the effect on noise - Long-term measurements	Appelqvist
15:05	Experimental characterization of stall noise toward its modelling	Bertagnolio
15:25	Discussion	
15:50	Break	
	Small Turbines - Christophe Delaire	
16:10	Noise reduction for small wind turbine by trailing edge modification	Yamagata
16:30	Noise directivity from a vertical axis wind turbine	Mollerstrom
16:50	Numerical investigation of the aeroacoustics of small vertical axis wind turbines	Weber
17:10	Discussion	
17:25	Presentations End	

6th International Conference on Wind Turbine Noise

Wednesday 22nd April 2015 - Oral Presentations - Hall 2		
08:30	See Hall 1	
	Background and Turbine Noise at Receivers-1 - Payam Ashtiani	
09:25	Background noise map creation through a CFD wind model	Bartolazzi
09:45	Methods for assessing background sound levels during post-construction compliance monitoring within a community	Duncan
10:05	Practical measurement method of wind turbine noise	Fukushima
10:25	Discussion	
10:45	Break	
	Background and Turbine Noise at Receivers-2 - Norm Broner	
11:05	Spectral discrete probability density function of measured wind turbine noise in the far field	Ashtiani
11:25	Research into a continuous wind farm noise monitoring system	Delaire
11:45	Noise optimized wind park operation	Petitjean
12:05	Wind Farm Noise Optimisation Tool	Fotheringham
12:25	Discussion	
12:45	Lunch	
	Infrasound - Sarah Large	
13:45	Progress report on synthesis of wind turbine noise and infrasound	Walker
14:05	Response to simulated wind farm infrasound including effect of expectation	Tonin
14:25	Perception and annoyance of low frequency noise versus infrasound in the context of wind turbine noise	Hansen
14:45	On the overlap region between wind turbine infrasound and infrasound from other sources and its relation to criteria	Leventhall
15:05	Health-based audible noise guidelines account for infrasound and low frequency noise produced by wind turbines	Berger
15:25	Discussion	
15:50	Break	
	Regulations 2 - Jean Tourret	
16:10	Noise protection regulations for wind turbines in Germany	Bauerdorff
16:30	Sensitivity analysis test on the Italian ISPRA-ARPAT methodology to assess noise impact of operational wind farms	Fredianelli
16:50	Parsimonius regulations for wind turbine noise	van den Berg (M)
17:10	Discussion	
17:25	Presentations End	

6th International Conference on Wind Turbine Noise

	Thursday 23rd April 2015 - Oral Presentations	
	Amplitude Modulation 1 - Sabine von Hunerbein	
08:15	**PLENARY** - An overview of recent research on AM and OAM of wind turbine noise	Madsen
08:45	The Institute of Acoustics' Working Group on Amplitude Modulation - Progress towards an agreed rating and assessment metric	Irvine
09:05	Measurements demonstrating mitigation of far-field AM from wind turbines	Cand
09:25	Addressing the issue of enhanced amplitude modulation: A developer's perspective	Cassidy
09:45	On the Measurement and Prediction of Wind-Turbine Swishing Noise	Cheong
10:05	Discussion	
10:30	Break	
	Amplitude Modulation 2 - Mark Bastasch	
10:50	Current challenges of assessing excess amplitude modulation character in wind turbine noise during EIA/planning phase	di Napoli
11:10	Can we really predict wind turbine noise with only one point source?	Ecotiere
11:30	Time-dependent interference: The Mechanism Causing Amplitude Modulation Noise?	Bradley
11:50	Low frequency amplitude modulation related to Doppler frequency shift: An experimental study of a 101m diameter wind turbine in a Swiss valley	Falourd
12:10	Detection of amplitude modulation in Southern Ontario wind farms	Halstead
12:30	Discussion	
12:50	Lunch	
	Amplitude Modulation 3 - Frits van den Berg	
13:50	Cotton Farm Wind Farm - long term community noise monitoring project - 2 years on	Stigwood
14:10	Affective response to amplitude modulated wind turbine sound	Von Hunerbein
14:30	Subjective experiments on the auditory impression of the amplitude modulation sound contained in wind turbine noise	Yokoyama
14:50	Indoor simulation of wind turbine amplitude modulated noise	Fernandez
15:10	Overview of IEEE standard development on amplitude modulation noise measurement	Xue
15:30	Discussion	
15:55	Closing	
16:00	Conference Ends	

MARSHALL DAY
Acoustics

EXAMINATION OF THE SIGNIFICANCE OF NOISE IN RELATION TO ONSHORE WIND FARMS

Commissioned by Sustainable Energy Authority of Ireland (SEAI)

MARSHALL DAY
Acoustics

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Project: **EXAMINATION OF THE SIGNIFICANCE OF NOISE IN RELATION TO ONSHORE WIND FARMS**

Prepared for: **SEAI**
Wilton Park House
Wilton Place
Dublin

Prepared by: **Marshall Day Acoustics**

Date: **29 November 2013**

TABLE OF CONTENTS

APPENDIX A GLOSSARY OF TERMINOLOGY

APPENDIX B WIND FARMS: ANCILLARY SOURCES OF NOISE

APPENDIX C WIND SPEED PROFILES

APPENDIX D GENERAL NOISE CONTROL METHODS

APPENDIX E REVIEW OF WIND FARM NOISE REGULATIONS IN OTHER JURISDICTIONS

APPENDIX F EXAMPLE NOISE MODEL SUMMARY DETAILS

APPENDIX G TENDER LITERATURE REVIEW DOCUMENTS

APPENDIX H BIBLIOGRAPHY

1.0 INTRODUCTION

The Department of Environment, Community and Local Government (DECLG) and the Department of Communications Energy and Natural Resources (DCENR) have commenced a technical update of the guidance on noise in the Wind Energy Development Guidelines 2006[1] (WEDG06).

The review is taking place in the context of Ireland's targets under Directive 2009/28/EC on the promotion of the use of energy from renewable sources. Ireland's National Renewable Energy Action Plan (NREAP) sets out how Ireland intends to achieve its individually binding national renewable energy (RE) target of 16% of energy demand by 2020: through 40% of electricity consumption, 10% of transport energy and 12% of heat energy being obtained from renewable sources.

The Sustainable Energy Authority of Ireland (SEAI) are assisting with the review and have commissioned a desk based study to review, and provide advice on, international best practice in relation to onshore wind farm noise which will be a key input into the review of WEDG06.

WEDG06 was issued under Section 28 of the Planning and Development Act, 2000, which requires both planning authorities and An Bord Pleanála to have regard to them in the performance of their functions. WEDG06 offers advice to planning authorities on planning for wind energy through the development plan process and in determining applications for planning permission.

The SEAI's stated objective for the desktop study of onshore wind farm noise is to:

> *"...obtain evidence upon which to evaluate the appropriateness of the Wind Energy Development Guidelines in relation to noise impacts and if considered necessary suggest changes."*

This report summarises the findings of a desktop study and concludes with comments about the effectiveness of WEDG06 for wind farm noise assessment with an emphasis on commercial scale wind farm developments. In particular, the effectiveness of WEDG06 is reviewed in light of the development and research that has occurred in the seven years since its publication. Recommendations are also provided for consideration as part of any subsequent update of WEDG06.

A key objective of all wind farm noise policies is to appropriately balance the protection of amenity for communities neighbouring wind farm developments with the wider interests of national infrastructure development which, in the Irish context, includes requirements to meet statutory wind energy targets.

[1] Available on the DECLG website at www.environ.ie

The appropriate balance will always be dependent on contextual factors that are specific to each county, country or region. Key examples of these factors include:

- The relative importance of onshore wind energy to the overall renewable energy strategy of a country or region
- Expectations and attitudes of the communities around the locations where wind farms are likely to be considered
- The scale of available development sites with suitable wind resources and compatible infrastructure.

This region-specific balance is an essential consideration when reviewing international guidelines and policy options.

The report comprises the following key sections:

Report Section	**Content**	**Related Work Package**
2	Scoping discussions	-
3	High level review of wind turbine noise	Package 1
4	International benchmarking: Introduction to Sections 5, 6 & 7	-
5	International benchmarking of wind farm noise control methods including consideration of cumulative noise and special audible characteristic	Package 2
6	International benchmarking of noise considerations during the planning stage for a wind farm	Package 2
7	International benchmarking of noise issues for operational wind farms noise control	Package 2
8	Review of current wind farm noise assessment practices in the Republic of Ireland	Package 3
9	Conclusions of desktop study	Package 4
10	Recommendations	Package 4
	Appendices addressing acoustic terminology, a literature review summary and bibliography.	-

2.0 SCOPING DISCUSSION

This section briefly outlines concepts of sound and how it can be measured as well as discussing the background for the current study and recent developments in wind farm noise assessment.

2.1 Acoustic basics

2.1.1 Sound and noise

Sound can generally be considered as what we hear with our ears. Noise, in particular, is unwanted sound.

That is, noise is a subset of sound, which is unwanted by a listener or group of listeners. Noise is therefore subjective. While noise is not technically a synonym for sound in day to day use, particularly in the field of acoustic consulting and noise impact assessments, the two terms are often used interchangeably.

Evaluation of sound involves several key concepts:

Frequency (pitch)

Sound can occur over a range of frequencies extending from the very low, such as the rumble of thunder, up to the very high such as the crash of cymbals. Sound is generally described over the frequency range from about 63 Hz up to 4000 Hz (4 kHz). This is roughly equal to the range of frequencies on a piano. The audible range of frequencies for humans is generally considered to span from about 20 Hz up to about 20,000 Hz. Frequencies below 20 Hz can also be audible if levels are sufficiently high.

Sound level (magnitude)

Decibel is the unit of sound level and is commonly denoted as dB. Adjusting the volume dial on a home stereo adjusts the sound level. The audible range of sound levels for humans is generally considered to span from 0 dB, the hearing threshold, up to 120+dB, where such high levels of sound can cause pain to listeners.

Changes in sound level

The decibel scale is logarithmic, not linear. This means that, for example, if two instances of the same sound occur at the same time, and each has a sound level of 30 dB, their combined level will be 33 dB. The combined level is not 60 dB.

Perceived changes in sound level

A perceived doubling in the loudness of a sound generally corresponds to a 10 dB increase in sound level[2]. That is, when listening to a sound that is 40 dB, increasing the sound level to 50 dB would subjectively be heard as a doubling in loudness. Increasing the sound level again, to 60 dB, would feel like a further doubling in loudness. Conversely, increasing the level of a given sound by 1-3 dB can often be imperceptible or only just perceptible while a 5 dB increase in sound level can be described as clearly noticeable[2].

[2] (Department of Health (Victoria), 2013)

Care should be taken, however, in applying these rules-of-thumb to noise measurements and noise limits. For example, wind farm noise is often measured for a period of weeks to collect data across a broad range ofweather conditions. Often, this large set of data is effectively averaged[3] to compare levels with applicable noise limits. Due to the data-averaging, a 3 dB change in sound level could be caused by a 3 dB increase in level during the entire assessment period or, alternatively, a much larger increase in sound level for only a portion of the assessment period. Typical subjective impressions of sound level could vary greatly between these two cases even though the average change in sound level is the same.

2.1.2 Sound indices

Changes in sound level with time

Sound is often not steady. The sound from traffic, music and the barking of dogs a reall examples of sounds that vary over time. When such sounds are measured, the sound level can be expressed as an average level, or as a percentile measure, such as the level exceeded for 90% of the time. Commonly used sound indices are L_{min}, L_{90}, L_{eq}, L_{10} and L_{max}. Figure 1 provides a time history plot demonstrating some examples of common sound indices as determined for a 30 minute measurement interval.

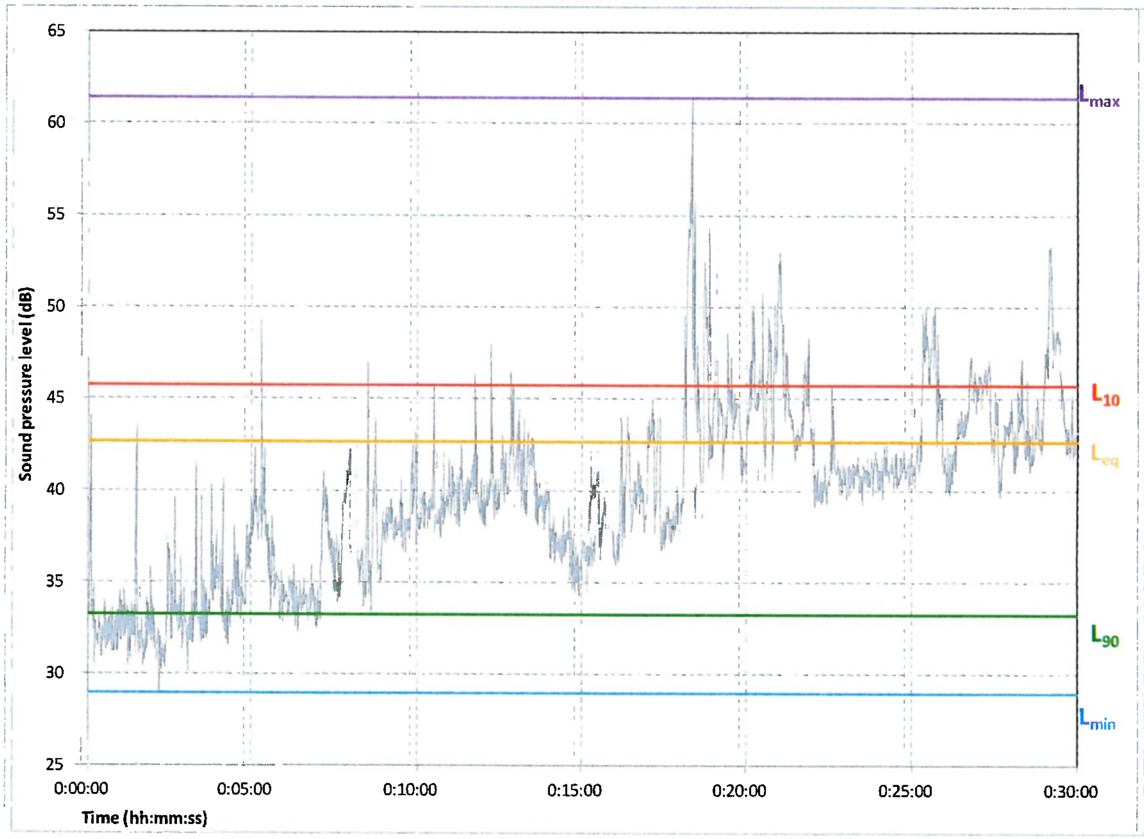

Figure 1: Example of noise indices that may be used to measure a time-varying sound level

[3] Typically using a regression analysis. Refer to Section 3.3 for details.

Frequency weightings

Where A-weighted decibels are used, the A-weighting approximates the response of the human ear over a range of frequencies. The A-weighting is one of many types of weightings and indices which adjust sound levels based on frequency content. Other examples include B, C and G weightings (see Appendix A for example weighting curves).

Example sound levels

Examples of typical noise levels experienced across a range of situations are presented in Figure 2 and Figure 3. Is it important to note however, that the levels presented are only indicative and appropriate as a 'rule of thumb' guide. Levels encountered in practice for a given activity could readily vary by ±10 decibels or more.

Sound	Noise Level (dB)	Effect
Boom Cars	145	
Jet Engines (near)	140	
Shotgun Firing Jet Takeoff (100–200 ft.)	130	
Rock Concerts (varies)	110–140	Threshold of pain begins around 125 dB
Oxygen Torch	121	
Discotheque/Boom Box Thunderclap (near)	120	Threshold of sensation begins around 120 dB
Stereos (over 100 watts)	110–125	
Symphony Orchestra Power Saw (chainsaw) Pneumatic Drill/Jackhammer	110	Regular exposure to sound over 100 dB of more than one minute risks permanent hearing loss
Snowmobile	105	
Jet Flyover (1000 ft.)	103	
Electric Furnace Area Garbage Truck/Cement Mixer	100	No more than 15 minutes of unprotected exposure recommended for sounds between 90–100 dB
Farm Tractor	98	
Newspaper Press	97	
Subway, Motorcycle (25 ft.)	88	Very annoying
Lawnmower, Food Blender	85–90	85 dB is the level at which hearing damage (8 hrs.) begins
Recreational Vehicles, TV	70–90	
Diesel Truck (40 mph, 50 ft.)	84	
Average City Traffic Garbage Disposal	80	Annoying; interferes with conversation; constant exposure may cause damage
Washing Machine	78	
Dishwasher	75	
Vacuum Cleaner, Hair Dryer	70	Intrusive; interferes with telephone conversation
Normal Conversation	50–65	
Quiet Office	50–60	Comfortable hearing levels are under 60 dB
Refrigerator Humming	40	
Whisper	30	Very quiet
Broadcasting Studio	30	
Rustling Leaves	20	Just audible
Normal Breathing	10	
		The threshold of normal hearing starts at about 1000 to 4000kHz.

Figure 2: Example A-weighted noise levels for a range of common activities [4]

[4] (National Institute of Deafness and other Communication Disorders (USA))

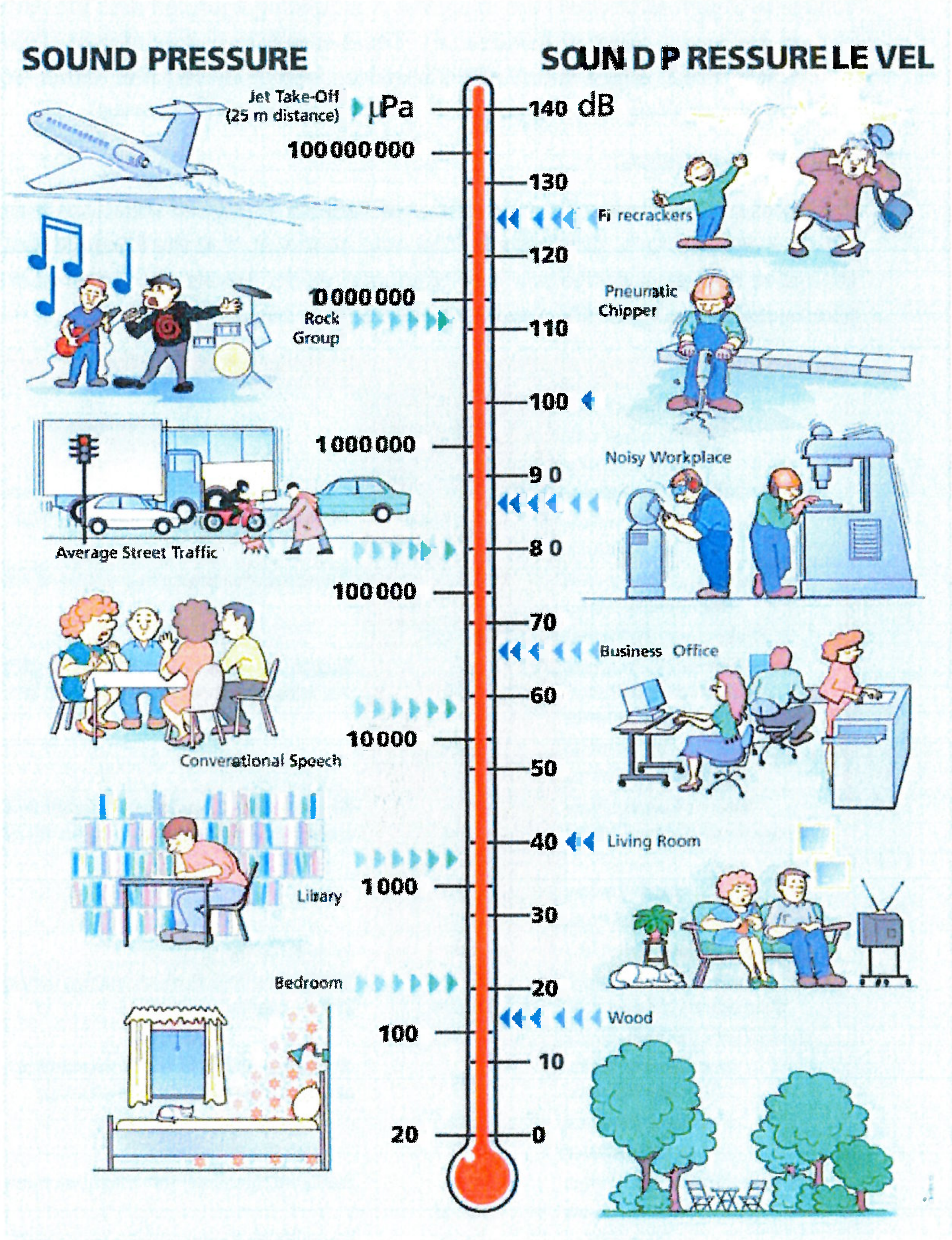

Figure 3: Example A-weighted noise levels for a range of common activities[5]

Additional indicative 'rule of thumb' levels are presented in Figure 4, an extract from the State Government of Victorian (Australia) Department of Health document *Wind farms, sound and health - Technical information*[6], including a reported level range for a typical wind farm operating at a moderate speed at a distance in the range 500m to 1000m.

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[5] (Bruel & Kjaer)

[6] (Department of Health (Victoria), 2013)

Table 3: Typical A-weighted sound levels for different sources (adapted from[4, 16])

Noise source	Sound level (dBA)
Quiet bedroom	20–25
Rural night-time background	20–40
Typical wind farm (at moderate wind speed 7 m/s)	35–45*
Car at 64 km/h at 100 m	55
Busy general office	60
Pneumatic drill at 15 m	95
Jet aircraft at 50 m	105
Threshold of pain	130

* Based on sound level measurements taken from multiple resident locations near two Victorian wind farms, at distances 500–1,000 m from the nearest turbine

Figure 4: Example A-weighted noise levels for a range of common activities[7]

2.2 Project background

Since the publication of the Renewable Energy Directive (2009/28/EC) mandatory targets have been set for all European states, with the overall target of 20% of all energy to come from renewable sources by 2020. In their contribution to this the Republic of Ireland has an overall renewable target of 16% of total final consumption from renewable by 2020, with a 40% contribution from renewable to the gross electricity consumption[8].

This puts legal requirements on the Government to increase the capacity for renewable energy. Whilst wind is an established renewable source of energy, an increased requirement for wind energy is likely to increase the number of potential wind farm neighbours, with associated potential noise impacts.

The Department of the Environment, Community and Local Government (DECLG) together with the Department of Communications Energy and Natural Resources (DCENR) have commenced a technical update of the guidance on noise in the *Wind Energy Development Guidelines 2006* (WEDG06), which superseded the original guidelines issued in September 1996.

With the agreement of the Minister for Housing and Planning, the Minister for Communications, Energy & Natural Resources asked the Sustainable Energy Authority of Ireland (SEAI) to assist DCELG and DCENR in their work to update WEDG06. It was agreed that SEAI would, with guidance from an interdepartmental group, commission a desk based study to review, and provide advice on, international best practice in relation to informing the guidelines on onshore wind farm noise. It was also agreed that this would form a key input into the review of the statutory guidelines.

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[7] (Department of Health (Victoria), 2013)

[8] See http://www.seai.ie/Publications/Statistics_Publications/Statistics_FAQ/Energy_Targets_FAQ/#What_are_Irelands

In common with other types of environmental noise sources, wind farms require a range of dedicated assessment techniques to deal with the issues specific to wind farms. The primary issue addressed by most wind farm noise guidance documents is considering how wind turbine or wind farm sound varies with changes in wind speed.

WEDG06 identifies noise as a relevant consideration for new wind farm developments and provides assessment guidance tailored to wind farms including broad guidance on noise limits and separation distances relevant for assessing new and cumulative proposals.

WEDG06 requires a noise assessment of proposed new developments, and requires both local planning authorities and An Bord Pleanála to have regard to WEDG06 in the performance of their functions under the Planning and Development Act, 2000. In common with previous versions of the guidelines, the current version seeks to strike a balance between the need to protect amenity of dwellings and other noise sensitive locations in rural areas where wind farms are often located, and the need to provide a viable framework for the expansion of wind powered renewable energy.

The technical update of WEDG06 presents an opportunity to review the suitability of existing wind farm noise assessment guidance and to consider provision of additional guidance that may support the application of the Wind Energy Development Guidelines to all phases of wind farm development to enable more consistent, reliable and transparent assessment processes for wind farm developments. Given the sensitivities associated with wind farm developments and noise related issues, it is envisaged that this would assist planning authorities in making more informed decisions, in turn benefiting community perception and understanding of the assessment process.

Delivering clear and robust noise assessment guidance is particularly relevant for wind farm developments as wind farms offer comparatively fewer methods of reducing or attenuating noise. For example, reducing noise from an operational wind farm typically requires operating turbines in reduced power modes, turning off turbines in some weather conditions or improving the sound insulation performance of dwelling façades. A number of conventional noise reduction methods that can work well with general noise sources, such as motorway barriers or acoustic enclosures for industrial equipment, are not practicable for reducing wind farm noise.

2.3 Developments in wind farm noise since 2006

WEDG06 was published in 2006. In many respects, key elements of wind farm noise assessment have remained fundamentally unchanged during the intervening period. For example, the 1996 document *The assessment and rating of noise from wind farms* (ETSU-R-97) still remains a widely used assessment tool in Ireland and correspondingly wind farm noise is largely assessed using A-weighted noise levels, with limits that have regard for the nature of the ambient noise environment at the receptor locations.

Since 2006 the public profile of wind farm noise issues has, however, arguably been heightened through a range of mechanisms including greater media exposure, the advent of social media and activity from lobby groups both opposing and supporting wind farm development. Public profile is also likely to continue changing over time. As more wind farm developments are completed a greater portion of the general population will acquire firsthand experience in viewing and hearing operational wind farms.

Whilst recent developments in the topic of onshore wind farm noise are implicitly incorporated into the body of this report, a broad snapshot of some key issues is outlined here to provide a more concise overview of topical issues. Notwithstanding this, it is recommended that the reader refer to the appropriate sections of this report for a detailed discussion of any particular issue.

Wind turbines have continued to increase in size and generating capacity since 2006, with capacities of up to 10MW reported to have been developed[9]. Changes in turbine design have the ability to contribute to reducing sound emission, through improved design. Conversely, increased turbine size could lead to higher sound emission and may alter the character of the sound[9].

Mechanisms for wind turbine sound generation have arguably become better understood since 2006, including advancements in understanding aerodynamic noise[10]. However, issues such as the prevalence, significance and onset of excessive amplitude modulation[11] are still not fully understood and are the subject on ongoing investigation[12].

A significant amount of institutional wind farm noise research has been carried out since the issue of WEDG06. This is likely due, in part, to the increasing number of wind farms in operation which are available to be researched and, in part, as a response to the increased public profile of wind farm noise issues. Examples of research projects include:

[9] (Bolin, Bluhm, Eriksson, & Nilsson, 2011)

[10] (Oerlemans, Detection of aeroacoustic sound sources on aircraft and wind turbines, 2009)

[11] Refer to Section 3.4 for descriptions of amplitude modulation.

[12] (Bass, Bowdler, McCaffery, & Grimes, 2011)

- Social surveys of annoyance (Pedersen, 2008[13])
- Review of low frequency noise content in wind turbine sound (Madsen et al, 2010[14])
- Research into perception of wind turbine sound (Hunerbein et al, 2010[15]).
- Differences in expectations of wind turbine noise leading to differences in reporting symptoms (Crichton et al, 2013[16])

Indeed at present there are several potentially significant studies in progress across various wind farm noise related disciplines, including:

- University of Adelaide *Resolving the mechanics of wind turbine noise production*[17]
- Health Canada *Wind turbine noise and health study*[18]
- RenewableUK *Fundamental research in amplitude modulation*[19]

Complaints and discussion of wind farm noise annoyance and potential wind farm noise related health effects have also heightened since 2006. Reports range from anecdotal accounts of annoyance and health effects by some wind farm neighbours to web content from lobby groups such as landscape guardian organisations and papers and reports from doctors and academics. Particular attention has been paid to potential special audible characteristics of wind turbine noise such as low frequency noise, infrasound and amplitude modulation[20]. Topical examples of reports and critiques include:

- A book titled *Wind Turbine Syndrome*[21] which investigates health complaints reported by a set of 37 wind farm neighbours.
- Work by Salt et al[22] concerning the sensitivity of the ear to infrasound
- Work by Nissenbaum et al[23] concerning effects of wind turbine noise on sleep disturbance and health.

Such documents have proven controversial and in some cases their findings are disputed. For example, a 2009 report prepared for the American and Canadian wind energy associations made the following comments about a 2009 pre-publication of the Wind Turbine Syndrome book:

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[13] (Pedersen & Larsman, The impact of visual factors on noise annoyance among people living in the vicinity of wind turbines, 2008) (Pedersen, van den Berg, Bakker, & Bouma, 2009)

[14] (Madsen & Pedersen, 2010)

[15] (Hunerbein, King, Hargreaves, Moorhouse, & Plack, 2010)

[16] (Crichton, Dodd, Schmid, Gamble, & Petrie, 2013)

[17] See: http://www.adelaide.edu.au/news/news58021.html

[18] See: http://www.hc-sc.gc.ca/ewh-semt/consult/_2013/wind_turbine-eoliennes/index-eng.php

[19] (Bass, Bowdler, McCaffery, & Grimes, 2011)

[20] Refer to Section 3.4 for a discussion of special audible characteristics

[21] (Pierpont, 2010)

[22] (Salt & Lichtenhan, 2011)

[23] (Nissenbaum, Aramini, & Hanning, 2012)

[...] the panel considered "wind turbine syndrome" and vibroacoustic disease, which have been claimed as causes of adverse health effects. The evidence indicates that "wind turbine syndrome" is based on misinterpretation of physiologic data and that the features of the so-called syndrome are merely a subset of annoyance reactions. The evidence for vibroacoustic disease (tissue inflammation and fibrosis associated with sound exposure) is extremely dubious at levels of sound associated with wind turbines.

Other cases, such as the sensitivity of the ear to infrasound, are the subject of ongoing debate[24].

Concurrently, a number of government agencies have prepared statements regarding potential association between wind farm noise and health effects. Examples include the Australian National Health and Medical Research Council (NHMRC) public statement dated July 2010[25] which states that:

There is currently no published scientific evidence to positively link wind turbines with adverse health effects.

Several notable guidance documents for wind farm noise assessment were developed during the 1990s and the early part of the 2000s when the potential for larger scale development of wind energy increased. The intervening period since the issue of WEDG06 has seen some of these documents revised, such as:

- New Zealand Standard 6808: 1998 *Acoustics - the assessment and measurement of sound from wind turbine generators*[26] which has been superseded by a 2010 version of the standard[27]
- International Electrotechnical Commission Standard 61400-11:2006 *Wind turbine generator systems - Part 11: Acoustic noise measurement techniques*[28], the international standard prescribing methods for measuring sound power levels from a turbine which was updated to Version 3.0[29] in December 2012
- The South Australian Wind Farm Guidelines 2003 which has been superseded by the document *Wind farms: Environmental noise guidelines* (July 2009)[30]

These revised documents generally detail refined versions of methodologies from the documents they supersede, as opposed to any fundamental shift in approach or methodology. This is consistent with some examples of recently developed guideline documents such as the Ontario Ministry of Environment *Noise Guidelines for Wind Farms*[31] produced in 2008 in the Canadian province of Ontario.

24 (Leventhall, Concerns about infrasound from wind turbines, 2013)

25 (National Health and Medical Research Council, 2010)

26 (Standards New Zealand, 1998)

27 (Standards New Zealand, 2010)

28 (International Electrotechnical Commission, 2006)

29 (International Electrotechnical Commission, 2012)

30 (South Australia Environment Protection Authority, 2009)

31 (Ontario Ministry of Environment, 2008)

While WEDG06 provides high level guidance on wind farm noise assessment, general practice in Ireland is to reference ETSU-R-97 for detailed guidance on assessment methodologies and measurement practices. In this context, the recently published Institute of Acoustics UK document *A good practice guide to the application of ETSU-R-97 for the assessment and rating of wind turbine noise*[32] (IOA GPG) published in May 2013 represents one of the most significant recent publications on wind farm noise in the Irish context, particularly in light of its endorsements by the English, Welsh & Scottish governments[33].

The IOA GPG was prepared to reflect current UK industry practice for wind farm noise assessments, where common and generally agreed practices have evolved from the application of ETSU-R-97 to new wind farm developments. Given the use of ETSU-R-97 in the context of WEDG06 and Irish wind farm developments, many of the IOA GPG comments and recommendations are, currently, as applicable to Irish wind farm developments as they are to UK projects.

2.4 Definitions and reference documents

There are a number of key terms and reference documents that are referred to regularly throughout this report. For clarity, details of the common references are provided here.

2.4.1 Definitions

Sound	**What we hear**
Noise	Unwanted sound
Wind farm neighbours	Property uses near a proposed or built wind farm that may be potentially impacted by wind farm noise. Associated terms include noise sensitive locations, dwellings, receptors and receivers[34].
Ambient noise	The total sound at a given position in the absence of the specific sound(s) being considered. At wind farm neighbours, ambient noise will typically refer to the noise or sound environment at the property excluding wind farm noise.
Background noise level	A type of measured sound level, commonly described in dB L_{A90}, being the level exceeded for 90% of the measurement period.

A complete list of acoustic terms used throughout this report is provided in Appendix A.

[32] (Cand, Davis, Jordan, Hayes, & Perkins, 2013)

[33] See: http://www.ioa.org.uk/about-us/news-article.asp?id=272

[34] A discussion of the types of properties classified as wind farm neighbours is provided in Section 3.3

2.4.2 Reference documents

Documents relevant to Irish wind farm noise assessments	
WEDG06	*Wind Energy Development Guidelines* Irish Department of Environment, Heritage and Local Government, 2006
ETSU-R-97	*ETSU-R-97 The assessment and rating of noise from wind farms*, Noise Working Group 1996, United Kingdom (Commissioned by the Department of Trade and Industry, UK)
NG3	*Guidance Note on Noise Assessment of Wind Turbine Operations at EPA Licensed Sites*, (EPA Ireland, Office of Environmental Enforcement)
Other wind farm noise assessment documents commonly referred to herein	
AS4595:2010	Standards Australia 4959:2010 *Acoustics – Measurement, prediction and assessment of noise from wind turbine generators*
DSO1284	Danish EPA document *Statutory Order on Noise from Wind Turbines (Translation of Statutory Order no. 1284 of 15 December 2011)*
IOA GPG	*A Good Practice Guide To The Application Of ETSU-R-97 For The Assessment And Rating Of Wind Turbine Noise* Institute of Acoustics UK, 2013, produced at the request of the UK Department of Energy and Climate Change (DECC)
IOA JS2009	Leventhall, G, Bullmore, A, Jiggins, M, Hayes, M, McKenzie, A, Bowdler, D & Davis, B 2009, 'Prediction and assessment of wind turbine noise – Agreement about relevant factors for noise assessment from wind energy projects', *Acoustics Bulletin*, March-April 2009, pp35-37.
NZS6808:2010	New Zealand Standard NZS 6808:2010 *Acoustics – Wind farm noise*
ONG2008	Ministry of the Environment (Province of Ontario, Canada), *Noise Guidelines for Wind Farms Interpretation for Applying MOE NPC Publications to Wind Power Generation Facilities* (October 2008)
SAG2009	Environment Protection Authority (State of South Australia, Australia) 2009, *Wind farms: Environmental noise guidelines* (July 2009)

A full list of referenced documents in provided in Appendix H.

2.5 Scope limitations and exclusions

Limitations

Deciding on the most appropriate noise control method for Irish wind farm development requires consideration of issues well beyond the comparatively narrow scope of assessments of noise impacts. Other relevant issues include effects on energy yield, community expectations, settlement patterns, regulatory constraints, regulator expertise and associated resource implications and competing requirements from other assessed effects such as, for example, landscape sensitivity analysis.

While recommendations developed simply on the basis of assessment of noise impacts can therefore only provide part of the information set required to decide on wind farm noise assessment practices, such recommendations are considered in this report to help inform any future review in the broader context. These recommendations are not, in isolation, an appropriate foundation for establishing noise control methods or assessment practices.

Issues not within the scope of this study

The following items are not directly addressed in this report:

- Extent of mitigation through turbine technology developments
  While it is recognised that refinements in turbine design have in many cases resulted in reduced sound emission, specific details of the methods of reducing sound and the levels of reduction achieved are not directly addressed in this report.

- Noise health impacts
  Health impacts of noise, including sleep disturbance and direct physiological effects of noise, are outside the scope of this study and are not considered directly in this report. It is noted however that health impacts of noise are a common consideration of regulators in their drafting of noise policies. Therefore, some limited, indirect consideration of health impacts is included in this report insofar as considering the noise control methods employed in different jurisdictions to manage wind farm noise. Additionally, where considered appropriate, this report references documentation provided by peak health bodies, such as regional departments of health, health protection agencies and the World Health Organisation, which discuss health issues associated with either general noise or wind farm noise. The brief overview of selected literature in Appendix G also considers studies where references are made to public health.

- Methodology and content of applications including Environmental Impact Assessments
  This report does not provide methodologies or prescriptive advice for assessment of wind farm noise as may be required for an environmental impact assessment.

- Capacity building for wind farms
  This report does not directly consider methods or strategies for increasing Ireland's wind energy generating capacity.

- Construction noise
  Noise associated with construction of wind farms is not addressed.

3.0 WIND FARM NOISE: SOURCE, PATH & RECEIVER (WORK PACKAGE 1)

This section provides a concise review of sources of noise from wind turbines, the propagation of sound away from turbines and the character and level of wind farm noise at common neighbouring locations.

3.1 Characteristics of wind farm noise

The noise produced by a wind farm is predominantly controlled by noise emissions from wind turbines. This section focuses primarily on wind turbine noise emission, discussing the following:

- Sources of wind turbine noise
- Methods for quantifying wind turbine sound levels
- Practical operation of modern wind turbines and associated sound level characteristics
- Relationships between turbine size and sound level

A full assessment of noise effects could also consider other sources including ancillary infrastructure such as substations, transmission lines and meteorological masts. A brief discussion of wind farm noise sources other than wind turbines is provided in Appendix B.

3.1.1 Anatomy of a wind turbine

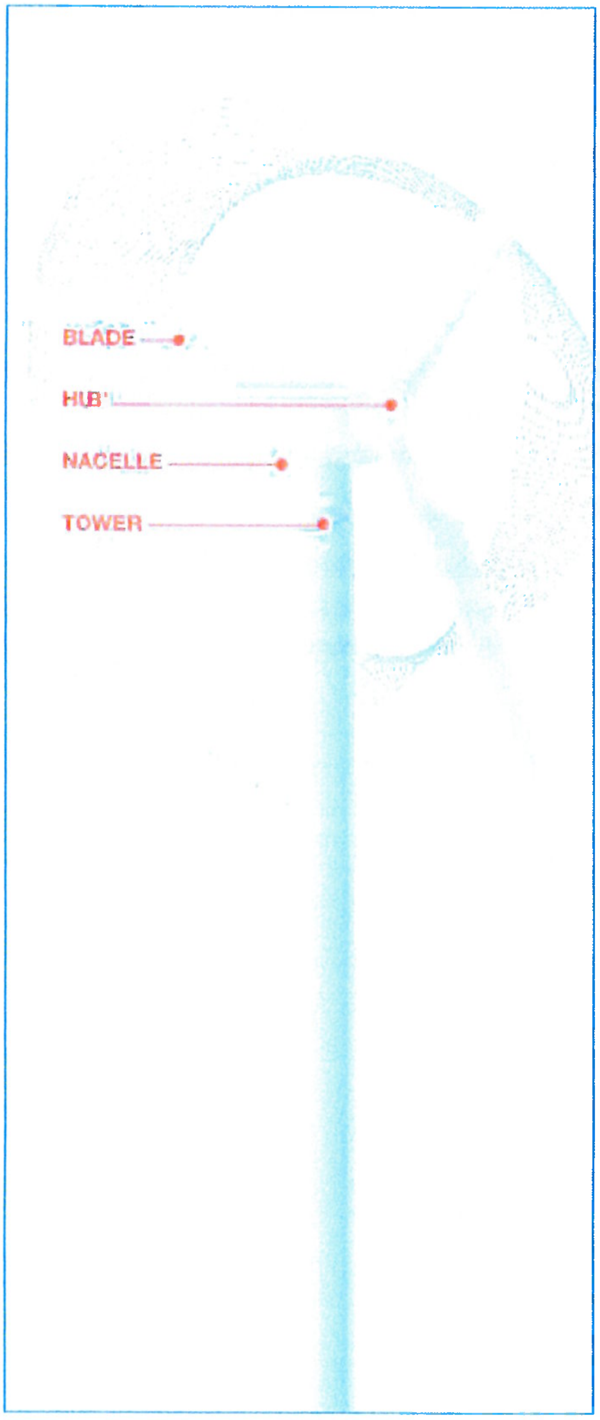

Figure 5: Schematic of a wind turbine[35]

Modern wind turbines are generally configured with a horizontal axis of rotation, comprising three blades with lengths of around 15-50m and tower heights typically ranging from 20m to 125m or more with tip heights reaching in excess of 175m. A schematic of a horizontal axis wind turbine is shown in Figure 5.

The electricity generating process begins with kinetic energy from wind creating lift on turbine blades (aerofoils) and rotating the turbine shaft. The shaft is often connected to an electrical generator via a gearbox which steps up the rotational speed between the shaft and the generator.

An electrical transformer, typically located at the base of the turbine tower, manages the transfer of electricity away from the turbine.

The turbine is turned to face into the wind by a 'yaw' system between the tower and nacelle. Some turbines, referred to as 'pitch controlled', include controls to rotate the angle of the blades with respect to the wind to regulate power output and rotational forces.

The components of a wind turbine are illustrated in Figure 6 below.

[35] (American Wind Energy Association, 2011)

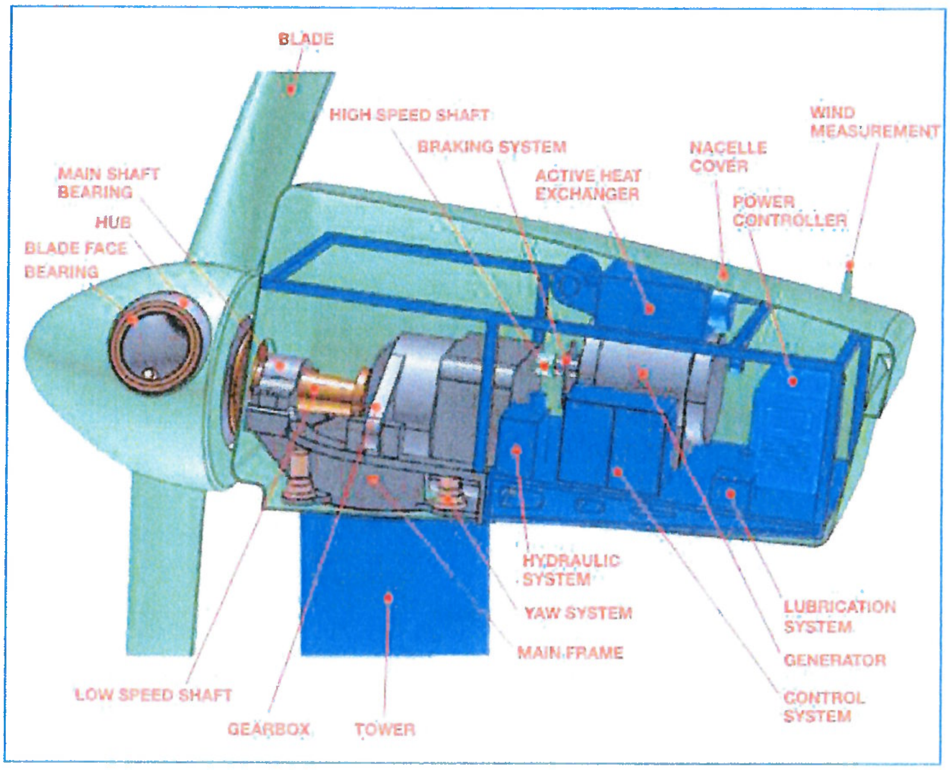

Figure 6: Anatomy of a wind turbine[36]

Alternative turbine types include two blade designs and turbines with a vertical axis of rotation. Due to their limited application they are not directly considered here.

3.1.2 Wind turbine noise sources

What distinguishes wind turbine noise emission from more conventional sources of sound is that it tends to increase with increasing wind speed. Concurrently, the ambient noise environment at neighbouring locations will also often change with wind speed. These variations in both wind turbine sound levels and receiver sound levels create a dynamic and variable interaction which has commonly prompted development of specific wind farm noise guidance documents in many jurisdictions.

A wind turbine's noise sources can be classified into two broad categories:

- mechanical noise from components in the hub and nacelle, and
- aerodynamic noise from the interaction between wind and turbine blades.

Mechanical noise in the nacelle, from sources such as the gearbox, generator and cooling systems, can be attenuated by conventional noise control methods. This can include methods to reduce vibrational forces in moving parts such as improved acoustic and vibration isolation around rotating equipment and improved sound insulation design of nacelle and machinery housings.

Aerodynamic noise involves complex phenomena and is comparatively more difficult to reduce. Aerodynamic noise from turbine blades is generally the dominant noise source from wind turbines[37].

[36] (American Wind Energy Association, 2011)

There are four mechanisms of aerodynamic noise generation on turbine blades, summarised in Figure 7 and Table 1.

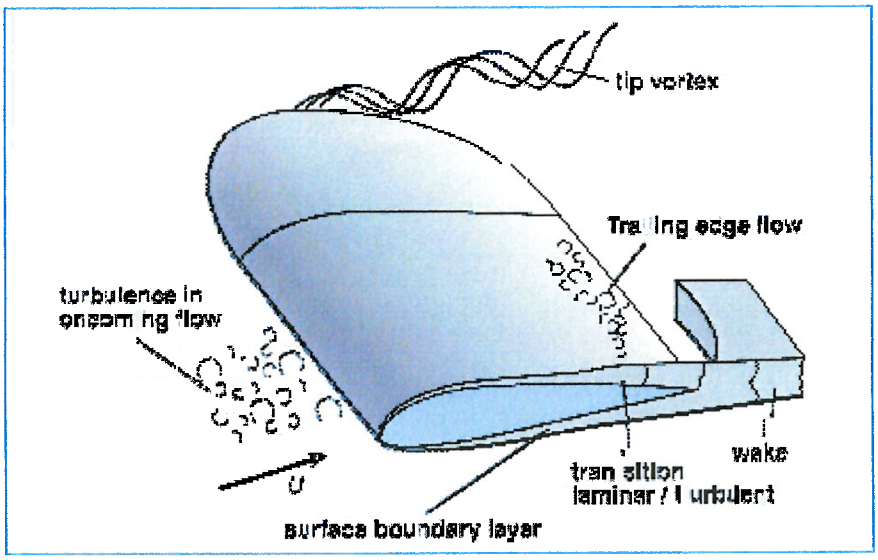

Figure 7: Turbine blade aerodynamic noise generation[38]

Table 1: Turbine blade aerodynamic noise generation[39]

Noise source	Mechanism	Sound characteristics
Inflow turbulence	Atmospheric turbulence in oncoming flow impinging on aerofoil	Broadband sound at lower frequencies
Tip noise	Difference in pressures on either side of turbine blade results in vortex shedding, which may interact with the aerofoil tip, radiating as noise	Broadband sound at higher frequencies
Trailing edge noise	Typically a turbulent boundary layer develops along the aerofoil (blade) cord, with turbulence being scattered as sound at the aerofoil trailing edge	Broadband sound at higher frequencies
Blade tower interaction	Airflow upwind of the tower is disturbed by the presence of the tower downwind, causing a changing in pressure on the aerofoil (blade) as it passes the tower	Broadband sound at lower frequencies, including sound below 20 Hz[40]

[37] (Oerlemans, Detection of aeroacoustic sound sources on aircraft and wind turbines, 2009)
(Oerlemans, Sijtsma, & Mendez-Lopez, Location and quantification of noise sources on a wind turbine, 2007)
(Doolan, 2011)

[38] (Oerlemans, Detection of aeroacoustic sound sources on aircraft and wind turbines, 2009)

[39] (American Wind Energy Association, 2011)
(Oerlemans, Detection of aeroacoustic sound sources on aircraft and wind turbines, 2009)

[40] (Guidati, Bareiz, & Wagner, 1994)

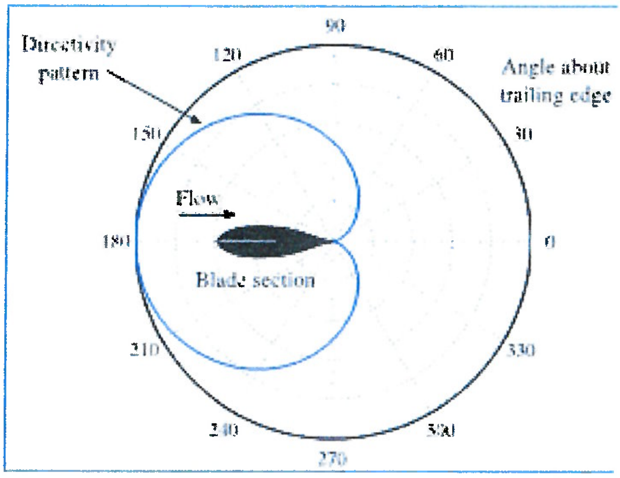

Figure 8: Trailing edge noise directivity pattern[41]

Figure 9: Wind turbine sound source localisation (clockwise rotation)[42]

Trailing edge noise is typically the dominant noise source from wind turbines[38]. It is broadband in chara and theoretically exhibits a cardioic radiation pattern towards the turb blade leading edge, as depicted in Figure 8.

This means that more trailing edge noise is radiated in some direction others and, in the current case, the trailing edge noise will be at a grea level in front of the blade than beh

Noise directivity from the blade or aerofoil trailing edge is considered the cause of the characteristic 'swi associated with wind turbine sounc

Due to its directivity pattern, trailin edge noise is directed towards a receiver at ground level during the down stroke of the blade, and awa from a receiver on the ground duri the up stroke. This is illustrated in Figure 9.

[41] (Oerlemans, Detection of aeroacoustic sound sources on aircraft and wind turbines, 2009)

[42] (Oerlemans, Sijtsma, & Mendez-Lopez, Location and quantification of noise sources on a wind turbine, 2007)

Some aspects of wind turbine sound are less well understood such as the special audible characteristic amplitude modulation which is discussed in Section 3.4.6. Potential causes for such aspects may include source generating mechanisms additional to those outlined above as well as propagation mechanisms such as turbine sound arriving at a dwelling in phase. However, the current state of available knowledge about these aspects is limited and is the subject of ongoing research[43].

3.1.3 Quantifying wind turbine sound

As with most general noise sources, the sound from a wind turbine can be quantified by determining its sound power level. This is a measure of the sound power output, which is a suitable input for sound propagation models, as discussed in Section 3.2.

The prediction of sound power output from a turbine is a complex undertaking, but the measurement of sound power from a given design is a carefully prescribed procedure, described in IEC 61400-11[44]. The use of the standard is a necessary step in the certification of a turbine for commercial use, and provides data which can be used to predict sound levels emitted from a wind farm, subject to the uncertainties described in Section 3 2.

The standard requires measurement of wind turbine sound on the ground near the turbine, with a separation distance approximately equal to the maximum turbine tip height. The measured sound pressure levels are used to calculate the sound power of the test turbine, and levels are correlated with wind speeds to detail how sound levels vary with wind speed. The wind speeds are generally assessed at the hub height of the turbine as this is considered to be a suitable representation of the wind conditions that determine the operating performance of the turbine[45]. In some cases there is a historical convention to express sound power levels as a function of standardised windspeeds, which are windspeeds assessed at hub height which are then re-referenced to 10m above ground level (AGL) using a reference roughness length z_{0ref} of 0.05m. It is important that the wind speed reference height, and any associated wind shear assumptions, are clear when referring to performance characteristics of a wind turbine at any wind speed. Refer to Appendix C for further details.

3.1.4 Characteristics of modern wind turbines

Modern wind turbines begin generating electricity at wind speeds of around 3 m/s to 4 m/s at hub height, referred to as 'cut-in' wind speed. Maximum power output is typically reached at around 10 m/s at hub height, referred to as 'rated power'. At greater wind speeds the rotational speed of the turbine blades must be controlled to prevent damage. This is achieved by either pitch or stall control.

Stall controlled turbines comprise blades that produce reduced lift and increased drag at wind speeds above rated power, thereby controlling rotational forces at high wind speeds. Pitch controlled turbines feather the angle of the blades above rated power, maintaining a steady torque and power output until a maximum or cut-out wind speed, around 25 m/s, where brakes are applied.

[43] (Bass, Bowdler, McCaffery, & Grimes, 2011)

[44] (International Electrotechnical Commission, 2012)

[45] The recommended method for assessing wind speeds is the use of power output data, which can be compared to published power curves to estimate wind speeds for the time period of interest.

In general, wind turbines produce very little noise when not turning, that is, at wind speeds below cut-in. Some noise is produced from yaw motors, blade pitch actuators, brakes, and hydraulic pumps which service these functions. The transformer at the base of the turbine is energised and may produce some noise. These noise sources are usually much quieter than the rated aerodynamic noise emissions of a turbine, and so are rarely responsible for noise complaints. However, these noises are more likely to contain tonal or impulsive features.

As the wind speed increases and the turbine begins to rotate, aerodynamic noise is generated. With pitch-controlled turbines, the sound level from the blades generally increases with wind speed until a point at or near the turbine's rated power. The sound level of pitch and stall regulated turbines differ markedly at wind speeds above rated power, as illustrated in Figure 10.

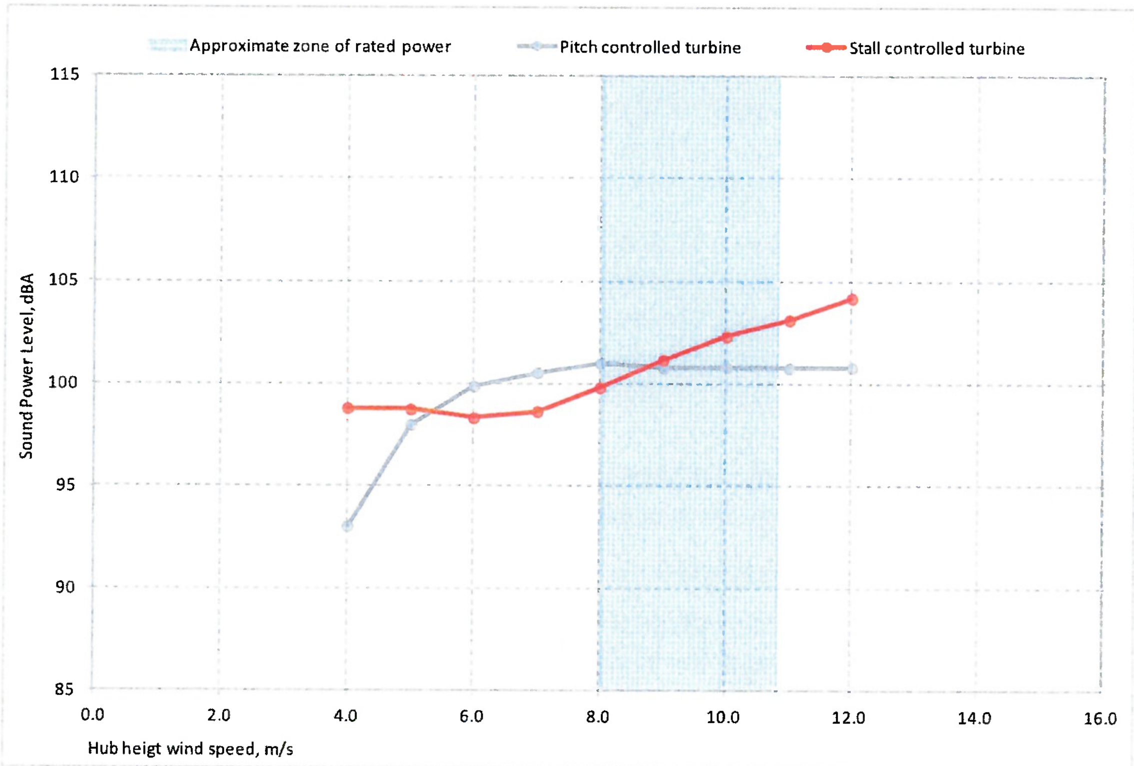

Figure 10: Example sound power level curves for pitch controlled and stall controlled turbines[46]

The sound level output from stall controlled turbines continues to increase above rated power, although power output plateaus or slightly decreases. Increased sound level is due to turbulence associated with turbine stall. A pitch controlled turbine's sound level reaches a maximum at rated power and remains constant, or decreases slightly afterwards.

[46] Wind turbine sound power levels are commonly measured at wind speeds approximately from cut-in to rated power. IEC 61400-11:2006, for example, requires determining sound power levels for the standardised wind speed range from 6m/s t0 10m/s at 10m AGL. It should be noted that while Figure 10 does not present sound levels above 12m/s, the wind turbines will continue to operate at higher wind speeds and will therefore also continue to produce sound.

The sound levels presented in Figure 10 are overall A-weighted levels. The observed A-weighted sound level trends can very when particular frequency intervals are considered. For example, a 2008 study[47] of low frequency noise from two up-wind turbines (1.5-MW and 660-kW) showed that infrasound noise emission from the stall and pitch regulated turbines in the study continued to increase above rated power. Low frequency noise and infrasound are discussed further in Section 3.4.

The most recent developments in wind farm power control have produced pitch regulated turbines which potentially produce better output power quality[48]. These factors have made pitch controlled turbines a common choice for multi-megawatt wind farm developments, both in terms of turbine designs and wind farm installations (as observed by the European Wind Energy Association[49], and a pattern reflected in Australian and New Zealand wind farms).

Modern multi-megawatt turbines can often be operated in different modes allowing reduced noise output, at the expense of power output, under certain operating conditions. The noise reduction achieved by various reduced power modes typically ranges from 1 decibel to 5 decibels or more[50].

This means that a turbines operation may be tailored to specific noise sensitive conditions, for example, a wind direction that supports sound propagation towards a nearby dwelling. This also allows turbines to be "derated" after installation, providing a means of mitigating noise levels once the farm is operational. When evaluating the noise characteristics of a particular wind farm design, it is important to specify not only the turbine but also its operational mode, so that its noise characteristics are known. The operating mode of the turbine may form part of the farm's noise management procedures, and should be understood when carrying out compliance testing.

3.1.5 Turbine size and sound level

A Danish study of wind turbine noise[51] surveyed the noise levels from 48 different wind turbine models with the aim of examining the relationship between emitted sound power and turbine size. The study surveyed 37 turbines of less than 2MW power output, representing small turbines, and 11 larger turbines, greater than 2MW power output, with the largest a 3.6 MW turbine.

The study used regression analysis to determine the trend in sound level output as a function of turbine size. It found a positive linear relationship, meaning that larger turbines may produce slightly more noise than small turbines, for equal power generation. A regression analysis of the study is shown in Figure 11 below for a nominal wind speed of 8m/s.

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[47] (Jung, Cheong, Shin, & Chueng, 2008)

[48] See http://www.wind-energy-the-facts.org/en/part-i-technology/chapter-3-wind-turbine-technology/technology-trends/pitch-versus-stall.html

[49] (Gardner, Garrad, Jamieson, Snodin, & Tindal, 2003)

[50] (Bowdler & Leventhall, Wind turbine noise, 2011) Chapter 2 & (Probst, Probst, & Huber, 2013)

[51] (Moller & Pedersen, 2011)

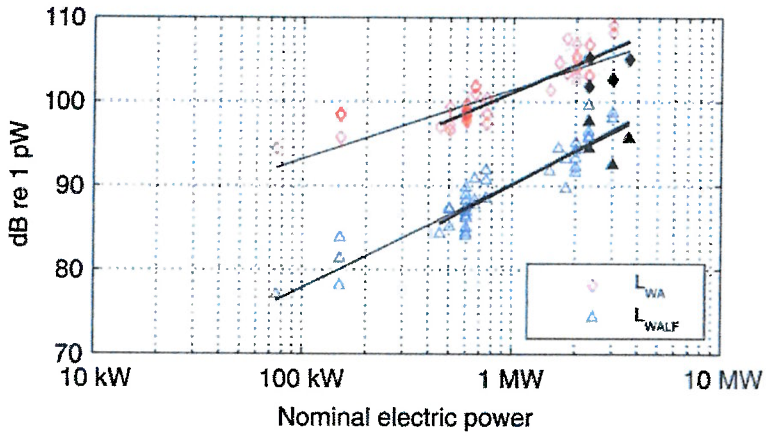

FIG. 1. (Color online) Apparent sound power levels (L_{WA} and L_{WALF}) in the reference direction as a function of turbine size. Wind speed is 8 m/s. Regression lines: all turbines included (thin lines), four turbines below 450 kW excluded (bold lines). Black-filled marks are for turbines 1–4.

Figure 11: Sound level versus turbine size[52]

For example, as shown by the regression line through the red points, a doubling of in turbine generating capacity from 1MW to 2 MW may result in slightly more than a doubling of the overall A-weighted sound power level (L_{WA}), that is, an increase of more than 3 dB. The study does, however, note that the relationship is not necessarily statistically significant[53]. Also, it should not necessarily be taken to mean that, for a given site, large turbines would result in more noise at a dwelling than smaller turbines. As the turbine size increases, greater distance between turbines is generally required to avoid detrimental interaction between turbines[54]. Also, as shown by the scatter of data in Figure 11, for a range of turbines with the same power generating capacity, sound level output can vary by several decibels.

The regression curve through the blue dots in Figure 11, the low frequency sound power levels (L_{WALF}), has a steeper slope than the A-weighted regression curve through the red dots implying that turbine size has a comparatively greater influence on low frequency noise. This trend can be further demonstrated by considering the frequency spectra of the turbines. The different spectra of turbines with power less than 2MW, and larger turbines with output greater than 2MW are illustrated in Figure 12, which illustrates a downward shift in the spectra of sound with increasing turbine size[55], in the order of 1/3 of an octave.

[52] (Moller & Pedersen, 2011)

[53] A comment in Section IV.A of the study notes: *It must be added that the slope of the regression line is not significantly higher than 10 dB [90% confidence interval 9.53–12.40, p(slope10 dB)¼0.133]. With a slope of 10 dB, the noise-occupied area is the same for small and large turbines for the same installed nominal electric power*

[54] This often is a factor in the total number of turbines which can be operated on a given site.

[55] That is, a shift to the left

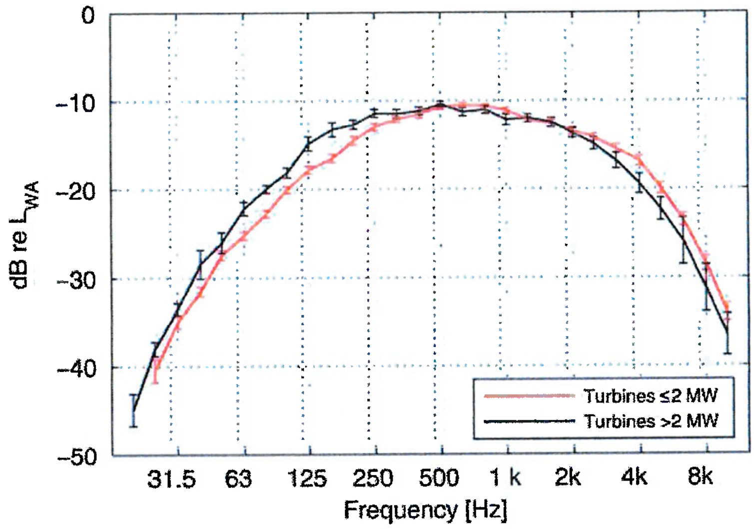

FIG. 4. (Color online) Normalized A-weighted apparent sound power levels in one-third-octave bands, means of two groups of turbines: ≤ 2 MW and > 2 MW. Error bars indicate ± 1 standard error of mean.

Figure 12. Spectrum comparison between larger and smaller turbines[52]

The study concludes that a *'further shift of similar size is suggested for turbines in the 10-MW range'*. However, this conclusion is based on data review for turbines up to 3.6MW only. Given the complex range of factors that could influence future turbine sound levels, it would seem wise to consider such comments judiciously.

3.2 Sound propagation

Noise from a wind farm arrives at a noise sensitive location almost exclusively by propagation through the air. Several studies have examined the possibility that ground-borne transmission could be significant, but have shown that such transmission produces vibration levels which are orders of magnitude less than that which can be perceived by humans[56].

The impact of wind farm noise therefore depends on the manner in which sound propagates through the air, and this forms the basis for noise level prediction methodologies. A number of methods exist to predict the level of sound received at noise sensitive locations. These methods have been developed as general tools for sound propagation, but significant effort has been made to validate their use specifically for wind farms as discussed in Section 3.2.2 below.

In the planning stages of a wind farm, it is necessary to apply these methods to establish the noise level which will be received by neighbours of a wind farm. This allows the developer to tailor the design of the wind farm and control the level of noise.

[56] (Bowdler, et al., 2009), (Styles, Stimpson, Toon, England, & Wright, 2005)

3.2.1 Factors of sound propagation

A number of physical factors affect the amount of sound propagated from source to receiver. Major factors include distance, absorption by air, interaction with ground and ground cover, interference by barriers, and wind effects. Minor factors include interaction with vegetation and buildings or other scattering features.

These factors are described in detail as follows.

Distance

Sound from a single-point source reduces in intensity at a rate of 6 decibels per doubling of distance. For instance a noise source which produces 70 dB at a distance of 5 metres could be expected to produce 64 dB at 10 metres, and 58 dB at 20 metres.

This change in intensity relates to the sound energy being spread over a greater area as the measurement point moves further from the source – the energy is potentially being shared by a greater number of receivers so each receiver receives less.

While at small distances a wind turbine may be difficult to view as a single-point source, the typical distances from which they may be heard (e.g. hundreds or thousands of metres) allows a wind turbine to be treated as a point source.

The sensitivity of noise level to source-receiver distance is large at close distances, but relatively small at typical distances that houses would be found from a wind farm. For example, at a distance of 1000 metres, it is necessary to move approximately 500 metres closer, or 1000 metres further from a point source to cause a 6 decibel change in noise level.

Air absorption

The interaction of sound energy with the atmosphere causes energy to be lost with distance. This loss occurs in addition to the reduction due to spreading discussed in the preceding section.

Unlike spreading attenuation, air absorption losses are calculated on a per-meter basis—the loss due to the 1st metre of travel is the same as the loss due to the 1000th meter of travel.

Air absorption also differs from spreading attenuation in that it is frequency dependant – high frequencies are lost more rapidly than low frequencies. The following table[57] describes the losses in decibels per 1000 metres of distance, for air at 70% relative humidity and 10˚ C.

Table 2: ISO 9613-1: 1993 Example air absorption coefficients

	One-third octave band centre frequency (Hz)								
Description	**63**	**125**	**250**	**500**	**1k**	**2k**	**4k**	**8k**	**Hz**
Air Absorption coefficient	0.12	0.41	1.04	1.93	3.66	9.66	32.8	117	dB/km

[57] (International Standards Organisation, 1993), ISO 9613-1:1993

It is apparent from Table 2 that at a separation distance of, for example, 1000m, air absorption removes very large amounts of high frequency sound, but makes almost no change to low frequency sound. This can be a significant factor in removing sounds such as whistles which are significant in the near field of a wind turbine, and shifting community attention to the low and mid-frequency features of a wind farm. A comparison of the air absorption coefficients from Table 2 with an example sound power level spectrum for a multi-megawatt turbine is illustrated in Figure 13. Comparing the magnitude of the wind turbine octave-band sound power levels (red bars) with the air absorption coefficients (red line) demonstrates that large portions of high frequency sound, in the 4 kHz and 8 kHz octave bands, will be attenuated by air absorption over a path of 1000m. The grey bars on the chart show A-weighted octave-band sound power levels for the wind turbine.

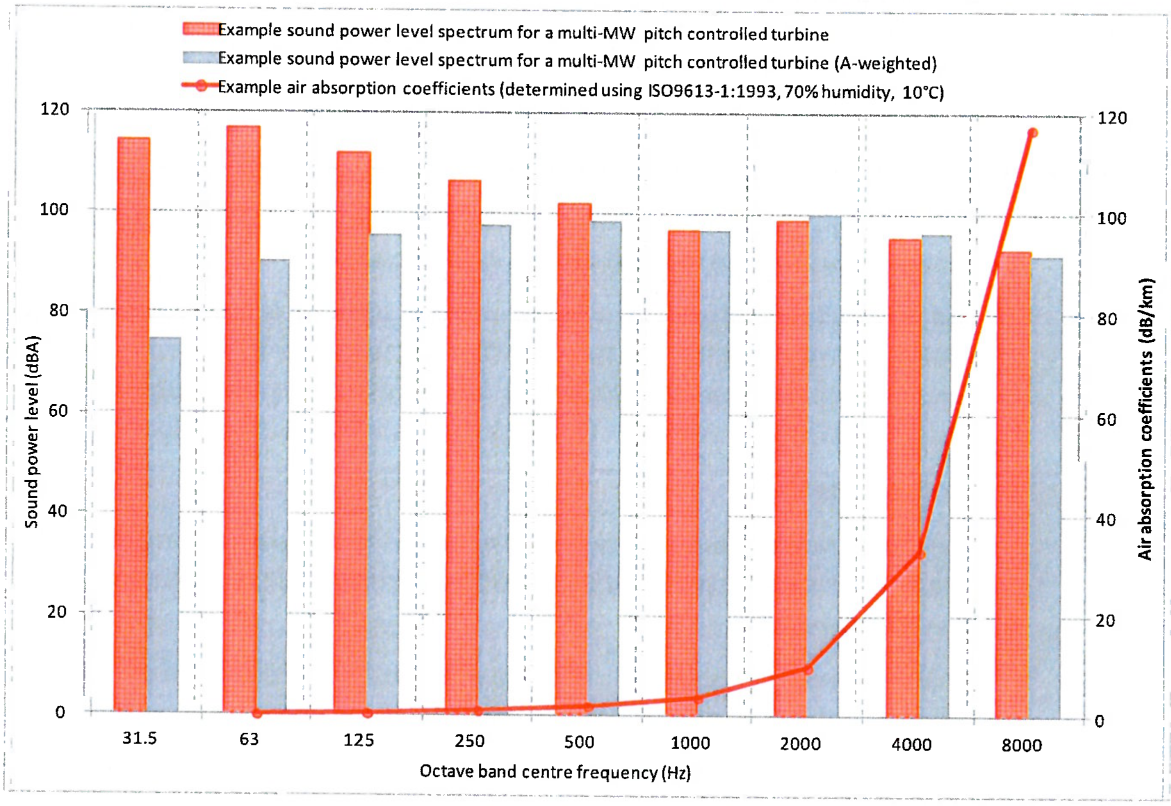

Figure 13: Example sound power level spectrum compared with air absorption coefficients

Ground effect

Ground effect concerns the interaction between reflections of sound from the ground and the direct sound path from source to receiver. Ground effect depends on the height of the source and the receiver, and on the characteristics of the ground, specifically its reflectivity or impedance.

For practical purposes, ground is characterised by its hardness or softness, generally relating to the amount of sound it reflects or absorbs. In more complex prediction models it is also characterised by roughness or unevenness.

Ground effect occurs when the ground is reflective to some degree, causing a series of peaks and dips in the frequency response of the received sound. When the ground is completely absorptive, no reflected energy reaches the receiver such that the resulting sound level is not affected[58].

The practical effect on wind farm sound from ground effect is typically that some frequencies will increase in level by 1 – 6 decibels, and others will decrease significantly. The significant changes generally occur in the lower midrange of frequencies – below 1 kHz.

Screening

Screening can provide attenuation generally between 0 – 20 decibels[58] when blocking or nearly blocking line of sight between a source and a receiver. The effectiveness of a screen or barrier depends on the difference in path length between the direct source-receiver path and the indirect source-barrier edge-receiver path.

For most practical situations involving wind farms, the screening attenuation is caused by terrain such as hills intervening in the propagation path. At the distances commonly involved, the potential path length differences are small, and the effective attenuation that can be realised is often less than 5 decibels. Special conditions arise when barriers are very close to receiver locations, and attenuation can be higher.

Screening attenuation varies by frequency, with greater attenuation offered to high frequencies than to low frequencies. At residential distances from wind farms, much of the high frequency noise content is already lost to air attenuation, and the screening effects must be considered in relation to the remaining lower frequency sound.

Barriers and screens can also change the degree of ground effect which is realised, as they may significantly change the amount of reflected sound which contributes to the energy at the receiver location.

Atmospheric effects

Sound propagation can be significantly affected by atmospheric conditions such as wind and temperature inversion. At wind farm sites, noise is mainly an issue under windy conditions when temperature inversions are uncommon, suggesting that wind effects are the most important atmospheric situation to consider.

The effect of wind on sound propagation is due to the wind speed gradients which arise as wind flows along the terrain. The resistance of flow along the ground causes the wind speed to be slower nearer to the ground, and faster with increasing elevation. The resulting wind speed gradient creates a sound speed gradient, which causes sound to bend in the direction of the slower flow.

[58] (Bowdler & Leventhall, Wind turbine noise, 2011)

For a receiver downwind from a source, this causes sound to bend toward the receiver. As a result, barrier attenuation can be reduced or eliminated, and ground reflection paths can be reinforced. This can result in a slight increase in sound level, around 2 dB[59], due to reinforced hard ground reflections. Where significant barrier attenuation is present the increases may be larger as these barriers become less effective.

For a receiver upwind from a source, the propagating sound bends upward, and a "shadow region" beyond a certain distance appears. In this region the attenuation of sound can be as much as 20 decibels[59].

Vegetation and Buildings

The attenuation provided by vegetation, for instance stands of wind break trees, is generally of limited magnitude—typically less than 1 decibel. However this attenuation can become significant when sound passes through large depths of trees or vegetation, such as through several hundred metres of plantation, where up to 10 decibels of attenuation is predicted by one noise model[60]—albeit under conditions where foliage is consistently high enough to block line of sight between the wind farm turbines and the receivers.

Buildings can also offer screening to noise sources, but in practical wind farm applications this is rarely significant. The screening in built-up areas is often negated by reflections from the sides of buildings.

3.2.2 Sound propagation models

A number of models have been developed to take the above aspects into account and predict sound levels at a distance from the source. They differ in method, complexity, and ease of use. Selecting an appropriate model for a given situation is a matter of striking a balance between these aspects.

A review of several noise models with respect to wind turbine predictions is presented in Wind Turbine Noise[61]. The review considers the ISO 9613-2[62], HarmoNoise, and Nord2000[63], and also briefly discusses other methods which are in some ways more accurate, but more difficult to practically implement. ISO 9613-2, HarmoNoise, and Nord2000 are discussed in further detail below along with limited applications models which offer simpler model set up in exchange for reduced prediction accuracy.

[59] (Bowdler & Leventhall, Wind turbine noise, 2011), Chapter 3.

[60] (International Standards Organisation, 1996), ISO 9613-2:1996, Annex A

[61] (Bowdler & Leventhall, Wind turbine noise, 2011)

[62] (International Standards Organisation, 1996), ISO 9613-2:1996

[63] (Plovsing, 2007)

ISO9613-2

The ISO 9613-2 propagation model is a general purpose noise propagation method which directly models the effects discussed previously. It has become established as the primary international standard for calculation of industrial noise into the environment. ISO 9613-2 predicts noise for receivers which are generally downwind (under light wind conditions) from sources. The model is validated in the Standard for a maximum source height of 30 metres, and a maximum source-receiver distance of 1000 metres. Within these bounds the stated accuracy of the model is +/- 3 dB. Use beyond these parameters is not precluded, but no statement of error bounds is provided in that case.

Work to validate the use of ISO 9613-2 has been described in a number of studies[64]. ISO 9613-2 has been shown to be a reliable predictor of wind turbine noise. It is limited in that it does not contain a means for predicting noise upwind of or crosswind to a wind farm, but in the common practice of calculating the worst-case scenario under a variety of meteorological conditions this is not necessarily a significant shortcoming. Some guidance has been provided[65] on the selection of parameters that are left to the investigator's discretion, to best achieve reliable results using ISO 9613-2 for wind farm prediction. Specific issues considered include barriers, to determine attenuation based on turbine tip height, and ground effects across including consideration of valleys and suitable values for the Ground Factor variable.

HarmoNoise and Nord2000

Nord2000 and more recently HarmoNoise have been developed as more detailed methods for predicting sound propagation, based on ray methods. Both models consider the same parameters as the ISO 9613-2 model, but handle ground reflections, barrier diffraction, reflection, and scattering, in a more detailed manner.

Of particular interest to wind farm applications, this allows the effects of wind movement to be more accurately modelled, and provides a means of predicting upwind noise propagation, albeit with a greater uncertainty than in the downwind case[66].

The accuracy of these models may be better than ISO 9613-2. For example, a recent wind farm noise modelling validation report for Nord2000[66] states that:

> *Generally the conclusion on validation is that for the tested situations Nord2000 shows a fine agreement with noise measurements for simple flat terrain with simple meteorology and for complex terrain with complex meteorology. When compared to ISO 613-2:1996 the Nord2000 model is an improvement especially for the complex situations.*

The accuracy of these models depends on a somewhat greater degree of input complexity, particularly with regard to terrain and ground characteristics. Therefore the improved accuracy may not be realised if limited data is available as input to the model.

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[64] (Bass, Bullmore, & Sloth, 1998), (Alberola, 2004), (Adcock, Bullmore, Jiggins, & Cand, 2007), (Bullmore, Adcock, Jiggins, & Cand, 2009), (Halstead & Hunt, 2007)

[65] (Bowdler, et al., 2009), (IOA JS2009)

[66] (Sondergaard & Plovsing, 2009)

Limited Application Models

In some instances, for example in the 1998 and 2010 versions of New Zealand Standard NZS6808, prediction methods have been offered which provide a lower accuracy in exchange for simpler data requirements and calculation complexity. The reduced accuracy is considered to err on the more conservative side of the true value, in other words an over-prediction of sound level.

In the 1998 version of the standard, a model is proposed which takes into account distance and air absorption, but not ground effect or barriers or miscellaneous attenuations. The standard permits calculation of the single-value A-weighted noise level only, rather than calculation of individual octave bands. This has since been shown to lead to under prediction at larger distances.

In the 2010 version of the standard, a simplified version of ISO 9613-2 is presented which requires the user to calculate noise in octave bands, and takes account of distance, air absorption, and ground attenuation in a simplified way. Barrier attenuation is not considered, and the requirement for using the simplified method is that it only be used when barriers are not occurring in the topography.

3.2.3 Implementations

Models such as the those discussed above can be evaluated manually or implemented into a spreadsheet, but are more usefully applied with software[67] which incorporates GIS data input and output, allowing a representation of the 3D environment to be integrated into the noise calculations and therefore into the design process.

Within any of these models, the sound level at a receiver which is produced by each source is calculated, and then these levels are summed to produce the total contribution of the wind farm .This result can be displayed as a table of noise levels at particular properties, or can be calculated over a grid of locations and presented as noise contours.

3.2.4 Design assumptions

As noted above, ISO 9613-2 predictions assume that receivers are generally downwind from each source. In the context of wind farm noise predictions, this implies that each turbine at a site is exposed to the same wind conditions at the same time. Using sound power level data measured in accordance with IEC 1400-11 typically further implies that each turbine has the same sound power output as the turbine that the test report relates to, irrespective of specific site conditions such as wind shear and turbulence effects.

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[67] Examples of this type of software include CadnaA (http://www.datakustik.com/index.php?id=52&L=1), IMMI (http://www.woelfel.de/en/products/modelling-software/immi-noise-mapping.html) and SoundPLAN (http://www.soundplan.com/)which are general purpose sound prediction packages, WindPRO (http://www.emd.dk/WindPRO/) and WindFarm (http://www.resoft.co.uk/English/) which is a purpose built wind farm design package incorporating other aspects of design as well as noise.

In practical terms, such assumptions are pragmatic and are generally considered appropriate for the purposes of an engineering assessment intended to provide a reliable representation of the upper noise levels expected in practice. Indeed, a range of comparative measurement and prediction studies[68] for wind farm sites have provided support for the use of ISO 9613, for example, when it is used in combination with an appropriate range of parameter values for inputs[69].

However, if input values are not selected carefully, assumptions of uniform wind conditions and uniform sound power output have the potential to over-estimate the expected upper noise levels. Adcock et al (2007)[70] note that:

> *...the assumption of a single wind speed reference for all turbines that form a large wind farm site may over estimate the actual wind speed seen by each individual turbine.*
>
> [...] *This means that a single wind speed reference will likely overestimate the sound emissions of the turbines nearest to a location of interest.*

3.3 Wind farm neighbours

As wind farms are commonly located in rural areas, wind farm neighbours are commonly residential or farming properties often with a low density of residential dwellings. In Ireland, the extent of dispersed rural housing can frequently mean that there are wind farm neighbours on all sides of a potential wind farm development.

A discussion of a common ambient noise environment at such wind farm neighbours is outlined below. A discussion of types of neighbours, primarily noise sensitive locations, is provided in Section 5.2.1.

The prominence of any wind farm noise at a noise sensitive location depends on two key sound related factors:

- The level and character of the wind farm noise
- The level and character of other ambient noise sources, which can potentially mask the wind farm noise

3.3.1 Wind farm sound levels and character

The level and character of wind farm noise at neighbouring locations will depend on the noise source features of the turbines and the influence of sound propagating factors as outlined respectively in Section 3.1 and Section 3.2 above.

Sound levels

Wind turbine sound will have a different level and character close to the turbine compared with further away. For example, if the level of sound at 200m from a wind farm is in the range of 50-55 dBA then at a distance of, say, 2400m it would be substantially reduced, likely in the range 25-35 dBA[71].

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[68] (Adcock, Bullmore, Jiggins, & Cand, 2007), (Bullmore, Adcock, Jiggins, & Cand, 2009), (Delaire, Griffin, & Walsh, 2011)

[69] For example, a ground factor G=0.5 , all turbines emitting sound levels equal to the test measured levels plus a margin for uncertainty, at a temperature of 10 degrees and relative humidity of 70%

[70] (Adcock, Bullmore, Jiggins, & Cand, 2007)

[71] Refer to Appendix F for a summary of the noise prediction model used to estimate these sound levels.

Wind farm sound levels at noise sensitive locations will vary with the direction of the wind. This is due to sound propagation effects that vary with downwind, as discussed in Section 3.2 as well as the moderate directivity of wind turbines as a noise source. Wind farm sound levels at a noise sensitive location will generally be higher when the location is downwind from the wind farm, as noted in Section 3.1.23 of the IOA GPG which states:

> *...the background noise environment can change due to wind direction in the presence of a distant noise source. In these circumstances, a change in wind direction between upwind and downwind of the dominant noise source could result in a 5 – 15 dB L_{A90} difference in levels.*

Sound character

The specific character of wind turbine or wind farm noise outdoors at a noise sensitive location will depend inherently on the features of the propagation path to the receiver location, as discussed in Section 3.2. Generally, the wind farm sound will contain comparatively less high frequency content as this will have been dissipated during propagation, primarily through air absorption. The perceived level of low and mid frequency sound may therefore be comparatively more prominent. However low and mid frequency sound levels can be subject to some variability due to the competing influences of barriers and ground effects.

Wind farm sound will generally include a noticeable swish from the rotating blades of individual turbines. This is generally considered to be an intrinsic character of wind farm noise except in cases where the swishing becomes excessive, as discussed in Section 3.4.

Sound levels indoors

Wind farm noise levels inside a dwelling or building at a noise sensitive location will generally be lower than outside. Assuming that a partially open window is the controlling path for sound from outdoors to indoors, wind farm noise levels indoors are typically expected to be 10-15 decibels lower inside.[72]

It can also be noted that most building materials reduce high frequency sound levels more readily than lower frequency levels. This means that wind farm noise levels indoors can contain a greater proportion of sound at lower frequencies, particularly to rooms or spaces with no open windows.

3.3.2 Ambient noise environment

The level and character of ambient noise depends on the environment surrounding the noise sensitive location, including any regularly occurring activities such as vehicle pass-bys. Factors that affect the ambient noise include: the separation distance to any nearby major noise sources; the presence of tree breaks; heavy vegetation, streams and waterways, and; other significant natural or manmade noise sources such as roadways and coastal activity.

In rural areas ambient noise levels can be low for significant periods of time, particularly at night and during periods of low wind at noise sensitive locations. Ambient noise levels typically increase with increasing wind speed, as demonstrated in Figure 14, extracted from ETSU-R-97, which plots the relationship between wind speed, on the horizontal axis, and overall A-weighted sound level on the vertical axis.

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[72] To typical indoor spaces such as bedrooms, offices and residential living areas (Waters-Fuller, MacKenzie, MacKenzie, & Lurcock, 2007)

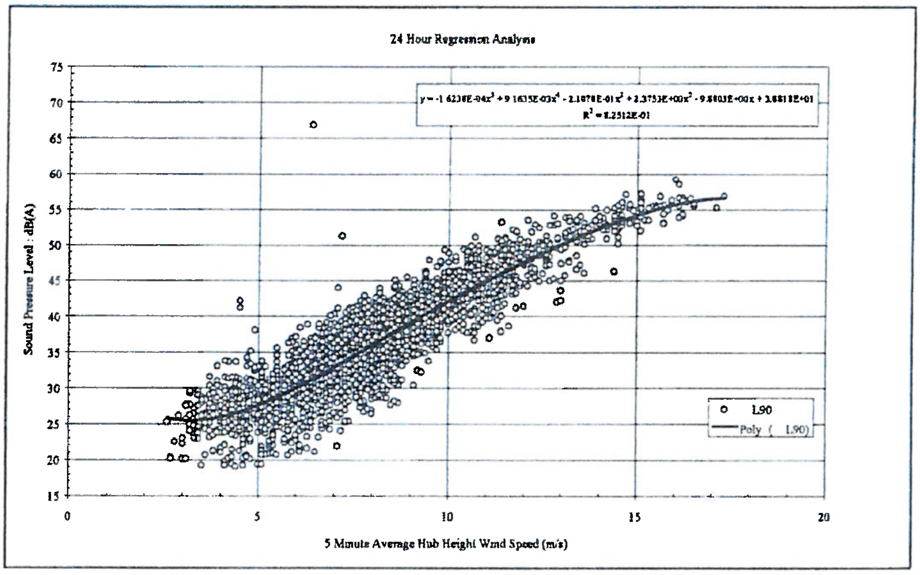

Figure A3 Regression analysis of all measured wind speed and noise data to determine the prevailing background noise level

Figure 14: Example data analysis for sound pressure levels vs wind speeds[73]

The ambient noise environment at a noise sensitive location can potentially be subject to significant variability in time and place, particularly in rural areas. Some ambient noise sources may come and go with time, for example seasonal variations associated with deciduous trees and leaf fall: some may vary with location, for example proximity to rivers or forests; while others may vary with weather conditions such as streams that swell after rainfall. Section 2.2.3 of the IOA GPG notes the following:

> *In many cases there will be significant variation in general background noise levels within the study area, because of topography and the varying influence of existing noise sources such as roads. In rural or semi-rural areas, noise generated by wind in trees is generally a dominant noise source at higher wind speeds and therefore the proximity of the monitoring location to trees and vegetation, and the type of such vegetation, may be significant. Noise from streams and other watercourses can also be a local factor.*

This variability will be evident in most site measurement data collected and it could be expected that different measurement campaigns at a common site but during different periods in time may result in measured noise levels that are not always in entire agreement. This is not to say that any of the measured data is incorrect, rather, it is simply a reflection of the inherent variability of the factors influencing the ambient noise environment.

3.3.3 Masking of wind farm noise

The prominence of any wind farm noise at noise sensitive locations depends not only on the complex array of sound propagation mechanisms between the source and receiver but also on the local ambient noise environment at the receiver. To this end, WEDG06 says:

[73] (The Working Group on Noise from Wind Turbines, 1996)

> *Turbine noise increases as wind speeds increase, but at a slower rate than wind generated background noise increases. The impact of wind energy development noise is therefore likely to be greater at low wind speeds when the difference between noise of the wind energy development and the background noise is likely to be greater.*
>
> [..] *At higher wind speeds noise from wind has the effect of largely masking wind turbine noise*

However, the ability of ambient noise to mask wind farm noise levels can be variable. While in some cases the masking can be effective, in other circumstances it can be less so - it has been noted by Sondergaard[74] that:

> *..the periodic and deterministic nature of wind turbine noise makes it more audible through the more stochastic wind noise.*

Masking noise is also less effective if its frequency characteristics are substantially different from the sound to be masked[75].

3.4 Special characteristics

Any sound with special audible characteristics is likely to cause annoyance at lower levels than the sound without these characteristics. Special audible characteristics that are considered in relation to environmental noise assessments can include amplitude modulation, impulsiveness, infrasound, low frequency noise and tonality.

Each of these characteristics is described briefly below including:

- Comments about definitions for each characteristic
- Examples of noise sources exhibiting each characteristic

The relevance of these characteristics to wind farm noise is variable. For example, impulsiveness is not commonly associated with wind farm noise while, conversely, tonality has been identified as an issue requiring mitigation works at some wind farms[76,77]. Comments regarding how each characteristic relates to wind farm noise are therefore also included below.

Comments regarding planning and operational stage assessments of special audible characteristics are provided in Section 6.3 and Section 7.4 respectively.

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74 (Bowdler & Leventhall, Wind turbine noise, 2011), Chapter 4

75 (Zwicker & Fastl, 2010)

76 (Cooper, Evans, & Petersen, 2013)

77 (Sondergaard & Pedersen, Tonality in wind turbine noise. IEC 61400-11 ver. 2.1 and 3.0 and the Danish/Joint Nordic method compared with listening tests, 2013)

3.4.1 Amplitude modulation

If a sound has a noticeable change in sound level, often which is regular and repeating, this can in some cases be described as amplitude modulation. Examples include a ringing telephone and the sound of waves crashing on the shore.

In practice, both describing and identifying amplitude modulation can be a source of some confusion. An HGC Engineering report[78] defines amplitude modulated sound as *"a sound which noticeably fluctuates in loudness over time."* The report also comments that:

> *There appears to be come confusion between this low speed temporal modulation of sound and low-frequency or low-pitched sounds. To avoid misunderstanding, it should be realised that any sound, with predominantly low, middle or high-pitched frequency content can be modulated in time, without changing the pitch of the sound.*

Depending on the context, amplitude modulation may refer to any kind of noticeable fluctuation of sound level or to a fluctuation of sound level which is more noticeable than normal. A degree of regularity of the fluctuating sound level can also be necessary.

Wind turbine sound is often described using terms such as swish, swoosh and whooshing. The use of such terms is likely due in part to the broadband noise generated from the trailing edge of the turbine blades. Some wind farm noise guidance documents, such as ETSU-R-97, state that some amount of amplitude modulation is a characteristic of wind turbine sound and that specified noise limits account for this character.

The University of Salford report NANR233[79] reviewing amplitude modulation at wind farms describes amplitude modulation, or aerodynamic modulation as it can also be called, as

> *"a greater than normal degree of fluctuation* [of sound level] *at about once per second which makes it more noticeable."*

The NANR233 was prepared following a report[80] investigating low frequency noise in which it was noted that *"the cause of complaints was not low frequency noise or infrasound, but was audible modulation of aerodynamic noise, i.e. aerodynamic noise which displays a greater degree of fluctuation than usual."*

Amplitude modulation has been the subject of considerable attention since the publication of WEDG06. Despite this, there is currently only limited evidence of the potential presence of this type of effect[81]. This may be due to the limited numbers of sites where the effect has been reported, and at the sites where it has been reported, the limited and specific atmospheric conditions required to result in the reported effect. However, some recent work suggests amplitude modulation may be more prevalent than previously thought[82].

At present there are no widely accepted methods of predicting either the occurrence or level of any amplitude modulation from wind farms.

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[78] (HGC Engineering, 2007)

[79] (Moorhouse, Hayes, von Hunerbein, Piper, & Adams, 2007)

[80] (Hayes Mckenzie Partnership Ltd, 2006)

[81] (Moorhouse, Hayes, von Hunerbein, Piper, & Adams, 2007)

[82] (Stigwood, Large, & Stigwood, Audible amplitude modulation - Results of field measurements and investigations compared to psyco-acoustical assessment and theoretical research, 2013)

A study sponsored by Renewable UK has been undertaken to improve the understanding of this enhanced amplitude modulation. At the time of writing, no reports of this study have been released.

Refer to Section 6.3 and Section 7.4 for further comments.

3.4.2 Impulsiveness

New Zealand Standard NZS 6808:2010 *Acoustics – Wind farm noise* (NZS6808:2010) defines impulsive sound as "*transient sound having a peak level of short duration, typically less than 100 milliseconds.*" Examples of impulsive noise include gunfire sounds, car door slamming and pile driving[83].

Many sound level meters include the capacity to measure sound with an impulsive time weighting, which has been developed to assess the significance of sound with impulsive characteristics. However, ISO 1996-2:2007 states the following with regard to assessment methods for impulsiveness:

> *There is no generally accepted method to detect impulsive sound using objective measurements. If impulsive sound occurs, identify the source and compare it to the list of impulsive sound sources in ISO 1996-1. In addition, make sure that the impulsive sound is representative and present in the measurement time interval.*

The characteristic swish associated with wind turbines tends to involve a fluctuation in A-weighted sound level of approximately +/-3 dB[84]. Whether or not this fluctuation is sufficiently rapid to be considered a possible impulsive sound, the variation in sound level is generally considered to be too small for the sound to be identified as a problematic impulsive sound.

There are currently no direct methods for predicting either the occurrence or level of any impulsiveness of wind farms noise. However, as it is not generally considered to be a significant feature of wind farm noise, the lack of assessment capability has not been identified as a significant shortcoming and has not been the subject of any significant recent research undertakings.

Refer to Section 6.3 and Section 7.4 for further comments.

3.4.3 Infrasound

A UK Department of Trade and Industry (DTI LFN) report *The measurement of low frequency noise at three UK wind farms* [85] notes that "*Infrasound is noise at frequencies below the normal range of human hearing, i.e. <20 Hz*". Despite the inference by the term itself, infrasound can be audible. This DTI report also notes that "*frequencies down to a few hertz are audible at high enough levels*".

[83] (International Standards Organisation, 1996), ISO 1996-1:2003

[84] See ETSU-R-97

[85] (Hayes Mckenzie Partnership Ltd, 2006)

Several points are worth noting:

- Infrasound is naturally occurring in the environment including sources such as waves and waterfalls[86,87]
- Infrasound is also present from manmade sources including aircraft, rail traffic and mining explosions[86,87]
- Human perception of sound energy in the infrasound frequency range is much less acute than other frequency bands[88]. Significant energy is required to produce levels of infrasound which are high enough to be perceived by humans.

With respect to infrasonic noise levels below the hearing threshold, the World Health Organization has stated[89] that:

> *There is no reliable evidence that infrasounds below the hearing threshold produce physiological or psychological effects*

In 2010, the UK Health Protection Agency published a report[86] on the health effects of exposure to ultrasound and infrasound. The exposures considered in the report related to medical applications and general environmental exposure. The report notes:

> *Infrasound is widespread in modern society, being generated by cars, trains and aircraft, and by industrial machinery, pumps, compressors and low speed fans. Under these circumstances, infrasound is usually accompanied by the generation of audible, low frequency noise. Natural sources of infrasound include thunderstorms and fluctuations in atmospheric pressure, wind and waves, and volcanoes; running and swimming also generate changes in air pressure at infrasonic frequencies.*
>
> *[...]*
>
> *For infrasound, aural pain and damage can occur at exposures above about 140 dB, the threshold depending on the frequency. The best-established responses occur following acute exposures at intensities great enough to be heard and may possibly lead to a decrease in wakefulness. The available evidence is inadequate to draw firm conclusions about potential health effects associated with exposure at the levels normally experienced in the environment, especially the effects of long-term exposures. The available data do not suggest that exposure to infrasound below the hearing threshold levels is capable of causing adverse effects.*

Some assessment guidance for infrasound is available. ISO 7196:1995[90] provides guidance on quantifying measured infrasound levels, using a G-weighting for adjusting measured frequency data. German Standard DIN 45680:1997[91] also provides guidance relating to part of the infrasound frequency range, down to 8 Hz, including advice regarding human hearing threshold levels. Measuring infrasound levels can be problematic; particularly outdoors where measurements can be significantly affected by wind induced noise on the microphone.

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[86] (The independent advisory group on non-ionising radiation, 2010)

[87] (Department of Health (Victoria), 2013)

[88] (International Organisation of Standardisation, 1995), ISO 7196:1995

[89] (Berglund & Lindvall, Community noise, 1995)

[90] (International Organisation of Standardisation, 1995) ISO7196:1995

[91] (Technical Committee Grundlagen der Schallmessung/-bewertung, 1997)

In relation to wind farms, an early study[92] of infrasound in 1997 as part of a UK government funded investigation reported measured levels of infrasound, low frequency sound and vibration in the vicinity of a wind farm comprising 450 kW turbines. The results demonstrated that noise levels complied with recommended residential criteria even on the wind turbine site itself, and the measured levels were below accepted levels of perception below 20 Hz.

The DTI LFN report[93] also indicated that measured infrasound levels in the vicinity of modern multi-megawatt wind farms were substantially lower than the threshold of hearing for even the most sensitive members of the population.

The UK Institute of Acoustics Bulletin in March 2009[94] included a statement of agreement between acoustic consultants regularly employed on behalf of wind farm developers, and conversely acoustic consultants regularly employed on behalf of community groups campaigning against wind farm developments (IAO JS2009) .The intent of the article was to promote consistent assessment practices, and to assist in restricting wind farm noise disputes to legitimate matters of concern. On the subject of infrasound the article notes:

> *Infrasound is the term generally used to describe sound at frequencies below 20 Hz. At separation distances from wind turbines which are typical of residential locations the levels of infrasound from wind turbines are well below the human perception level. Infrasound from wind turbines is often at levels below that of the noise generated by wind around buildings and other obstacles. Sounds at frequencies from about 20 Hz to 200 Hz are conventionally referred to as low-frequency sounds. A report for the DTI in 2006 by Hayes McKenzie concluded that neither infrasound nor low frequency noise was a significant factor at the separation distances at which people lived. This was confirmed by a peer review by a number of consultants working in this field. We concur with this view.*
>
> *A Portuguese group has been researching 'Vibro-acoustic Disease' (VAD) for about 25 years. Their research initially focussed on aircraft technicians who were exposed to very high overall noise levels, typically over 120 dB. A range of health problems has been described for the technicians, which the researchers linked to high levels of low frequency noise exposure. However other research has not confirmed this. Wind farms expose people to sound pressure levels orders of magnitude less than the noise levels to which the aircraft technicians were exposed. The Portuguese VAD group has not produced evidence to support their new hypothesis that infrasound and low frequency noise from wind turbines causes similar health effects to those experienced by the aircraft technicians.*

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92 (Snow, 1997)

93 (Hayes Mckenzie Partnership Ltd, 2006)

94 (Bowdler, et al., 2009)(IOA JS2009)

Recent measurements in Australia[95] have demonstrated that infrasound and low frequency sound produced by regularly encountered natural and man-made sources, such as the infrasound produced by the wind or distant traffic is comparable to that of modern wind turbines, noting that:

> *Infrasound levels in the rural environment appear to be controlled by localised wind conditions. During low wind periods, levels as low as 40 dB(G) were measured at locations both near to and away from wind turbines. At higher wind speeds, infrasound levels of 50 to 70 dB(G) were common at both wind farm and non-wind farm sites.*
>
> *Organised shutdowns of the wind farms adjacent to* [sic: measurement locations] *indicate that there did not appear to be any noticeable contribution from the wind farm to the G-weighted infrasound level measured at either house.*

In response to ongoing concerns regarding potential health effects associated with these types of emissions, the Australian Government's National Health and Medical Research Council issued a public statement in July 2010 titled *Wind Turbines and Health* supporting the view that there is no published scientific evidence to positively link wind turbines with direct health impacts.

Conversely, a cooperative study into infrasound and low frequency noise at a wind farm in Wisconsin USA by four acoustic consulting firms considered that:

> *The four investigating firms are of the opinion that enough evidence and hypotheses have been given herein to classify LFN and infrasound as a serious issue, possibly affecting the future of the industry. It should be addressed beyond the present practice of showing that wind turbine levels are magnitudes below the threshold of hearing at low frequencies*

Infrasound remains a comparatively high profile issue in some jurisdictions and it is the subject of ongoing research[96].

For comments regarding prediction methods for infrasound refer to Section 3.4.4 as the comments regarding low frequency noise prediction are also generally applicable to infrasound.

Refer to Section 6.3 and Section 7.4 for further comments.

3.4.4 Low frequency noise

The specific range of frequencies encompassed for an assessment of Low Frequency Noise can vary. A Casella Stanger report[97] provides the following comments regarding low frequency noise:

> *Low frequency noise is not clearly defined but is generally taken to mean noise below a frequency of about 100 to 150 Hz.*

---

[95] (Sonus Pty Ltd, 2010), (Evans, Cooper, & Lenchine, Infrasound levels near wind farms and in other environments, 2013)

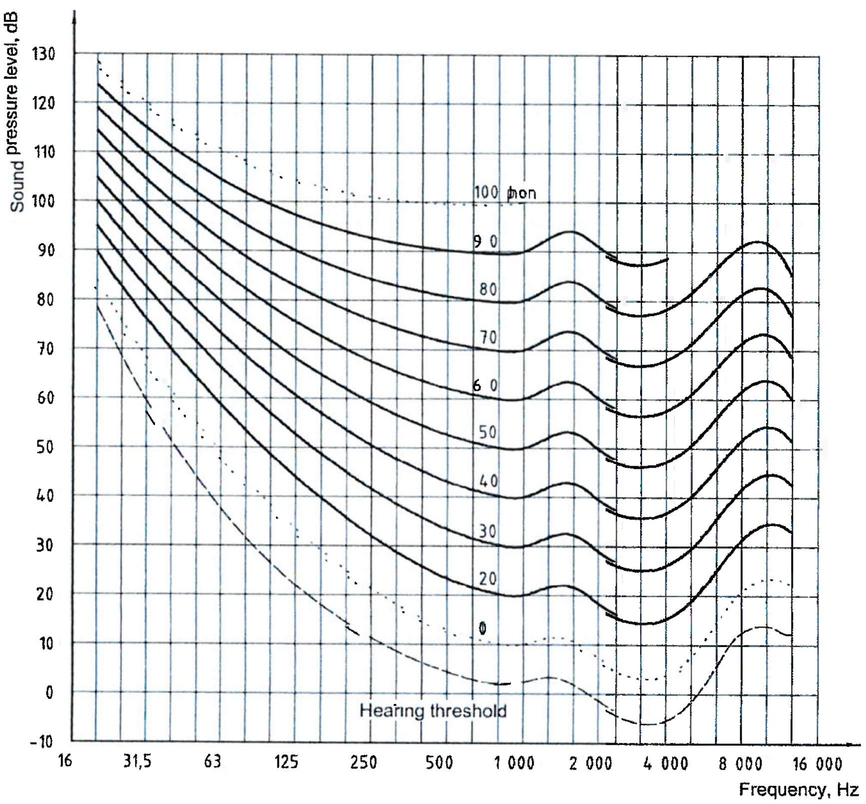
[96] For example, the South Australia EPA Waterloo Wind Farm Noise Study: http://www.epa.sa.gov.au/environmental_info/noise/wind_farms/waterloo_wind_farm_noise_study

[97] (Casella Stanger, 2001)

Leventhall[98] states that *"low frequency noise is defined as from about 10 Hz to 200 Hz."* A State Government of Victorian Department of Health document[99] details low frequency noise as occurring at frequencies less than 200 Hz.

The sound of a horn on a large ship is an example of low frequency noise. The lowest key on a piano is 27.5 Hz which is also in the low frequency range.

Human thresholds to low frequency noise are much less sensitive than to sound in other frequency ranges, such as the range of speech frequency. The relationship between the sensation of 'loudness' and frequency is demonstrated in Figure 15, which shows combinations of sounds of differing frequency and level judged to be equally loud by people.



NOTE 1 The hearing threshold under free-field listening condition, T_f, is indicated by a dashed line.

NOTE 2 The contour at 10 phon is drawn by dotted lines because of the lack of experimental data between 20 phon and the hearing thresholds. Moreover, the 100-phon contour is also described by a dotted line because data from only one institute are available at this loudness level.

Figure A.1 — Normal equal-loudness-level contours for pure tones
(binaural free-field listening, frontal incidence)

Figure 15: Equal loudness contours for pure tone sounds[100].

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[98] (Leventhall, 2004)

[99] (Department of Health (Victoria), 2013)

[100] (International Organisation of Standardisation, 2003), ISO 226:2003

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For assessment of low frequency noise, the World Health Organization has stated[101] that:

Since A-weighting underestimates the sound pressure level of noise with low-frequency components, a better assessment of health effects would be to use C-weighting.

C-weighted broadband noise levels are often cited in low frequency noise assessment guidance documents. For example, the German Standard DIN 45680:1997[102] provides a relative preliminary assessment of low frequency noise by comparing measured A and C weighted sound levels for the same sound:

To determine whether the noise to be investigated is low-frequency noise as defined in this standard, take the difference between the L_{Ceq} and L_{Aeq} values, or that between the L_{CFmax} and L_{AFmax} values, measured during the measurement time interval. If this difference is greater than 20 dB, perform measurements using third-octave band filters

Other available assessment methods can include preliminary assessment and trigger levels, expressed as C-weighted decibels, above which a detailed investigation should be carried out or, alternatively, limits proposed explicitly as C-weighted levels[103].

By contrast, in Denmark, for example, the DSO1284 document has maintained reference to A-weighted levels using a tailored index, $L_{pA,LF}$, which only considers sound levels in the frequency range from 10 Hz to 160 Hz.

In relation to wind farm noise, a 2011 Danish study of wind turbine noise[104] discussed in Section 3.1.5 above states in its abstract that

"Even when A-weighted levels are considered, a substantial part of the noise is at low frequencies, and for several of the investigated large turbines, the one-third-octave band with the highest level is at or below 250 Hz. It is thus beyond any doubt that the low-frequency part of the spectrum plays an important role in the noise at the neighbours"

Concurrently, a 2011 Swedish review[105] of available literature about low frequency noise from wind turbines noted the following.

LFN [Low Frequency Noise] *from modern wind turbines are audible at typical levels in residential settings, but the levels do not exceed levels from other common noise sources, such as road traffic noise. Although new and large wind turbines may generate more LFN than old and small turbines, the expected increase in LFN is small.*

[101] (Berglund & Lindvall, Community noise, 1995)

[102] (Deutsches Institut fur Normung, 1997)

[103] (NSW Department of Planning and Infrastructure, 2011), (Broner, 2011)

[104] (Moller & Pedersen, 2011)

[105] (Bolin, Bluhm, Eriksson, & Nilsson, 2011)

The Victorian Department of Health document[106] notes that:

> *...low frequency sound from wind farms may be audible at neighbouring residences, and may become more prominent at night under stable conditions. However, while it may be audible, the actual impact of low frequency sound on residents near wind farms is low, because of the low levels produced overall.*
>
> *For example, the levels of low frequency sound 600 m from a large wind turbine, measured both indoors and outdoors, are lower than in many other environments, such as light industrial or suburban areas or inside a passenger car.*

This is consistent with recent low frequency noise measurement work from South Australia[107] which concluded:

> *Measured low frequency noise levels were considerably higher in urban areas than in rural areas....*
>
> [...]
>
> *Typically, low frequency noise levels at the two* [sic: measurement locations near wind farms] *were not noticeably higher than those at the two rural houses away from wind farms.*

Refer to Section 6.3 and Section 7.4 for further comments.

3.4.5 Tonality

ETSU-R-97 describes tonal noise as "*noise containing a discrete frequency co mponent most often of mechanical or gin*". Examples include the hum from an electrical transformer, which exhibits low frequency tones, the dial tone on a phone, a mid frequency tone, and whistling which tends to comprise higher frequency tones.

An example of a frequency spectrum exhibiting tonal peaks is illustrated in Figure 16, an extract from IEC61400-11[108].

[106] (Department of Health (Victoria), 2013)

[107] (Evans, Cooper, & Lenchine, 2013)

[108] (International Electrotechnical Commission, 2012)

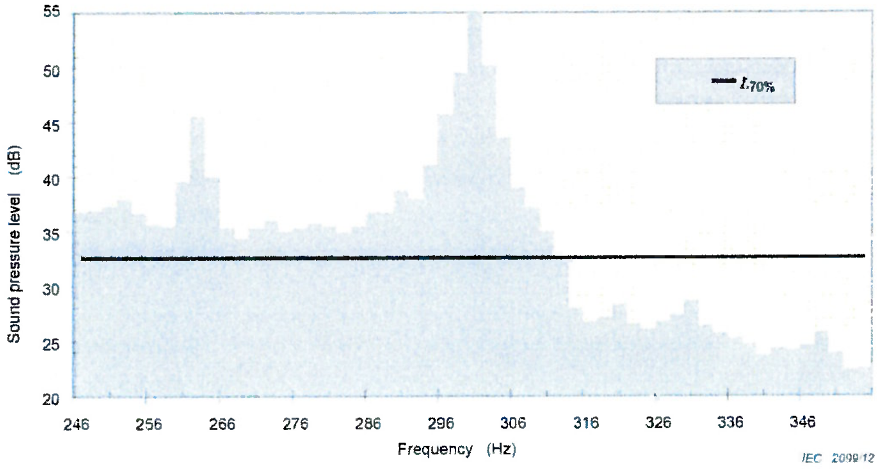

Figure 8 – Illustration of $L_{70\%}$ level in the critical band

Figure 16: Example of a partial frequency spectrum exhibiting tonal peaks

Wind turbine sound can be tonal in some cases, for example if there is a defect in a turbine blade or a fault in the mechanical equipment such as the gearbox. Typically however, a correctly operating wind turbine is not considered to have tonal sound emission.

A detailed tonality assessment method is provided in IEC61400-11[108] and so typically forms part of the data set that is supplied from the turbine manufacturer. Alternatively, in lieu of providing this data as part of the wind turbine specification, a manufacturer will often simply guarantee, on the basis of the results of a tonality assessment according to IEC 61400-11, that the wind turbine is not tonal.

Refer to Section 6.3 and Section 7.4 for further comments.

3.4.6 Discussion

Special audible characteristics are not unique to wind farms and can be a readily occurring characteristic of many types of noise. Often jurisdictions will have existing regulations or methods in place to assess such characteristics such that the discussion in a wind farm guidance document need only refer to the existing information, perhaps with additional comments about how to address variations with wind speed.

Further comments regarding regulating special audible characteristics, their prediction and their measurement are provided in Section 5.5, Section 6.3 and Section 7.4 respectively.

4.0 INTERNATIONAL BENCHMARKING (WORK PACKAGE 2)

The international benchmarking review, which is the core task of Work Package 2 of the briefing documents, is described across three report sections, as follows.

Section	Topic	Outline
5	Control methods for wind farm noise	Review of control methods for wind farm noise including discussion of cumulative impacts, setbacks & special audible characteristics.
6	Planning stage assessments	Planning considerations including background noise monitoring.
7	Operational assessments	Operational considerations including post-construction noise measurement procedures.

5.0 CONTROL METHODS FOR WIND FARM NOISE (WORK PACKAGE 2)

This section provides a review of wind farm noise control and assessment methods used internationally. This is followed by consideration of a number of specific noise control issues including cumulative impacts and setbacks.

5.1 Types of noise control methods

A range of different control methods is available to regulate noise from wind farms. Three key methods which are commonly applied for wind farm noise are outlined briefly in this section.

An informative discussion of general noise control methods is also provided in Appendix D.

5.1.1 Absolute noise limits

Absolute limits establish a fixed numeric value that must be complied with regardless of the specific ambient noise environment at the property. This style of method can involve assigning noise limits at receptors based on the level of noise sensitivity of the receiver. Commonly this is managed by classifying receivers according to land zoning. For example, land in a commercial zone is likely to be less noise sensitive than land zoned residential. To match this expectation, land in a commercial zone will often have higher noise limits, allowing greater levels of sound exposure, than residential zones.

Advantages of an absolute noise limit include its ease of application to different sites and the comparative simplicity of assessment. However, as absolute noise limits do not take into account the noise environment prior to the introduction of the noise source in question, their use can result in varied levels of change to the ambient noise environment.

For example, residential properties in different locations may have the same noise limit because of common land zoning. If a potential noise producer is considering moving adjacent to one or other of the properties, the producer's decision would not involve noise control issues as they would be the same for either site. Similarly, if one of the residential properties happens to be near a major road then the residents may not even notice noise from the potential future neighbour above existing levels of traffic noise. Conversely, if the other residential property was adjacent to a quieter, minor back street with no significant noise sources in the area, they may find noise from their potential future neighbour to be much more intrusive.

5.1.2 Relative or Background based noise limits

The relative (or background based) noise limit method takes into account the noise environment at the potential affected receiver without the introduction of the noise source under assessment. Relative limits are usually in the form of a noise level plus some pre-determined margin. For example, 'the background noise level L_{A90}, plus 5 dB.'

An advantage of relative limits is that they can be tailored to the ambient noise environment at the site of interest. A disadvantage is that they can be less responsive to sudden future changes in land use and can result in background noise creep.

5.1.3 Combination of absolute and relative limits

The combination approach to noise limits typically employs a relative noise limit, as described above, in conjunction with a lower bound or absolute noise limit that would apply in particularly quiet ambient noise environments. The lower bound or absolute component of the noise limit is typically chosen so that appropriate amenity protection is provided in the quiet environments where the limit would apply.

The objective of this style of limit, which incorporates a lower bound, is to not unduly restrict development in very quiet areas, a point that is well described in WEDG06 in relation to wind farm noise:

> [...] *in very quiet areas, the use of a margin of 5dB(A) above background noise at nearby noise sensitive properties is not necessary to offer a reasonable degree of protection and may unduly restrict wind energy developments which should be recognised as having wider national and global benefits.*

It should also be noted that assessing compliance with a relative noise limit in very quiet environments can often be difficult due to practical limitations of readily available noise measurement equipment.

For example, the noise floor of a sound level meter can influence measured sound levels in very quiet areas resulting in less accurate measurements. A pragmatic advantage of combination style limits, therefore, is the comparative ease of assessing compliance with the absolute component of the limit in very quiet environments.

5.2 Review of international noise limits for wind farms

The core objective of wind farm noise policies is to balance the advantage of developing wind energy projects with protecting the amenity of the surrounding community from adverse noise impacts, as noted in WEDG06, which states that:

> *An appropriate balance must be achieved between power generation and noise impact. Noise impact should be assessed by reference to the nature and character of noise sensitive locations.*

5.2.1 Receptor types

General noise policy guidelines and documents in a jurisdiction are typically adequate for identifying properties or types of properties which are more sensitive to noise and therefore should be included in any assessment of noise effects be it from a wind farm or some other noise source. For example, in Ireland the Environmental Protection Agency Act, 1992 requires assessment of noise as a nuisance to a person:

> *'In any premises in the neighbourhood or to a person lawfully using any public place'*

Relating to wind farms, WEDG06 provides the following guidance regarding receptor types:

> *'Noise impact should be assessed by reference to the nature and character of noise sensitive locations. In the case of wind energy development, a noise sensitive location includes any occupied dwelling house, hostel, health building or place of worship and may include areas of particular scenic quality or special recreational amenity importance.'*

In the UK, the discussion of receptor types in the recently released IOA GPG is limited. However, Section 2.2.4 of the GPG does provide comments in relation to suitable noise monitoring locations which are likely to be applicable to general assessment also:

Background noise measurements should preferably be made in the vicinity of noise-sensitive receptors, principally houses (existing or for which planning consent is being sought / has been given) and any building used for long-term residential purposes (such as a nursing home).

In Canada, the ONG2008 notes that:

the Point of Reception may be located on any of the following existing or zoned for future use premises: permanent or seasonal residences, hotels/motels, nursing/retirement homes, rental residences, hospitals, camp grounds, and noise sensitive buildings such as schools and places of worship.

The Australian SAG2009 defines relevant receivers as:

Relevant receiver locations are premises:

- *where someone resides or has development approval to build a residential dwelling;...*

Australian Standard AS4959:2010 *Acoustics – Measurement, prediction and assessment of noise from wind turbine generators* (AS4959:2010) defines Receivers as:

A location requiring prediction of the impact of wind turbine generator noise. Generally taken to be an existing dwelling, a future dwelling with development approval, or the location of potential future noise sensitive development (an occupied dwelling where people might sleep or stay) promoted by the planning system for that jurisdiction

NZS6808:2010 notes that:

In some instances holiday cabins and camping grounds might be considered as noise sensitive locations. Matters to be considered include whether it is an established activity with existing rights

Commercial and industrial land uses are not commonly located adjacent to wind farm projects and are not commonly included in regulatory limits. Indeed wind farm guidelines commonly identify sleep disturbance as a primary issue, which is not typically applicable to commercial and industrial applications.

5.2.2 Approaches to wind farm noise limits

What distinguishes wind turbines, and in particular wind farms, as a noise source is that sound levels tend to increase with increasing wind speed. This introduces challenges of measuring and assessing wind farm noise due to the presence of wind effects and other noise sources caused by wind in the environment. Levels of both ambient noise and wind farm noise have the potential to vary significantly depending on the meteorological conditions at any given time.

An example of a how these variations can be addressed is in the specification of an absolute noise limit and an associated wind speed at which the turbine noise sound be assessed. For example, a noise limit of 42 dB L_{Aeq} at a wind speed of 6 m/s referenced to 10m AGL.

An alternative means of coping with ambient noise levels that vary with wind speed, is the use of relative noise limits across a range of wind speeds, effectively with a separate ambient noise level/limit established for each integer wind speed over some pre-determined assessable range of wind conditions. The noise limit at a given wind speed can be determined from an estimate of background noise levels at that wind speed, determined from a regression analysis. For example, for the regression curve illustrated in Figure 14 above, the background noise level at 10 m/s is approximately 42 dBA. For a relative noise limit of the form 'the background noise level L_{A90}, plus 5 dB', the associated limit value at 10 m/s would be 47 dBA.

Wind farm noise limits can also use the combination approach which is based on relative limits and includes an absolute limit component which is typically applied at low wind speeds. The absolute component of the limit removes the dependence on relative limits under conditions of very low ambient noise, on the assumption that during periods of low noise levels an adequate level of amenity protection can be provided irrespective of the margin between the background noise level and the source level.

Because wind farm noise depends on the weather conditions, particularly wind speed and direction, occurring at a particular time, the level of sound at given receiver will also vary with time. Irrespective of this, wind farm noise limits are often developed on the premise that the noise would be constantly present at receptor locations[109]. In other words, the noise limits are not adjusted to account for the rate of exposure to the wind farm noise at the receptor location.

5.2.3 Noise limits and control methods

Table 3 below summarises the approach to wind farm noise control in key international regions, with emphasis on areas where wind farm noise policy is well established and has, potentially, benefitted from longer term application and any resulting refinement of the methods. This section should be read in conjunction with the more detailed review of control methods used across different regions is provided in Table 16 in Appendix E.

[109] Examples of such limits are detailed in NZS6808:2010 and SAG2009

Table 3: Summary of outdoors wind farm noise limits across jurisdictions*

Noise limit category	Region	Absolute limit**	Relative limit**
Absolute limit***	Spain	≈ 45-50 dB(A)	-
Absolute limit	Denmark	37-44 dB L_{Aeq}	-
	Germany	≈ 35-55 dB L_{Aeq}	-
	Netherlands	≈ 47 dB L_{Aden}	-
	South Korea	40-55 dBA	-
	Sweden	35-40 dB L_{Aeq}	-
Combination limit	Australia	35-40 dB	+5 dB, L_{A90}
	Canada	≈ 40-50 dB L_{Aeq}	+0-7 dB, L_{A90}
	France	30 dBA	+3-7 dB
	Ireland	35-45 dB $L_{A90(10min)}$	+5 dB, $L_{A90(10min)}$
	New Zealand	35-40 dB	+5 dB, L_{A90}
	United Kingdom	35-43 dB $L_{A90(10min)}$	+5 dB, $L_{A90(10min)}$
Other	USA	Varies by state	

* The descriptors used to specify noise limits very across jurisdictions. For example, the Irish limit is expressed in terms of $L_{A90(10min)}$ while the Danish limits is described in terms of L_{Aeq}. The relationship between different descriptors is not constant and can vary with the type of noise being measured as well as the requirements of each particular assessment methodology. As a guide, however, the variation between the wind farm noise limit descriptors in the table may range from 0 dB to 3 dB or more. ETSU-R-97, for example, estimates that $L_{A90(10min)}$ wind farm sound levels are likely to be 1.5-2.5 dBA less than measured L_{Aeq} levels over the same period.

** Limits generally applicable outdoors at residential or noise sensitive locations without involvement in the wind farm project. Refer to Table 16 in Appendix E for further details.

*** The Spanish absolute limits can also include a minimum setback distance in some cases. Refer to Table 16 in Appendix E for further details.

It can be seen from Table 3 that, for the countries considered, approximately half have developed absolute noise limits without a relative noise limit component while half have implemented combination noise limits which include both absolute and relative components.

With the exception of the French regulations, absolute noise limits[110] at residential dwellings typically range from 35-45 dBA. This is comparable with the noise limit range currently specified in WEDG06 for Irish wind farm developments. Irish noise limits are discussed further in Section 8.0.

Limit values in the range 35-45 dBA are typically employed where the limits are intended for protecting resting and sleeping conditions. For example, Section C.5.1.2 of NZS6808:2010 provides the following comments to justify its choice of absolute noise limits:

> *This* [outdoor noise limit, 40 dB $L_{A90\,(10\,min)}$] *is based on an internationally accepted indoor sound level of 30 dB L_{Aeq} to protect against sleep disturbance (refer to Berglund, Lindvall, and Schwela). This assumes a reduction from outdoors to indoors of typically 15 dB with windows partially open for ventilation. The typical reduction of 15 dB would reduce an external level of 40 dB L_{A90} to 25 dB L_{A90}. Given that the internal target is 30 dB L_{Aeq} this allows for the difference between L_{EQ} and L_{90}, and for variations in the outside to inside reduction*

It should be noted that differences in noise level descriptor, and to a greater extent, assessment methodology can mean that two regions which share a common numerical base noise limit may have different wind farm noise outcomes. This is discussed further below.

5.2.4 Associated assessment methods

While Table 3 details numerical values for noise limits, it should be recognised that the methodology used to assess compliance with limits, and the specific form of the limits, are integral to the resulting outcomes. Regions which share a comparable noise limit may produce very different outcomes for wind farm neighbours, as well as developers and regulators, due to the form of the limit and its assessment.

For example, it could be conjectured from Table 3 that the noise limits in the UK and Denmark are largely comparable, with absolute limits approximately[111] in the range of 35-45 dB. However, applying the relative component of the UK limit can require potentially extensive additional assessment by way of unattended background noise monitoring and analysis. This additional assessment work could be viewed as a burden on a proposed development or, concurrently, as a means of facilitating development through increased noise limits at higher wind speeds. In comparison, the Danish limit is an absolute limit and applies at one or two windspeeds. There is no dependence on ambient noise levels, that is, there is no relative limit, and the assessment and any resulting commissioning measurements are likely to be comparatively simpler to apply.

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[110] Including absolute limit components of a combination noise limit

[111] The approximate range makes allowance for differences in limit caused by the use of different noise level descriptors. For example, L_{Aeq} vs $L_{A90(10min)}$

As this example demonstrates, while noise limits can be specified as well defined numerical values, details of associated assessment methodologies could readily result in differences in outcome. Common points of difference across guidance documents include choice of noise index, for example L_{A90} and L_{Aeq} and the choice of noise prediction method used for planning stage assessment. An in-depth review of assessment methodologies across different jurisdictions is outside the scope of this document. In lieu, it should be noted that the limits detailed in Table 3 are most useful to review the types of control method used internationally for wind farm noise, rather than directly comparing noise limit levels as the latter is not necessarily a reliable indicator of outcomes.

5.3 Separation distances and setbacks

5.3.1 Overview

Minimum separation distances or setbacks between wind turbines and noise sensitive locations are applied as a control method in some jurisdictions. In contrast to noise limits which, by design, typically only directly address the potential impacts of noise, setbacks can be implemented to address a number of potential issues concurrently. For example, there is a view that a minimum set back distance could concurrently address:

- Noise impact
- Shadow flicker
- Visual impact
- Safety issues addressed through provision of clearance to major roadways etc.

Accordingly, in reviewing a setback distance in a particular jurisdiction the intention of the setback should be clearly understood. Watson et al[112] carried out a review of setback distances in various Canadian provinces in 2011. Their concluding remarks note that:

> *The planners we interviewed did not use a consistent method to determine appropriate setback distances. Setbacks proposed by planners were informed by the local context and subjected to modifications during the political and public process. Jurisdictions with similar setbacks may have arrived at the setback distances through very different means.*

In the simplest and perhaps most common form, setbacks specify a minimum allowable distance between a wind turbine and the nearest noise sensitive location. More complex setbacks are specified as a factor of the height or size of the source. For example, a minimum distance that is at least five times the hub height of a wind turbine.

5.3.2 Merits and drawbacks

Anecdotally, set backs are not commonly used as a direct method for noise control either for wind farms or for more general types of noise source. However, in some cases a set back required for reasons other than noise control, such as occupational health and safety buffer zones, may have a secondary benefit of reducing noise emission.

As discussed in Section 5.3.1, advantages of setbacks include the simplicity and transparency of assessment. This can be of particular benefit to regulatory authorities with limited resources. Watson et al note that "*most respondents* [municipal authorities] *chose to establish distance setbacks, often due to a lack of expertise or resources.*"

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[112] (Watson, Betts, & Rapaport, 2011)

Disadvantages of setbacks in relation to controlling noise impact include the following:

- It is not possible to reliably link setback distance with sound level or character without knowing the given wind turbine sound emission levels, the wind farm layout, and the topographic details which control sound propagation
- Setbacks are a comparatively static method that is less responsive to changes in the wind farm noise situation over time. For example, if the noise level of new wind turbines drops dramatically at some point in the future, and development at that time is regulated using setback distances established based on current wind turbine technology, then significant areas of land may be precluded from development even though the associated noise impacts could be considered acceptable were they to be assessed directly[113].
- Setbacks do not necessarily take account of the number of turbines proposed for a particular project or the propagation attenuation between turbines and receivers.
- Setbacks do not promote technological advances for reduction of turbine noise
- Setbacks do not take into account the effect of background noise to mask, or not, wind turbine noise. In some cases this can mean that areas may be considered unsuitable for development despite the wind farm noise potentially having a negligible contribution to the ambient noise environment. Examples of this scenario include locations close to busy motorways and noisy coastal areas.
- Setbacks may preclude areas with dispersed settlement patterns from wind farm developments when they may otherwise be considered suitable if assessments were based on controlling noise levels directly.

5.3.3 Setback examples

To illustrate the shortcomings of simple setbacks as a noise control method, several examples are presented

1. Reference case: Single Commercial Turbine

   A single 2.3 MW turbine in plain view of the receiving location 700 m away is predicted to produce a sound level of approximately 35 dB L_{Aeq} at full output.

   A 2.3MW model is a large-scale modern turbine, and it is highly likely that even smaller and quieter turbines could be found which would result in an even lower noise level at the receiver.

[113] And conversely if wind turbine noise levels increase dramatically at some point in the future.

2. Multiple Commercial Turbines

   A wind farm of 25 3MW turbines, meeting a 700 m setback rule and spaced according to the technical constraints of "5 rotor diameters downwind and 3 diameters crosswind", is predicted to produce a sound level of around 47 dB L_{Aeq} at 700 m from the edge of the wind farm. It is important to note in this case, and for most wind farms, that the nearest turbines are not solely responsible for the noise received at a given location.

   The wind farm sound levels in this scenario are 12 decibels higher than the reference case even though the setback distance to the receiver in each case is the same, 700m. In this example a setback could incorrectly promise a degree of protection to neighbours which would not be realised.

3. Multiple Commercial Turbines in shielded Terrain

   The 25-turbine wind farm in the preceding example, built on terrain in which the receiving house is sited opposite a hill which obstructs the house from view of the wind farm, produces a level of produces a predicted wind farm sound level[114] of approximately 35 dB L_{Aeq}.

   This example demonstrates that variations in the height of the turbines, or the hill, or the residence site, can have a significant further reduction on noise level. The wind farm sound levels in this scenario are approximately the same as the reference case, despite the proposed wind farm in this scenario comprising 25 turbines rather than 1.

4. Property affected by high noise levels

   None of the simple scenarios above have taken into account the existing noise environments surrounding the house in question. Such an assessment could show that, during windy conditions, the existing background level is already higher than relevant noise limit and may not produce any significant noise effect. In this case a given setback could be unnecessarily restrictive to the design of the wind farm.

An overview of modelling parameters for the above examples is provided in Appendix F.

5.3.4 Setbacks in practice

Comments provided in WEDG06 include reference to separation distances as follows:

> *Separate noise limits should apply for day-time and for night time. During the night the protection of external amenity becomes less important and the emphasis should be on preventing sleep disturbance. A fixed limit of 43 dB(A) will protect sleep inside properties during the night. In general, noise is unlikely to be a significant problem where the distance from the nearest turbine to any noise sensitive property is more than 500 metres.*

[114] Barrier attenuation is discussed in Section 3.2.
It should be noted that the model used to generate the predicted sound levels for Scenario 3 includes a limit to barrier attenuation of 20dB. This level of attenuation is greater than is typically be included in a wind farm noise assessment where limits of 2-5dB are common. The greater allowance for barrier attenuation in this example is intended to provide a less conservative and more realistic account of wind farm sound levels in the presence of significant obstacles.

A 2011 review by the Minnesota Department of Commerce of wind farm setbacks applied in various jurisdictions internationally[115] notes that average setback distances range from 470 m to 700 m.[116] The review suggests that in many cases setbacks are applicable in tandem with the more commonly employed control method of noise limits. The following details are also noted:

- A range of setbacks are applied across some of Germany's sixteen regions, ranging from 300-500m up to 1000m
- In 2011, France introduced a mandatory requirement for a setback of at least 500 m to all residential areas
- Some municipalities and counties in Sweden have adopted setbacks in the range of 400m to 1000m

A 2009 report from the Ontario Ministry of Environment (MOE), *Development of Noise Setbacks for Wind Farms Requirements for Compliance with MOE Noise Limits*[117], establishes possible setbacks for noise:

> *...with the intention of facilitating the planning and review process of such projects while protecting human health and the environment.*

A range of setbacks is provided from 550m to 1500m, depending on the number of turbines being proposed and their estimated sound power levels.

An amendment to wind farm development guidelines[118] in the Australian state of Victoria in 2012 details an indirect approach to setbacks which effectively requires all residential properties within 2000m of a wind farm to be involved in the project:

> *If an existing dwelling is located within two kilometres of any turbine that forms part of a proposed wind energy facility, the permit application must be accompanied by evidence of the written consent of the owner of the dwelling. The application is prohibited by the planning scheme where evidence of written consent is not provided. This does not apply:*
>
> 1. *where the turbine is principally used to supply electricity for domestic or rural use of the land*
> 2. *on land in a residential zone, an industrial zone, a business zone or a special purpose zone. This allows for the consideration of turbines in an urban setting.*

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115 (Haugen, 2011)

116 The conclusion of (Haugen, 2011) notes,
"Some countries or regions only had one setback distance rather than a range of distances [...] *For countries with required or recommended wind turbine setback distances, the average lower setback distance is approximately 470 meters(1,542 feet), and the average upper setback distance is approximately 700 meters(2,297 feet)...*

117 (Ontario Ministry of the Environment, 2009)

118 (Victoria Department of Planning and Community Development, 2012)

5.3.5 Discussion

It is considered that set backs are not universally appropriate for managing noise emission from wind farms. In particular, the relationship between distance from a wind farm and noise effects is significantly variable[119]. Setbacks may also be comparatively slow to respond to changes in turbine technology such as development of significantly quieter or louder turbines at some point in the future.

In contrast, the issues noted above can be addressed inherently where noise limits are applied directly as the control method. That is, specific circumstances of a development such as the number of turbines, turbine sound level, propagation effects and, potentially, the ambient noise environment at receptors, can all be accounted for with a noise limit method. Conversely, it can be noted that the application of noise limits is typically more complex than setbacks.

As noted by the examples above, setbacks have the potential to either over-protect or under-protect wind farm neighbours. This means, in turn, that setbacks have potential to result in poor levels of amenity protection in some cases, and poor utilisation of wind resources in others. In this sense, noise limits may offer a comparatively better means of achieving a reliable balance between acceptable levels of amenity protection and capacity for infrastructure development.

5.4 Cumulative noise impacts

The cumulative noise impact of multiple wind farms is an ongoing issue as wind farm developers seek to optimise the use of the limited land areas with viable wind resources, particularly in countries with high rural population densities such as Ireland.

5.4.1 Approach to cumulative limits

Limits for total wind farm noise

In the UK, the guidance provided in ETSU-R-97 recommends that noise limits should apply to the cumulative effect of all wind turbines affecting noise-sensitive premises, noting:

> *"It is clearly unreasonable to suggest that, because a wind farm has been constructed in the vicinity in the past which resulted in increased noise levels at some properties, the residents of those properties are now able to tolerate higher noise levels still."*

While it would be easiest to consider all turbines as one wind farm with one set of limits, in practice proposed or operational wind turbines may be under the control of multiple separate parties with each development the subject of separate planning applications and subject to separate planning conditions, if subsequently approved.

[119] Depending on the details of the wind farm including the number of turbines and their spacing as well as the topography of the wind farm site and surrounding area.

To address some of the challenges associated with cumulative assessment, the Department of Energy and Climate Change (DECC) in the UK requested the Institute of Acoustics prepare a guidance document - *A Good Practice Guide To The Application Of ETSU-R-97 For The Assessment And Rating Of Wind Turbine Noise* (IOA GPG) - outlining current good practice in the application of the ETSU-R-97 assessment methodology for wind turbine developments, which address cumulative noise assessment. The summary note of the IOA GPG states that "*whenever a cumulative situation is encountered, the noise limits for an individual wind farm should be determined in such a way that no cumulative excess of the total ETSU-R-97 noise limit would occur.*"

Noise limits per wind farm

Some guideline documents assign noise limits per wind farm which, in effect, means the limits for total wind farm noise can be higher than the limits applied to any particular wind farm. For example, Section 4.2 of AS4959:2010 notes that:

> *To provide a satisfactory level of protection of amenity against the potential adverse effects of wind farm noise, the cumulative impact of all wind farm development in an area should meet the noise limits derived from measurements of the background noise environment at relevant receivers prior to any wind farm development taking place.*

These comments imply that the noise limits can apply per wind farm, provided that background noise data used to establish limits does not include contribution from any operating turbines.

Discussion

For either approach to limiting cumulative noise impacts, assessment requires further development of the methods available for assessing noise from one wind farm development. For example, how should cumulative noise limits be established at a property if they have a noise agreement in place for one of the projects? Alternatively, if a property is far enough removed from two separate developments that it is not explicitly included in the assessment for either project, how will it be identified for inclusion in an assessment of cumulative effects, for which the impacts could be more significant? Also, how should adjacent wind farms be assessed if the basis for wind speed analysis uses a different reference height for each project?

The IOA GPG provides a fairly comprehensive and robust account of methods to assess cumulative impacts which generally reflects current industry practice. The discussions below are therefore presented with reference to the details provided in the IOA GPG, unless noted otherwise.

5.4.2 When is cumulative assessment needed?

If two wind farms are proposed to be immediately adjacent to each other then it is immediately apparent that a cumulative assessment of noise from both wind farms together will be necessary. Similarly, if two wind farms are proposed to be located tens of kilometres apart, then a cumulative assessment of noise from both farms is unlikely to be required. For cases between these two extremes it is less obvious when a cumulative assessment is required and, if it is, how noise sensitive locations should be identified for assessment.

To address these issues, the IOA GPG recommends that a cumulative assessment of noise be considered when a proposed wind farm produces a level of noise that is within 10 dB of noise from any existing wind farm(s) at the same receptor location.

An alternative approach is noted in Section 6.4.9 of the ONG2008 document which implies that cumulative impact assessments only need to be carried out at dwellings which are located within 5km of more than one wind farm development:

> *The standard on which the noise impact prediction method is based, namely standard ISO 9613-2, Reference [6], is designed for source/receiver distances up to about 1000 m. Although the use of the standard may be extended to larger distances, other factors affecting sound level contributions from the distant sources may need to be considered. In practice, sound level contributions from sources such as wind turbines located at very large distances from receptors are affected by additional attenuation effects. To address the above in a prediction method, contributions from sources located at very large distances from receptors, larger than approximately 5 km, do not need to be included in the calculation.*

5.4.3 Background noise

As noted by the IOA GPG, ETSU-R-97 sets relative noise limits based on the prevailing background noise level and requires that the background levels are not influenced by existing turbine noise. The IOA GPG offers a number of options for deriving suitable background noise levels in the presence of existing turbines including: switching turbines off during background surveys; measuring during upwind conditions; using proxy locations not affected by turbine noise; and using background data from the original wind farm noise assessment with consideration to differences in wind speeds between the site.

5.4.4 Derivation of fixed lower limit

As noted by the IOA GPG, ETSU-R-97 noise limits for the day-time period include a fixed or absolute limit that generally applies at lower wind speeds when background levels are low, and is within the ranges of 35-40 dB L_{A90}. The justification for the choice of the fixed part of the limit depends on a number of factors: the number of properties affected by noise; the effect of the fixed limit on the potential power generating capacity of the wind farm; and the duration and level of exposure. Consideration of these factors may result in different absolute limits being justified depending on whether all turbines affecting a receiver location are considered, or just those from a single wind farm development.

Ordinarily, the absolute limits would be selected based on a single wind farm considered in isolation; however it may be appropriate to consider an absolute limit based on all turbines for the purposes of determining a cumulative limit and derivation of subsequent partial limits.

5.4.5 Derivation of the relative noise limits

The options available for determining the relative noise limits for each wind farm in isolation - so that cumulative noise limits are not breached - is dependent on the planning stage arrangements of each separate wind farm, e.g. in planning, consented, operational, and individual site layout and noise limit considerations. For example if the applications are concurrent, there is an opportunity to apportion partial limits applicable to each development in isolation, such that the total cumulative limits (fixed part and relative to background) are not exceeded. This may not be possible if one of the wind farms is already consented and has “used up” the available cumulative limit already.

The IOA GPG recommendations aim to use the "noise budget" fairly so that wind resources can be optimised. Under most scenarios some level of cooperation, coordination and negotiation between neighbouring developer teams and the local planning authority is key to the success of the process to determining "fair" relative noise limits.

Strategic planning can also assist in efficient appraisal of cumulative impacts, promoting proposals that provide greater contribution to renewable targets.

The summary provided in the IOA GPG states that:

> *" whenever a cumulative situation is encountered, the noise limits for an individual wind farm should be determined in such a way that no cumulative excess of the total ETSU-R-97 noise limit would occur."*

5.4.6 Comparison of Cumulative Noise Impacts with Derived Noise Limits

An assessment of cumulative impacts can in some cases consider directional effects as some receptors may not be simultaneously downwind from all wind farms. Such an approach would not typically be employed in the first instance but could be considered, for example, if it was not possible to demonstrate compliance with the cumulative noise limits based on downwind propagation from all turbines and the layout of the turbines meant such an approach was likely to over predict levels compared to those which would occur in reality.

A potential outcome of directional considerations in application of the IOA GPG, however, is that noise levels from two separate wind farms could be higher than if the two projects were developed as a single wind farm where directional effects are commonly not considered.

5.4.7 Cumulative impacts in practice

As noted in Section 5.4.1, in the UK wind farm noise limits apply to total or cumulative wind farm noise levels.

Similarly, in New Zealand, Section 5 6.1 of NZS6808:2010 notes that:

> *The noise limits in 5.2 and 5.3 should apply to the cumulative sound level of all wind farms affecting any noise sensitive location.*

Comparably, the ONG2008, Section 6.4.4 states:

> *If a Point of Reception or a Participating Receptor is or can be affected by adjacent, approved Wind Farms, the detailed noise impact assessment must address the combined impact of the proposed and the adjacent Wind Farms. The distance requirements described in Sections 6.4.1 and 6.4.9 apply.*

Where Australian Standard AS4959:2010 indirectly details noise limits per wind farm, the SAG2009 similarly notes that:

> *...as for staged development, any additional wind farm that may impact on the same relevant receiver as an existing wind farm should meet the criteria using the background noise levels as they existed before the original wind farm site development.*

5.5 Special characteristics

As noted above in Section 3.4, where special audible characteristics are present the sound is considered to be subjectively more annoying. To account for this increased annoyance, corrections are typically applied to sound where special audible characteristics are observed. These corrections either apply as a reduction to the noise limit or a penalty added to the predicted or measured sound level. For example, Section 5.4.2 of NZS6808:2010 requires that:

> *Wind turbine sound levels with special audible characteristics [...] shall be adjusted by arithmetically adding up to +6 dB to the measured level at a noise sensitive location.*

Some wind farm noise policies require that an assessment of special audible characteristics comprise a subjective test followed by an objective test. ETSU-R-97 states the following:

> *The determination of the character of the noise emitted by wind turbines is performed by both a subjective and an objective test. This takes the form of listening to the emitted noise at the affected property and/or performing objective measurements of the incident noise at the property.*

Assessing special audible characteristics subjectively on-site can in some cases be critical for a robust compliance appraisal for the following reasons:

- For some special audible characteristics, objective assessment methods have limited accuracy and could result in false negative[120] or false positive[121] assessments. Examples can include unattended outdoor measurements of infrasound, low frequency noise and impulsiveness.
- For some special audible characteristics, objective assessment methods have limited correlation with rates of annoyance.
- If audio samples have been collected, reviewing these samples during post-processing can misrepresent the significance of characteristics of a sound because of variability in the audio playback system.

Depending on the jurisdiction, penalties for special audible characteristics can be either one off or, perhaps less commonly, additive, as the following two examples demonstrate.

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[120] Failing to identify a special audible characteristic when it *is* present

[121] Identifying a special audible characteristic when it is not present or is attributable to ambient noise rather than the noise in question.

Table 4: Examples of penalty arrangements for special audible characteristics

Example	Guidance document	Comment
A	NZS6808:2010, Section B4	*Only one adjustment value* [sic: for special audible characteristics] *shall be applied to each measurement, even if more than one type of special audible characteristic is present.*
B	Tasmanian Noise measurement procedures manual[122], Section 6.1	*If a sound contains more than one of the characteristics, then all applicable individual adjustments must be made and the adjustments are all linearly added to the measured level.* *If the total adjustment exceeds 10 dB, the total adjustment is to be regarded as 10 dB.*

The choice of a suitable penalty for special audible characteristics is intrinsically linked to the underlying noise control method in the jurisdiction, and the associated measurements and assessment methods. Therefore, two jurisdictions applying different special audible characteristic penalties could conceivably arrive at a comparable outcome for wind farm noise owing to other differences in assessment methods.

A variation on the requirement to apply penalties is incorporated into some guidance documents that recognise special audible characteristics should not typically be a component of a correctly functioning wind turbine or wind farm. For such cases, in lieu of a penalty, there is a requirement for the wind farm operator to correct any issues that may be contributing to any observed special audible characteristics. For example, SAG2009 notes:

> *These guidelines have been developed with the fundamental characteristics of noise from a wind farm taken into account. These include the aerodynamic noise from the passing blades (commonly termed 'swish') and the infrequent and short-term braking noise.*
>
> *However, annoying characteristics that are not fundamental to a typical well maintained wind farm should be rectified. Such characteristics may include infrasound (low frequency noise below the audible frequency range that manifests as a rattle in lightweight materials such as glass) or adverse mechanical noise (perhaps generated as a failure of a component).*

Special audible characteristics are discussed further in Section 6.3 and Section 7.4.

[122] (Tasmania Department of Primary Industries, Water and Environment, 2004)

6.0 PLANNING STAGE ASSESSMENTS (WORK PACKAGE 2)

This section summarises key practices relevant to assessment of wind farm noise during the planning process which are used to inform regulatory authorities and the community about the likely impacts of the wind farm and to inform decisions on granting planning permission for a development.

6.1 Assessment of wind farm noise during planning

During the planning phase of a wind farm development, before the wind farm is built, compliance with noise limits, if applicable in a given jurisdiction, is typically demonstrated using predictions of wind farm noise.

Sound levels from the wind farm are predicted to surrounding receptor locations, using prediction methodologies such as those outlined in Section 3.2 above. The predictions are generally based on proposed turbine layouts developed by the proponent, along with wind turbine sound power level data supplied by one or more proposed turbine suppliers.

Predicted noise levels can be compared with established noise limits for each receptor location being assessed to determine whether the planned wind farm complies with the limits.

6.2 Measuring background noise levels

Measurement of background noise levels can be inherently variable whether around a wind farm site or at other rural or urban sites proposed for development, particularly when unattended noise monitoring is involved[123].

In relation to wind farms where noise limits include a relative noise limit component, that is with a margin above background noise level, it is common for background noise levels to be measured at several receptor locations during the planning stage. There are no universally accepted methods for quantifying background noise levels at receptor locations around either proposed or operational wind farms, effectively on account of the difficulties associated with measuring noise levels in the windy environments where wind farms are located. The methods that are employed across different jurisdictions all have a range of advantages and disadvantages which are briefly outlined here and also in Section 7.2.

Common to several methods[124], however, is the unattended measurement of noise levels using logging equipment for a period of a week or more. In most cases, this measurement approach has been derived from the approach originally described in the UK document ETSU-R-97. The measurements commonly record background noise levels at receptor locations which allows the determination of relative noise limits at the location. In some cases, the data measured at one location can be considered representative of other nearby receptor locations with the collected data used as a proxy to establish noise limits at the other locations.

[123] (Adcock, Bullmore, & Flindell, Balancing risks and uncertainties in environmental noise measurements, 2005)

[124] ETSU-R-97, NZS6808:2010, AS4959:2010, SAG2009

The background noise levels, typically L_{A90} or L_{A95}, are measured across a series of consecutive 10 minute periods. The measurements can be required to continue either for a minimum number of days, such as 10 days[125], or for a sufficient time to collect a minimum number of data points, for example, 2000[126]. Emphasis is generally placed on collecting a sufficient amount of data across a representative range of weather conditions, particularly periods where wind direction is from the wind farm to the receptor, for wind speeds from cut-in, where the turbines start generating electricity, to rated power, where turbines reach their maximum power generation capacity.

In some cases it can prove difficult to capture sufficient data for some weather conditions, if they do not frequently occur at the site. This issue can be addressed by nominating a maximum monitoring period. For example, the New South Wales Draft document *NSW Planning guidelines: Wind farms*[127] states that monitoring should be carried out for a *maximum* of six weeks.

At the end of the monitoring period the measured levels can be compared with wind speed and in some cases wind direction, data that is typically collected by the wind farm proponent on the proposed site. The purpose of collecting wind speed data at the wind farm rather than, say, the receptor location is that it better represents the weather conditions that would be incident on proposed turbines and is therefore an indicator of the operating performance and sound levels that the turbines would have at a given point in time.

The reference height for wind speed monitoring and reporting has the potential to influence assessment outcomes. Wind speeds have historically been referenced to 10m AGL and assessments carried out using ETSU-R-97 generally continue to reference wind speeds at this height. Where this is done, care is required to take due account of site windshear influences. This typically involves initially referencing site measurements to the hub height of the proposed turbines and avoiding direct measurement of wind speeds at 10m AGL. The IOA GPG recommends the following:

> *The standard procedure should be to reference noise data to standardised 10 metre wind speed. The standardised 10 metre wind speed is obtained from the turbine hub height wind speed by correcting it to 10 metre height using a ground roughness factor of 0.05.*

A further discussion of wind speed reference heights is provided in Appendix C.

The analysis of collected noise levels can involve filtering the data set to remove periods which may have been effected by rain or wind buffeting of the microphone during periods of high wind speed at the monitoring location. This filtering requires collection of additional data at site, ideally in the form of rainfall rates and wind speeds local to the noise monitoring location, for example by installing a met mast at approximately 1.5-2m AGL near the noise logger[128]. Additionally, the noise measurement microphone can be protected by one or several wind screens to reduce the occurrence of wind buffeting[129].

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125 NZS6808:2010 recommends a minimum noise measurement period of 10 days.

126 SAG2009 states that *"sufficient data is considered to be approximately 2000 measurement intervals..."*.

127 (NSW Department of Planning and Infrastructure, 2011)

128 In some cases, weather data from a proxy location can be used to assess the influence of extraneous noise from rainfall and high local wind speeds at the noise monitoring location.

129 (Davis & Lower, 1996)

A regression analysis can be carried out for the noise level and wind speed data to determine an estimated relationship between noise levels at the receptor location and wind speeds at the proposed wind farm site. An example of such a regression analysis is provided in Figure 10 in Section 3.3.2.

A note-worthy alternative to measuring background noise levels for establishing relative noise limits is an approach employed in Ontario Canada, where the regulatory authority's guidance document ONG2008 provides a nominal set of *'wind induced background sound levels'* across a range of applicable wind speeds and prescribes limits based on this data. The guidelines note:

> *The measurement of wind induced background sound level is not required to establish the applicable limit. The wind induced background sound level reference curve [...] was determined by correlating the A-weighted ninetieth percentile sound level (L_{90}) with the average wind speed measured at a particularly quiet site. The applicable L_{eq} sound level limits at higher wind speeds are given by adding 7 dB to the wind induced background L_{90} sound level reference values, using the principles for establishing sound level limits described in Publication NPC-232...*

6.3 Special audible characteristics

Consideration of special audible characteristics during the planning stage of a wind farm development can be considered broadly in three parts as outlined in Table 5.

Table 5: Assessment approach for special audible characteristics

Category	Special audible characteristics	Comments
Not directly assessed	Amplitude modulation Impulsiveness	There are currently no reliable means of predicting the occurrence of excessive amplitude modulation or impulsiveness during the planning stage of a wind farm development.
Assessed based on measurements	Tonality	Tonality assessment results according to IEC 61400-11 can inform a wind farm planning assessment.
Assessed based on predictions or not directly assessed	Infrasound (partial) Low frequency noise	Prediction of sound pressure levels across the frequency range from 200 Hz to less than 20 Hz is possible, with limited accuracy. In many jurisdictions low frequency noise and infrasound are not required to be directly assessed during the planning stage for a wind farm.

Each of these categories is discussed directly below.

6.3.1 Unassessed characteristics

Amplitude modulation and impulsiveness are complex characteristics of sound that involve variations in level, time and frequency. The obstacles to developing suitable prediction and measurement methods for these characteristics include:

- *Limited understanding of source mechanisms*
  Causes of excessive amplitude modulation, for example, are not well understood. Possible influencing factors include weather conditions at the turbine, aerodynamic conditions at the turbine blades, turbine controls and propagation effects. Accounting for such a wide range of potential sources, each with a potentially unique generating mechanism, in any prediction method is likely to be problematic at least until the source mechanisms are better understood.

- *Limited site occurrences*
  The literature search for this report has not uncovered any documented cases of impulsive characteristics at a wind farm. Similarly, while there is some emerging evidence of amplitude modulation at some wind farms[130], its occurrence is commonly cited as being infrequent[131].

- *Lack of reliable metrics to assess effects*
  As discussed in Section 3.4 above, neither impulsiveness nor amplitude modulation have widely accepted metrics that are field proven and are shown to correlate with peoples subjective impression of the sound. This, in turn, prohibits the development of prediction tools and regulations.

6.3.2 Measurement based assessment

As with amplitude modulation and impulsiveness, there is no readily available method for predicting tonality, primarily due to the wide range of potential sources. For example, tonal noise could potentially be generated from imperfections on the blades leading to whistling noise, mechanical or electrical noise from the nacelle, or noise from the transformer associated with the turbine which is typically located at the base of the turbine tower[132].

However, the levels of tonal audibility that are measured as part of an IEC61400-11 assessment of sound power levels for a turbine provide an indication of the likelihood of tones from that turbine during operation. For example, SAG2009 notes:

> *If tonality is a characteristic of the WTG noise, 5 dB(A) should be added to the predicted or measured noise level from the wind farm.*
>
> *To help determine whether there is tonality, the method and results of testing (such as in accordance with IEC 61400–11) carried out on the proposed WTG model to determine the presence of tonality should also be specified in the development application*

---

130 (Stigwood, Large, & Stigwood, Audible amplitude modulation - Results of field measurements and investigations compared to psyco-acoustical assessment and theoretical research, 2013)

131 (Moorhouse, Hayes, von Hunerbein, Piper, & Adams, 2007)

132 (Bowdler & Leventhall, Wind turbine noise, 2011), Chapter 4, page 116

The application of IEC61400-11 data is, however, limited. The levels of tonal audibility established using this method relate to locations that are typically 100-200m from a single turbine. Extrapolating these results to greater distances, such as are typical for common receptor locations, is complex and will be significantly influenced by the frequency dependent propagation characteristics of the intervening path as well as the ambient noise levels at each receptor considered.

6.3.3 Prediction based assessment

Unlike amplitude modulation, impulsiveness and tonality, which can involve complex variations in time, level and frequency, infrasound and low frequency noise essentially represent an extension of the broadband frequency range that is currently addressed by sound propagation prediction methods such as ISO 9613-2:1996, discussed in Section 3.2. However, the ISO9613-2:1996 prediction method has been developed using octave-band algorithms for octave band centre frequencies from 63 Hz to 8 kHz. The nominal lower frequency limit for the method therefore does not fully encompass the infrasound or low frequency noise regions of the sound spectrum.

While the prediction of infrasound and low frequency noise during the planning stage of a wind farm is not especially common, since the release of WEDG06, some guidance has been provided for such predictions, with Danish research contributing significantly.

Infrasound

There are currently no methods for predicting infrasound levels across the frequency range 0 Hz to 20 Hz which have a well documented record of reliability or accuracy.

However, the Danish EPA document *Statutory Order on Noise from Wind Turbines (Translation of Statutory Order no. 1284 of 15 December 2011)* (DSO1284) provides a method for estimating expected wind farm noise levels at low frequencies from 10 Hz to 160 Hz. The method is comparable to ISO 9613-2:1996 but details a number of parameter values that are expected to provide a more robust prediction of lower frequency sound.

DSO1284 includes a criterion, expressed in terms of dB L_{pALF}, assessed indoors. The criterion states:

> *The total low-frequency noise from wind turbines may not exceed 20 dB* [L_{pALF}] *at a wind speed of 8 and 6 m/s indoors in dwellings in open countryside or indoors in areas with noise sensitive land use respectively.*

However, the calculations are carried out in one-third octave bands and insertion loss values adjusting outdoor predicted levels to indoor predicted levels are well documented so prediction of other indices such as a G-weighting may be possible[133], though likely with increased uncertainty tolerance.

For G-weighted assessments of infrasound, ISO 7196:1995 notes the following in its introduction:

> *Weighted sound pressured levels which fall below about 90 dB*[G] *will not normally be significant for human perception.*

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[133] At least for the part of the G-weighted frequency range encompassed by the DSO1284 method: frequencies of 10Hz up to 160Hz.

Low frequency noise

The DSO1284 method extends up to 160 Hz and therefore includes a significant component of the low frequency region meaning the method could be used to provide estimates of low frequency noise, perhaps in conjunction with results of ISO 9613-2:1996 at frequencies of 63 Hz and greater where the ISO 9613-2:1996 method has been validated.

A further method for calculating low frequency noise would be the use of the Nord2000 prediction method. This method is not widely used internationally, likely due to the need for a wider range of input parameters into the model, many of which can often be difficult to determine. However, the model has been validated for frequencies down to 25 Hz[134].

Predicted levels of low frequency noise could be compared to a noise limit value to assess compliance. As an example, predicted L_{pALF} levels could be compared to the DSO1284 criterion of 20 dB L_{pALF} noted above as a measure of compliance. Further discussions of low frequency noise criteria are provided in Section 7.4.4.

Sound power level data

For the prediction of noise levels in either the infrasound or low frequency regions, it is important to recognise that predictions carry a greater margin of uncertainty owing to the greater uncertainty associated with the measured or reported sound power level data for the nominated turbines.

Test standard IEC 61400-11[135], which is the common reference for sound power level data reported by manufacturers, details a method for measuring wind turbine sound power levels at frequencies of 20-50 Hz and greater. In our experience, reported uncertainty values at low frequencies can range from +/-1 dB up to approximately +/-6 dB or more at frequencies below 63 Hz. The standard does not provide any detailed methodology for measuring across the full range of frequencies for either infrasound or low frequency noise.

6.3.4 Discussion

With the exception of tonality, special audible characteristics are not commonly directly predicted or assessed during the preparation of a planning application for a wind farm. As noted in Section 6.3.1 in relation to amplitude modulation and impulsiveness, this approach has likely evolved pragmatically, reflecting the limited documenting of occurrences at operating wind farms.

Recently, perhaps reflecting the heightened profile of wind farm developments in some jurisdictions, there has been a trend towards including some assessment of infrasound and low frequency noise special audible characteristics. In addition to the Danish example discussed in Section 6.3.3, the *Draft NSW Planning guidelines: Wind farms*[136] provides the following comments which imply a requirement to assess C-weighted noise levels during planning phase:

> *It should be noted that the low frequency characteristic penalty applies only if excessive low frequency noise is present, or predicted to be experienced at the relevant receiver.*

[134] (Plovsing, 2007)

[135] (International Electrotechnical Commission, 2006), (International Electrotechnical Commission, 2012)

[136] (NSW Department of Planning and Infrastructure, 2011)

It could be considered that not directly assessing special audible characteristics during a planning assessment increases the risk of a wind farm not complying with noise limits once it's operational. However, as discussed in Section 7.4 below, wind farm noise guidance documents typically include an operational stage assessment method for special audible characteristics. This means that any operational wind farm exhibiting special audible characteristics will be penalised for their presence, regardless of the circumstances of the planning stage assessment.

An alternative to this approach is to assume, during the planning stage, that all wind farms exhibit special audible characteristics and that a penalty for their presence should therefore be included in the planning assessment. While this kind of approach is less commonly adopted an example of it is documented in the Australian Environment Protection and Heritage Council (EPHC) guidelines *National wind farm development guidelines – Draft July 2010*[137] which state:

> *These guidelines recommend that certain audible characteristics be assessed as part of the wind farm development but only tonality is assessed at the pre-construction phase. Other characteristics are assessed at the post construction phase. As this poses a risk to an operator it is recommended that a 5 decibel penalty be added automatically to the predicted level of a wind farm to provide certainty and a safety margin in the event that these unpredicted audible characteristics are found at the compliance monitoring stage.*

Such an approach is particularly conservative and equates to establishing a noise limit that is 5 dB more onerous than it otherwise would be. It should also be noted the Australian EPHC guideline has not been finalised and is not directly used for wind farm noise assessments in Australia.

A consequence of this approach could be the inadvertent exclusion of wind farm developments from some areas due to having to account for special audible characteristics that are never actually present in practice. Such an approach could therefore be disadvantageous for increasing wind energy capacity.

[137] (Environment protection and heritage council, 2010)

7.0 OPERATIONAL ASSESSMENTS (WORK PACKAGE 2)

This section summarises key assessment practices relevant to operational wind farms, in particular, assessing whether the wind farm is satisfying its noise emission obligations consistent with planning documentation and any association planning permit conditions. Accordingly, a range of available post-construction assessment methods are discussed in detail as are a number of methods for addressing special audible characteristics.

7.1 Assessment of noise from operational windfarms

There are a range of means for assessing levels of operational wind farm noise.

In the simplest case, the noise levels are not directly assessed, on the premise that the noise issues were sufficiently addressed during planning stage of the development.

More directly, assessment can be carried out in response to complaints, on an as-needs' basis, as is generally the case for UK wind farms. This kind of assessment would typically only be carried out at a complainant's property and would not necessarily inform a regulatory authority of the broader wind farm noise situation.

An assessment of operational wind farm noise can also be included as a requirement in planning approval documents or permit conditions. Such requirements can often involve measurements at a number of receptor locations around a wind farm. The locations are typically selected on the basis that they are representative of the larger set of sensitive receptors.

A further approach to assessment can rely on noise measurements close to turbines rather than an receptor locations, with noise prediction modelling relied on to confirm outcomes at receptor locations. This style of approach has been adopted recently in the Netherlands[138].

A range of commonly available measurements methods is discussed below.

7.2 Post-construction noise monitoring methods

7.2.1 Unattended measurements at receptor locations

As discussed in Section 6.2 above, measuring ambient noise levels at receptor locations during the planning stage of a wind farm development, before a wind farm is built, can often involve medium term unattended noise monitoring and subsequent correlation of noise levels with time synchronised wind speed data.

When a wind farm is operational, post-construction, an obvious methodology for assessing wind farm noise is to repeat this process: to measure ambient noise levels at neighbouring receptor locations and compare these levels with applicable noise limits. This approach is illustrated in Figure 17.

[138] (Voklijk & Dijkstra, 2011)

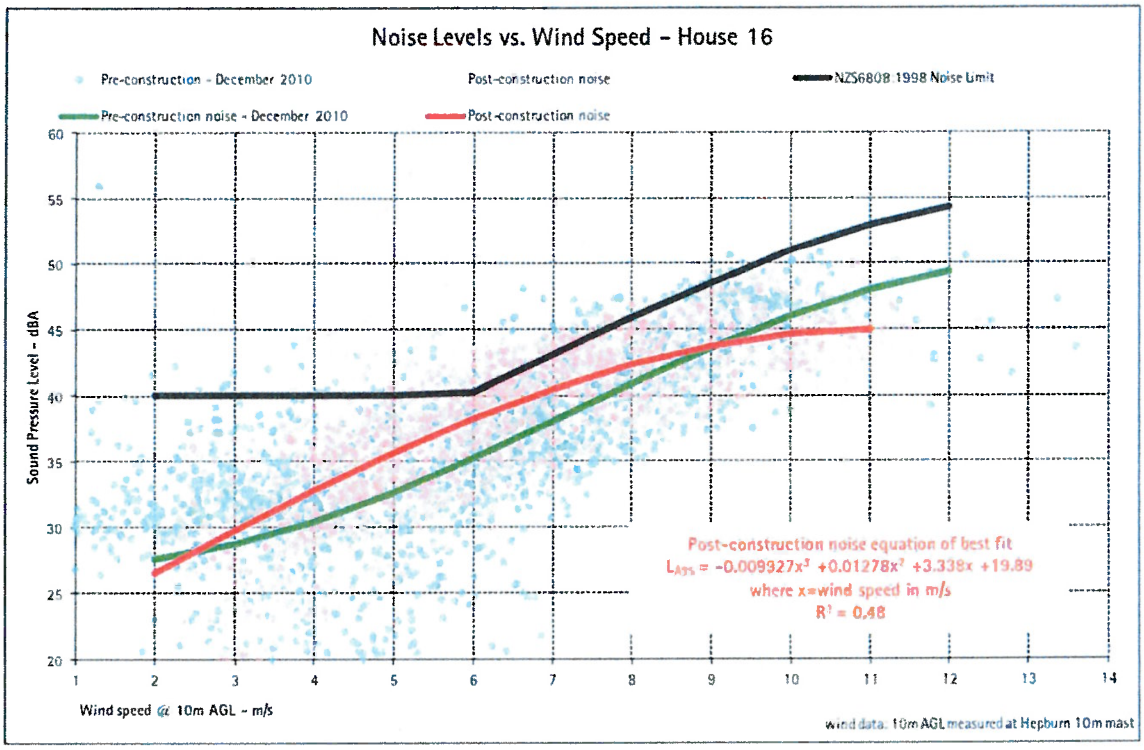

Figure 17: Example of post-construction measured background noise levels[139]

It can be seen in the figure that the measured post-construction noise level (red line) is closest to the limit value (black line) at the mid-range wind speeds. In this example, the noise limits at lower and higher wind speeds are less relevant for compliance assessment, as the margin between measured noise levels and limits is comparatively greater.

An important consideration with this approach is whether the measured post-construction noise levels are significantly influenced by ambient noise. This is because the measured post-construction noise levels will necessarily include not only wind farm noise but also noise from all other ambient sources in the areas. A recent draft Australian wind farm development guideline document[140] notes the following:

With unattended measurements it is generally only ever possible to demonstrate compliance with assessment criteria. In the case that measurements suggest noncompliance there will be doubt as to whether the measured levels are dominated by wind farm noise emission or some other source.

One particular scenario when this is likely is where the background noise environment at the monitoring location, in the absence of wind farm noise emission, has become louder. This may be a result of new trees having been planted around the monitoring location, or an increase in foliage on trees relative to when the original background noise monitoring was carried out.

[139] Chart extracted from (Marshall Day Acoustics Pty Ltd, 2012)

[140] (Environment protection and heritage council, 2010)

Some standards address this matter directly. For example, Section 7.5.3 of NZS6808:2010 notes that:

> *Post-installation measurements will capture both the wind farm sound and the background sound. In order to assess the wind farm sound level alone, the contribution of the background sound shall be removed from the regression curve drawn in 7.5.2 at each integer wind speed*

The note to Section 7.5.3 goes on to say:

> *While a simple energy subtraction of background and post-installation sound levels is not strictly mathematically correct for L_{90} centile levels, the difference may be taken as the L_{90} wind farm sound levels.*

In practice, pre-construction background noise levels are often used to correct the measured post-construction noise levels for the influence of ambient noise. An obvious issue with this approach, aside from mathematical technicalities referred to in NZS6808:2010 as noted above, is that months or years can often elapse between the pre-construction and post-construction measurements. This substantial time delay increases the uncertainty associated with the correction process. In New Zealand this issue has been addressed in some planning permit conditions requiring that pre-construction background noise level monitoring be repeated not more than 2 years prior to any post-construction noise commissioning measurements[141].

There are a number of direct advantages of this approach to monitoring and, concurrently, a number of technical challenges, primarily associated with assessing levels of wind farm noise that are comparable to the existing ambient noise levels at receptors. The key advantages and disadvantages are outlined in Table 6 below.

[141] (Tararua District Council and Masterton District Council, 2013)

Table 6: Merits and drawbacks of unattended measurements at receptor locations (extract [142])

Pros	Cons
Direct account of the actual noise levels at the receptor locations, rather than relying on predictions.	Evidence supports that predictions offer a reliable means of determining wind farm noise levels at receptor locations.
Demonstrates that noise levels at receptor locations comply with the requirements.	Measurements at some receptor locations are significantly complicated by background noise variations. Complex results can create uncertainty about compliance outcomes.
Supports the methods used to design wind farms, in turn offering credibility for the use of those methods for future projects.	Continued emphasis on the need for measurements at receptor locations may inadvertently undermine the perceived reliability of predictions.
Extended unattended survey durations enable a range of conditions to be assessed.	Repeated wide scale surveys at receptor locations are impractical to demonstrate ongoing compliance.
	The bias toward prolonged unattended surveys limits the amount of compliance information available for audible characteristics.
The results offer a valuable reference for objective noise policy reviews.	The results are typically not retained in centralised public records, and the results are not correlated with community satisfaction/dissatisfaction with noise.
Allows for a practical method of adjusting for background influence which is sufficient for demonstrating compliance at the majority of receptor locations.	Background noise levels are inherently variable, and in instances where background noise levels are higher, the assessment is dependent on alternative data sources not detailed in the guidance documentation.

7.2.2 Attended measurements at receptor locations

Attended measurements at receptor locations can assist in confirming the contribution of the ambient noise environment to total noise levels.

This process typically involves attended measurements for a period of one to several days. Measurements of wind farm noise at receptor locations are carried out in conjunction with measurements during regular periods of wind farm shut down, in order to estimate the influence of ambient noise levels during the wind farm measurements.

There can be difficulties with this approach, in coordinating site wide shut down and start up of turbines. Additionally, a significant amount of shut down testing may be necessary to capture a sufficient amount of data over a suitable range of wind conditions which can be costly both in terms of measurement time and lost power generation.

[142] (Delarie, Griffin, Adcock, & McArdle, 2013), pp 10-11

Conversely, this method offers the advantage that ambient noise level data, with the wind farm off, is captured on the same day as the wind farm noise level measurements. This is in contrast to the unattended approach to monitoring, where the data used for background correction may have been captured months or years before the compliance monitoring is carried out.

7.2.3 Derived points

As noted above, in cases where the background noise environment at the receptor, in the absence of wind farm noise, may have become louder since the time of the original background noise level measurements, then unattended monitoring may not demonstrate compliance with noise limits due to ambient noise rather than wind farm noise, even if the analysis makes a correction for background.

In such situations, unattended monitoring could be carried out at a secondary or derived location which is likely to offer a better signal to noise ratio for wind farm noise. The intention with such monitoring is to repeat measurements near to the original monitoring location, but removed from any obvious sources of elevated extraneous noise. The Australian EPHC draft wind farm development guideline document[143] provides the following guidance:

- *The secondary location selected for monitoring shall be the same distance from the wind farm, be exposed to noise emission from the same wind turbines and be of the same geographical setting as the original location. The predicted level of wind farm noise emission must be the same at each location.*
- *The expected background noise level, in the absence of wind farm noise emission, should be lower at the secondary location. This may be achieved in practice by placing the sound monitoring equipment in a nearby field or other location that may be further away from trees or other sound sources associated with the original location.*

7.2.4 Intermediate points

Somewhat analogous to derived points, measurements at intermediate points between the wind farm and receptor can be helpful to address ambient noise level related issues at receptor locations. The *Draft NSW Planning guidelines: Wind farms*[144] provides the following comments about intermediate locations:

> *To improve the ability to undertake compliance measurements alternative techniques may be employed. Such alternate methods will need to be assessed individually and on their merits. Methods may include the use of supplementary intermediate locations between the wind farm and the relevant receiver where the signal to noise ratio is much higher, and for which there are well established theoretical and empirical relationships to the relevant receivers. Data from such sites may be used to supplement and support conclusions obtained at the receiver locations.*
>
> *In most cases, it is expected that intermediate locations will be chosen from predicted noise contour maps and that these intermediate locations would return L_{eq} levels of around 45 –55 dB(A) under down wind conditions or be at around 400m from the nearest turbines.*

[143] (Environment protection and heritage council, 2010)

[144] (NSW Department of Planning and Infrastructure, 2011)

A key advantage of intermediate locations is the improved signal to noise ratio. A disadvantage of this method is that results are not likely to be directly comparable to those at the receptor location and a degree of inference will be required to estimate wind farm noise levels at receptors from the intermediate location results:

- In the case that the measured levels at the intermediate location satisfy the noise limits applicable to a more distant receptor, it could be expected that wind farm noise levels at that receptor will be lower[145] and therefore also comply with the noise limits. In such cases the inference from one location to another is reasonably simple.
- However, if measured levels at the intermediate location are greater than the receptor noise limits, then any assessment of compliance at the receptor location would need to take account of the extent of uncertainty associated with inferring noise levels at the receptor.

7.2.5 Alternative monitoring equipment

A further alternative to unattended monitoring at receptor locations, for cases which are significantly influence by ambient noise, is the use of alternative monitoring techniques. This can include the use of noise loggers which monitor frequency data, such as one-third octave band noise levels, which can in some cases identify extraneous noise such as insect noise[146].

Additionally, recording the audio signal during measurements can be helpful in some cases to allow a listening study of selected time periods to identify extraneous noise sources as well as the subjective contribution of wind farm noise to measured levels. Care must be taken with this analysis however, as the actual sound field at the site may not be sufficiently represented by the audio recording and desktop playback process. Further, analysing audio recordings can lead to onerous analysis requirements which potentially are not justified by the certainty of the outcomes that they provide.

A further alternative is the use of directional noise monitoring equipment. SAG2009 notes:

> *Recent advancement in acoustic data acquisition (such as directional noise monitors) has introduced a method to separate wind farm noise contribution from other sources. If the methods above* [sic: unattended measurements at receptor locations] *can not be used for the compliance checking, alternative techniques may be employed*

However, care is also required with this approach as directional measurements may not satisfy applicable measurement standards in the jurisdiction. Additionally, directional monitoring equipment can be limited in output ability and may not be able to produce statistical noise levels such as the widely used L_{A90} descriptor.

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[145] Exceptions to this circumstance are possible where significant shielding or ground effects influence propagation to the intermediate location but have little influence on propagation to the receptor location.

[146] (Griffin, Delaire, & Pischedda, 2013)

7.2.6 Sound power level testing and model verification

The discussion of *Intermediate points* above notes that the method relies on measuring wind farm noise at a location with suitable signal to noise ratio and then extrapolating these measured levels to receptor locations which are further away. A variation to this approach is to carry out sound power level testing near to turbines: the intent of testing being to confirm the validity of the sound power levels used during the planning stage noise modelling.

These test results could be used in combination with derived point measurements to develop a case demonstrating expected levels of wind farm noise at the receptor locations.

Alternatively, the testing can be used in combination with weather information and noise models to calculated long term average noise indices, such as the L_{den}, at receptor locations[147].

7.3 Complaints handling

The initial point of contact for a noise complaint in Ireland should be the local regulatory authority. All local authorities have to comply with the Recommendations providing for Minimum Criteria for Environmental Inspections (RMCEI)[148].

This procedure requires the local authority to log complaints and investigate them. In cases where the local authority has investigated the complaint and the problem persists the complainant should contact the Environmental Protection Agency (EPA). However the EPA will typically only become involved when the relevant local authority has been given an opportunity to investigate the noise complaint.

7.4 Special characteristics

The range of methods employed to assess and regulate special audible characteristics across the various jurisdictions considered in this report are varied. Some guidance documents rely explicitly on objective assessments while others apply subjective and objective assessments in tandem. Section B1 of NZS6808:2010 notes that:

> *Sound that has special audible characteristics, such as tonality or impulsiveness, is likely to cause adverse community response at lower sound levels, than sound without such characteristics. Subjective assessment can be sufficient in some circumstances to assess special audible characteristics.*

7.4.1 Amplitude modulation

To our knowledge there are no widely accepted methods for assessing or regulating excessive amplitude modulation from wind farms.

To date, a number of relevant guidance documents have generally considered that amplitude modulation is a characteristic part of wind turbine sound which is inherent in the setting of noise limits, implying that special audible characteristics penalties would not commonly be applied. For example, item 27 from the Executive Summary for ETSU-R-97 notes the following:

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147 (Voklijk & Dijkstra, 2011)

148 (Kramers, 2008)

The noise levels recommended in this report take into account the character of noise described as blade swish. Given that all wind turbines exhibit blade swish to a certain extent we feel this is a common-sense approach given the current level of knowledge.

Also, AS4959:2010 states:

When setting limits of acceptability, the limits should take into account the fundamental characteristics of wind farm noise, including aerodynamic noise from the rotating blades, occasional aerodynamic modulation, [...]

However, where amplitude modulation is greater or more prominent than normal, enhanced or excessive amplitude modulation may be considered to be present which may be more likely to justify a special audible characteristics penalty. Comment CB3.1 of NZS6808:2010 states the following:

By the very nature of wind turbine blades passing in front of a support tower, some amplitude modulation will always be present in the sound of a rotating wind turbine although this will not always be audible at distances from the wind farm. Amplitude modulation special audible characteristics occur when there is significant amplitude modulation of the aerodynamic sound from one of more wind turbines such that there is a greater than normal degree of fluctuation as a function of the blade passing frequency (typically about once per second for larger turbines).

NZS6808:2010 details a methodology aimed at determining whether enhanced amplitude modulation is a characteristic of the assessed noise. However, this method is described as interim and should be preceded by a subjective evaluation of the character of the noise to establish whether enhanced amplitude modulation is a noticeable feature. The method is detailed in Section B3.2 of the standard and states that:

...modulation special audible characteristics are deemed to exist if the measured A-weighted peak to trough levels exceed 5 dB on a regularly varying basis, or if the measured third-octave band peak to trough levels exceed 6 dB on a regular basis in respect of the blade pass frequency

Comment CB3.2 notes the following regarding the interim method:

This method is considered to be an adequate interim test that has been used in New Zealand. It is envisaged that appropriate objective tests for modulation special audible characteristics will be developed in future to replace B3.2 [Interim method] *or provide a more robust objective method than B3.2.*

Recently, a method for assessing amplitude modulation formed part of the consent for the Den Brooke Wind Farm[149]. This method shares a similarity of approach with the NZS6808:2010 method. Subsequent discussions in the IOA Acoustics Bulletin[150] have provided conflicting views about the suitability of the proposed method.

[149] (Appeal Decision: Land to the south east of North Tawton and the south west of Bow, 2011)

[150] (Bass J. , Investigation of the 'Den Brook' amplitude modulation methodology for wind turbine noise, 2011), (Stigwood, Wind farms and the control of excess amplitude modulation (EAM) [Letter], 2012), (Bass J. , Response to Wind farms and the control of excess amplitude modulation (EAM) [Letter], 2012)

Some recent research[151] has outlined methods for measuring amplitude modulation more readily, based on assessment in a frequency domain. However, these newer methods have not been widely tested across a wide range of situations nor have there been any detailed studies of potential correlations between the metrics and annoyance.

7.4.2 Impulsiveness

Section 8.4.8 of ISO1996-2:2007 states that there is "*no generally accepted method to detect impulsive sound using objective measurements*" .

Notwithstanding this historically there have been a limited number of examples of impulsiveness assessment methods. For example, the Tasmanian Noise measurement procedures manual includes a procedure for assessing impulsive sound which has been used to assess impulsiveness at some wind farm projects. The method is as follows:

> *"An impulsiveness adjustment is determined by taking a measurement when impulsive noise is observed using a sound level meter set initially to fast and then impulse time response. If it is found after taking measurements with these two time responses that the impulse level is greater than 2 dB above the fast response measurement, then the difference is the impulsiveness adjustment."*

AS1055-1:1997[152] provides an assessment method which is similar to the Tasmanian Noise measurement procedures manual method. However, the in relation to this method it has been noted that[153] "*in some cases, impulsiveness may be indicated using the AS1055.1 assessment method when, subjectively, it is not considered to be present*".

7.4.3 Infrasound

Guidance for assessment of infrasound levels from operational wind farms and examples of its regulation are very limited. This absence of regulation is perhaps consistent with the consensus of documents discussed in Section 3.4 which indicate infrasound levels are not significant at receptor locations.

Some general guidance is available for assessment of infrasound, irrespective of noise source, including the use of G-weightings[154] [155]. Care must be taken when applying these methods to wind farm noise, particularly if measurements are intended to be carried out outdoors where the influence of wind on the microphone can be very significant.

Examples of measurement methodologies that may be suitable are included in recent research work carried out in Denmark[156] and Australia[157]. However, these methods were developed for specific assessment scenarios and may require significant development to allow them to be applied more generally.

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[151] (McCabe, 2011), (Lundmark, 2011)

[152] (Standards Australia, 1997)

[153] (Environment protection and heritage council, 2010)

[154] (International Organisation of Standardisation, 1995) ISO7196:1995, (Jakobsen, 2001)

[155] See: http://www.mst.dk/English/Noise/recommended_noise_limits/noise_zones/noise_zone_low_frequency_etc/

[156] (Sondergaard & Sondergaard, 2008)

[157] (Sonus Pty Ltd, 2010) (Evans, Cooper, & Lenchine, Infrasound levels near wind farms and in other environments, 2013)

7.4.4 Low frequency noise

Wind farm noise policy documents do not generally provide assessment procedures for identifying low frequency noise. Where reference is made to the issue it is generally accompanied by comments suggesting that low frequency noise is not expected to be problematic for modern wind turbine installations. For example, Section 5.5.2 of NZS6808:2010 states:

> *Claims have been made that low frequency sound and vibration from wind turbines have caused illness and other adverse physiological effects among a very few people worldwide living near wind farms. The paucity of evidence does not justify at this stage, any attempt to set a precautionary limit more stringent than those recommended in 5.2 and 5.3.*

The *Draft NSW Planning guidelines: Wind farms*[158] does include an assessment method for low frequency noise. The first element of the proposed criteria is an outdoor screening test based on the following:

> *If it is shown that the C-weighted noise (measured from 20 Hz upwards) from a wind farm (excluding any wind induced or extraneous C-weighted noise) is repeatedly greater than 65 dB(C) during the daytime or 60 dB(C) during the night-time a more detailed low frequency noise assessment should be undertaken.*

The draft NSW Guideline[158] states that if the quoted values are exceeded, a more detailed low frequency noise assessment should be undertaken based on a procedure which requires measurements inside non-associated residences. The draft Guideline recommends the UK Department of Environment Food and Rural Affairs (DEFRA) document *Proposed criteria for the assessment of low frequency noise disturbance*[159] as the relevant reference to assess internal low frequency noise levels.

The DEFRA document is well researched and includes a recommended methodology and proposed criterion which are valuable references for the assessment of low frequency noise levels inside residential dwellings. Subsequently, the draft Guideline proposes that the DEFRA criterion be used to determine if the noise levels are excessive, and where found to be excessive, to apply a 5 dB penalty to the measured or predicted L_{Aeq} noise level. However, applying the DEFRA criterion in this manner, as a definitive test for excessive noise levels, extends beyond its intended application. Specifically, the DEFRA document states:

> *"It is suggested the proposed criterion be used not as a prescriptive indicator of nuisance, but rather in the sense of guidance to help determine whether a sound exists that might be expected to cause disturbance. Some degree of judgement is required by the EHO [Environmental Health Officer] is both desirable and necessary in deciding whether to class the situation as a nuisance, and is likely to remain so. One of the main reasons is that, from the control cases, it is clear that problems do not necessarily arise when the criteria are exceeded. Indeed, we can conjecture that genuine LFN complaints occur only in a few such cases. Therefore, factors like local knowledge and understanding of the broader situation are likely to remain important aspects of the assessment. [...]"*

[158] (NSW Department of Planning and Infrastructure, 2011)

[159] (Moorhouse, Waddington, & Adams, 2005)

Aternative approaches to assessing low frequency noise levels include comparison of A-weighted and C-weighted noise levels, as discussed in Section 3.4. This style of method is used in the German Standard DIN 45680:1997[160] and the Tasmanian *Noise measurement procedures manual*[161], though these documents are not tailored to wind farm assessment specifically but are more general in application.

As with infrasound, measuring low frequency noise outdoors can be problematic due to the contaminating influence of wind over the microphone[162]. However, some recent studies of low frequency noise levels outdoors in windy environments have been completed[163], though not in the context of assessing compliance with regulatory limits. Careful consideration also needs to be given to any indoor measurements of low frequency noise as measured levels can readily vary across different microphone positions in a room[164].

7.4.5 Tonality

At an operational wind farm, a tonality assessment in accordance with IEC61400-11[165] can be carried out at locations close to the turbine. If such an assessment does not identify any tones, then tones are generally unlikely to be identified at more distance receptor locations.

To carry out a tonality assessment at receptor locations, as is perhaps more appropriate given this would be the location where annoyance would be most likely to occur, there are a number of methods available:

- *Simple assessment methods*
  Such as that detailed in Annex D of ISO 1996-2:2007[166] based on one-third octave band centre levels. Given the potential complexity of tones from wind turbines, including tone frequencies that can vary with time, it is considered that such simplified methods may often not be suitable and that, pragmatically, it's more helpful to implement complex methods in the first instance.

- *IEC 61400-11 method*
  The sound power level test method can be repeated at the more distant locations, though some deviations from the documented methodology are necessary to account for the greater separation distance to the monitoring location and the potential increase in monitoring duration. Additionally, the method does not provide guidance on what magnitude of penalty might apply to any identified tones.

- *ISO 1996-2:2007 Reference method*
  Perhaps the most commonly used complex tonality assessment method, it includes a sliding penalty scale from 1 to 6, based on a range of values of tonal audibility. However, as the method has been developed for general application, some ambiguity would exist about how it should be applied in the wind farm context, to manage the variations in tonal audibility that are likely to occur with changes in wind speed.

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[160] (Technical Committee Grundlagen der Schallmessung/-bewertung, 1997)

[161] (Tasmania Department of Primary Industries, Water and Environment, 2004)

[162] (Hessler & Hessler, 2011)

[163] (Evans, Cooper, & Lenchine, 2013)

[164] (Bowdler & Leventhall, Wind turbine noise, 2011), Chapter 4

[165] (International Electrotechnical Commission, 2006), (International Electrotechnical Commission, 2012)

[166] (International Standards Organisation, 2007) ISO 1996-2:2007

- *ETSU-R-97 tonality assessment*
  This method has been developed specifically for assessment of tones at wind farm neighbours. The method is comparable to both ISO 1996-2:2007 and IEC 61400-11 and includes a sliding penalty scale. Notwithstanding this, the method is perhaps less widely used and may only have regular application in the UK.

Discussion

It is our understanding that the methods presented in ISO1996-2:2007, IEC61400-11 and ETSU-R-97 are all effectively based on the Joint Nordic Method[167] (JNM). Although the three methods have been developed from a common foundation document, tonal audibility levels determined using each method are likely to be slightly different as various changes are made in each guideline, to suit varying applications and measurements circumstances.

It is noted that the ISO1996-2:2007 and ETSU-R-97 methods define penalties ranging between 2-6 dB and 1.54-5 dB, respectively, depending on the level of tonality. No penalties are defined in IEC61400-11.

A brief overview of advantages and disadvantages of each method is provided in Table 7.

Table 7: Tonality assessment method overview

Method	Pros	Cons
IEC 61400-11 method	Developed for wind turbine tones and directly relatable to wind turbine sound power level test results	No direct guidance for assessing tonality at noise sensitive receivers
	Directly implemented in proprietary software packages	No direct guidance on annoyance or applying penalties for certain values of tonal audibility
ISO 1996-2:2007 Reference method	Widely used for a range of noise sources	No direct guidance on assessing tonality across a range of wind speeds
	Provides guidance on suitable penalties	
ETSU-R-97 tonality assessment	Developed specifically for assessment of wind turbine tones at neighbouring noise sensitive locations	Not widely used outside the UK
	Provides guidance on suitable penalties	

[167] (Pedersen, Sondergaard, & Andersen, 1999)

8.0 WIND FARM NOISE ASSESSMENT IN IRELAND (WORK PACKAGE3)

This section provides a review of legislation, guidelines and commonly employed assessment practices for wind farm noise in Ireland. This includes a detailed review of the guidance offered by WEDG06 and a comparison between the WEDG06 advice and other approaches used internationally. Additionally, a discussion and overview of submissions from recent public consultation work is provided.

8.1 Review of current assessment practices

8.1.1 Planning and Development Act 2000

Applications for wind farm developments within Ireland that are below the threshold for strategic infrastructure as set out in the Planning and Development Act 2000 (as amended) are primarily assessed by the planning authority for the area where development is proposed.

When making its decision in regard to a planning application, the planning authority is restricted to considering the proper planning and sustainable development of the area, with regard being had to the matters set out in s34 of the Act of 2000 as amended. This includes, where relevant, the policy of the Government, the Minister or any other Minister of the Government.

Planning authorities must also have regard to any additional requirements in their Development Plan, Local Area Plans or Wind Energy Strategies.

8.1.2 Ministerial Guidelines

Section 28 of the Planning and Development 2000 Act, as amended, provides that the Minister may at any time issue Guidelines to planning authorities regarding any of their functions under the Act and planning authorities must have regard to those guidelines in the performance of their functions. The Wind Energy Development Guidelines 2006 (WEDG06) were published under this section.

8.1.3 WEDG06

WEDG06 identifies noise as a relevant consideration for new developments, and provides broad guidance on the types of noise limits and separation distances to be considered when assessing new and cumulative proposals.

WEDG06 identifies noise as having potential *Environmental Implications* and requires the noise impact to be assessed by reference to the nature and character of noise sensitive locations. It presents criteria based on a combination of absolute limit values and relative limits that allow a margin above the existing background noise[168]. A detailed review of noise related aspects of WEDG06 is provided in Section 8.3.

8.1.4 LARES

Local authorities commonly deliver wind-energy strategies in response to the statutory requirement to have regard to WEDG06 and to facilitate a plan-led approach to the sensitive siting of wind farms.

[168] Refer to Section 5.0 for discussion of noise control mechanisms including absolute and relative noise limits.

Along with local authority wind energy strategies, some authorities develop renewable energy strategies to facilitate planning for the use of all local renewable energy resources. In relation to this, SEAI have provided the following comments:

> *A number of local authority stakeholders indicated to SEAI that they would welcome assistance in the preparation of more comprehensive renewable energy strategies for their areas. In 2013 the SEAI published a methodology and template to guide local authorities in the preparation of their Local Authority Renewable Energy Strategy (LARES). This methodology aims to facilitate consistency of approach in the preparation of LARES, and to assist local authorities in developing robust, co-ordinated and sustainable strategies in accordance with national and European obligations. The LARES methodology usefully provides an overview of all current EU and Irish policies and guidance relevant to planning for renewable energy development. The key land use interactions for onshore wind energy developments are identified in Appendix A4 of the methodology with reference to the WEDG06.*

8.1.5 Additional guidance

ETSU-R-97

ETSU-R-97 was drawn up under the direction of a UK Working Group on Wind Turbine Noise in 1996 with the aim of providing advice to developers and planners on the environmental assessment of noise from wind turbines.

ETSU-R-97 provides a detailed methodology for the assessment of noise from wind turbines but does not prescribe all relevant assessment choices. ETSU-R-97 lays down noise requirements for wind turbine proposals with the intention of offering a reasonable degree of amenity protection to properties located within proximity to the proposed wind turbine(s). The criteria detailed in ETSU-R-97, which are in the form of noise limits, are based on a number of references including existing research, existing guidance and regulation relating to noise emissions and the requirement for the provision of renewable energy sources.

The document recommends that separate noise limits apply for daytime and night-time with the emphasis on the protection of external amenity during the daytime and the prevention of sleep disturbance during the night-time.

The limits are set relative to background noise at nearest noise-sensitive properties and should reflect the variation in both turbine source noise and background noise with wind speed. The noise limits are specified for conditions where wind speeds are 12m/s or below at a height of 10m. ETSU-R-97 considered that impacts due to noise from the turbines will be significant only if the limits are exceeded.

Current practice in the UK commonly involves refinements of some of the methods detailed in ETSU-R-97, such as those detailed in IOA JS2009 and the IOA GPG.

EPA licensed sites

The Environmental Protection Agency (EPA) has produced its own guidance document[169] in relation to the operation of wind turbines at EPA licensed sites. This document proposes a cumulative noise limit for both the site and the turbine, with different limits applicable for the day and night-time.

The EPA references the same documents as the ETSU-R-97 as an applicable guideline for carrying out noise modelling and background assessment for noise impact assessments.

8.1.6 Variations in the application of WEDG06

The planning authority in each County Council area generally applies planning conditions in relation to noise. Below are example planning conditions from two wind farm sites in different counties:

- Site 1
  "Noise levels arising from the operation of the wind farm shall not exceed 40 dB(A) L_{A90} when measured over a ten minute period during the daytime and a fixed limit of 43 dB(A) at night-time at any noise sensitive location."
- Site 2
  During the operational phase of the development noise levels when measured over any 10-minute period externally at the nearest dwellings shall not exceed 45 dB(A) L_{A90} or 5 dB above LA90 between the hours of 08:00-20:00 and 43 dB(A) otherwise

The conditions on both sites comply with WEDG06, but provide significantly different noise limitations on the wind farm in each area. The daytime limit at Site 1 is 5 dB lower than site 2.

8.2 Comparison with Irish noise assessment practices for other sources

It can be helpful to compare assessment practices for wind farm noise to those of other noise sources which are regularly encountered such as roads and general industry.

As discussed in Section 5.2 in relation to wind farm limit comparisons, differences in noise level descriptor, and to a greater extent, assessment methodology can mean that two noise sources which share a common numerical noise limit may have different noise outcomes The examples provided in this section should therefore only be used for general information and not for direct comparison to wind farm noise limits.

8.2.1 Roads

The National Roads Authority (NRA) produced *Guidelines for the Treatment of Noise and Vibration in National Roads Schemes*. This guideline defines an assessment procedure for proposed roads developments and sets a design goal for new roads developments of 60 dB L_{den}[170] at the nearest residential façade.

[169] (Environment Protection Agency (Ireland), 2011)

[170] L_{den} is a noise indicator that is a composite of the long term L_{eq} values for the day, evening and night periods. See Glossary for full description

In Northern Ireland the *Noise Insulation Regulations (Northern Ireland) 1995* provides a target level of 68 dB $L_{A10,\ 18hr}$[171] at the façade of residential properties in the vicinity of new roads.

8.2.2 Industrial Operations

The Republic of Ireland Environmental Protection Agency (EPA) has provided a *Guidance Note for Noise* (NG4) to assist licensed sites with the assessment of their noise emissions. Suggested limit values from such sites range depending on the time of day:

- Daytime (0700-1900hrs) - 55 dB $L_{Ar,t}$[172]
- Evening (1900-2300hrs) - 50 dB $L_{Ar,t}$
- Night-time (2300-0700hrs) - 45 dB $L_{Aeq,t}$

The noise limits may apply to individual sources of noise on the site itself, at the boundary of the site or at the nearest noise sensitive location.

8.3 Comparison with international wind farm noise assessment practices

8.3.1 Critique of WEDG06

A detailed review of the key noise related comments in WEDG06 is provided in Table 8 page over.

[171] The $L_{10,18hr}$ is the noise level exceeded for 10% of an 18 hour period

[172] $L_{Ar,t}$ Is the rated noise level equal to the L_{Aeq} during a specified time interval plus a specified adjustment for tonal character and/or impulsive sound.

in WEDG06

ise sources associated with the operation of wind turbines; aerodynamic noise caused by blades passing hanical noise created by the operation of mechanical elements in the nacelle - the generator, gearbox ive-train. Aerodynamic noise is a function of many interacting factors including blade design, rotational flow turbulence; it is generally broadband in nature and can display some "character" (swish). wind turbine is tonal in nature.

nology and design have resulted in reduced noise emissions. Aerodynamic refinements that have ies quieter include the change from lattice to tubular towers, the use of variable speed operations, and bine designs. Improvements in gearbox design and the use of anti-vibration techniques in the past ten nificant reductions in mechanical noise. The most recent direct drive machines have no high-speed and therefore do not produce mechanical noise.

	Comments
ies have no high- herefore do not	In light of the tonal comments at the end of paragraph 1, it should perhaps be noted that electrical and hydraulic components of the wind turbine may still produce tonal noise, even if the transmission elements are eliminated.
tubular towers, and the switch to	In our experience, the majority of turbines installed commercially since 2006 feature tubular towers and a 3-blade pitch controlled design. In this sense the comments in WEDG06 are correct. However, in light of current wind turbine trends the comments appear dated and could benefit from being updated or removed.

s wind speeds increase, but at a slower rate than wind generated background noise increases. The ɛvelopment noise is therefore likely to be greater at low wind speeds when the difference between noise ɔpment and the background noise is likely to be greater. Wind turbines do not operate below the wind n speed, usually around 5 metres per second. Larger and variable speed wind turbines emit lower noise n smaller fixed speed turbines. Noise from wind turbines is radiated more in some directions than others, ·periencing the highest predicted noise levels. At higher wind speeds noise from wind has the effect of bine noise.

	Comments
ɛds increase, but ' background noise	This statement is often true when the wind farm and the receiving locations are exposed to the same wind flow. However it is not uncommon for hills and other ground features to cause poor correlation between wind farm and receiver wind conditions. When this occurs, the amount of noise masking offered by local wind is less certain.
nent noise is vind speeds when vind energy ise is likely to be	The declaration that impacts of wind farm noise are greater at low wind speeds, where the difference to background noise levels is larger, does not account for the absolute level of the noise in question. It could be inferred from the statements that the absolute noise limit components are not appropriate (SeeWEDG06 Section 5.6 Paragraph 4 below). The term 'impact' would perhaps be more usefully phrased as awareness or audibility.
' the wind speed ound 5 metres per	Modern wind turbines typically have cut-in speeds in the order of 3-4 m/s at hub height, which may equate to approximately 2-3m/s at standardised 10m AGL wind speeds. In light of this, the WEDG06 statement could benefit from updating and clarification.

nd carefully considered siting of turbines is essential to ensure that there is no significant increase in ny nearby noise sensitive locations. Sound output from modern wind turbines can be regulated, thus s, albeit with some loss of power.

nust be achieved between power generation and noise impact.

	Comments
considered siting there is no levels at any	*"Ensuring no significant increase in ambient noise levels"* is a much more stringent design goal than is generally recommended, and would significantly constrain wind development. The comment is also inconsistent with the discussions of noise limits that follow at paragraph 6. The introductory wording to this could be more appropriately worded, "*... is essential to ensure that the noise contribution of a wind farm is controlled to a reasonable and appropriate level.*"
bines can be lems, albeit with	This statement is generally correct, particularly for multi-MW wind turbines which are commonly provided with the ability to operate in reduced-power modes As the statement is provided in the context of siting and design considerations there is an implication that noise-reduced operational modes are a relevant consideration for the planning stage of a development. In some jurisdictions, such noise reduced modes are not commonly relied on during planning, where the key task is to establish the ability of a proposed scheme to satisfy all relevant planning requirements.
ieved between "	This is considered to be the fundamental objective of WEDG06. It may therefore benefit from further emphasis and discussion, perhaps including elevation to the start of the noise section.

ssessed by reference to the nature and character of noise sensitive locations. In the case of wind energy ısitive location includes any occupied dwelling house, hostel, health building or place of worship and may ır scenic quality or special recreational amenity importance. Noise limits should apply only to those areas ıtion or activities for which a quiet environment is highly desirable. Noise limits should be applied to ıould reflect the variation in both turbine source noise and background noise with wind speed. The ich allows reliable measurements to be made without corruption from relatively loud transitory noise s, should be used for assessing both the wind energy development noise and background noise. Any ıot be considered as part of the prevailing background noise.

	Comments
reference to the ve locations."	It is not clear how an assessment should reference the nature and character of noise sensitive locations. This statement does not provide clarity. Additional guidance would be necessary to avoid dispute about how local noise character is factored into an assessment.
ation in both noise with wind	With modern pitch-controlled turbines there is less need to introduce the complexity of a wind-speed dependent, relative noise limits.
considered as part	The purpose of this statement is to ensure that existing turbine noise is not used to justify further increases to the appropriate noise limit for future wind development. This should be reinforced by also stating that "*The prevailing limit to wind farm noise should apply to the cumulative noise contribution from all wind farms impacting on a noise sensitive location.*"

'imit of 45 dB(A)10 or a maximum increase of 5dB(A) above background noise at nearby noise sensitive ›propriate to provide protection to wind energy development neighbours. However, in very quiet areas, 'B(A) above background noise at nearby noise sensitive properties is not necessary to offer a reasonable may unduly restrict wind energy developments which should be recognised as having wider national and n low noise environments where background noise is less than 30 dB(A), it is recommended that the), 10min of the wind energy development noise be limited to an absolute level within the range of 35-40

	Comments
IB(A) or a background noise considered wind energy	The recommendation of a base limit of 45 dB(A) is somewhat inconsistent with the remainder of the noise limit advice in this document. The use of "background + 5 dB" as an adjustment for increased ambient noise is generally a practical means of considering areas already exposed to significant steady sources of noise (such as roads or industry). Where the predominant ambient noise is wind-related, a "background + 5" noise limit introduces significant complexity to the planning and compliance testing stages of the project.
gin of 5 dB(A) ›ise sensitive reasonable degree	This comment seems inconsistent with the discussion of 45 dB absolute noise limits that precedes it. If the comment is intended to provide a context for the introduction of the concept of the 35-40 dB absolute noise limits, it could benefit from re-wording to address the inconsistency.
ıckground noise is I that the daytime ıergy development vithin the range of	This advice is consistent with approaches used in some jurisdictions internationally, but would benefit from guidance in choosing a limit from the 35 – 40 dB range. The use of a 40 dBA fixed limit for general noise sensitive areas, and a 35 dBA limit for highly sensitive areas has precedents.

uld apply for day-time and for nighttime. During the night the protection of external amenity becomes nphasis should be on preventing sleep disturbance. A fixed limit of 43 dB(A) will protect sleep inside ht.

	Comments
ɔr day-time and for ection of external the emphasis ıance. A fixed limit roperties during	For other sources of noise, international practice is typically to define lower noise limits for night periods. In practice, assessing noise effects from a wind farm during the day can be difficult due to the influence of other activity noise sources. For this reason a more concise and practical rule could be developed without separating the day into different periods. Moreover, if a wind farm design were to take advantage of separate day and night noise limits it would result in having installed power generating capacity which could not be used during large parts of the day. Further, separating the day into different periods would create a more complex task for the council to ensure the developer followed these requirements.

ly to be a significant problem where the distance from the nearest turbine to any noise sensitive property Planning authorities may seek evidence that the type(s) of turbines proposed will use best current :rms of noise creation and suppression.

	Comments
'gnificant problem turbine to any 500 metres"	The difficulties with using a fixed setback (at any distance) to control noise effects are discussed in Section 5.0. For example, where problem have occurred at wind farms internationally, many have had adverse noise effects at distances of beyond 500 metres.
nce that the types 'rent engineering d suppression."	A specific noise assessment of a wind farm should incl ude the noise parameters of the turbines intended to be used, and it is worthwhile to require that the final design of the wind fa rmbe documented prior to construction, along with a specific assessment demonstrating that it will be able to comply with noise limits.

8.3.2 Strengths of current assessment practices

Current wind farm noise assessment practices in Ireland, which generally rely on ETSU-R-97 - particularly for larger developments, are broadly comparable with those used in other jurisdictions in the region, particularly the UK. The practices are also comparable to those used in other regions including New Zealand and Australia.

As noted in Section 2.3, several guidance documents for wind farm noise assessment that were developed during the 1990s and the early part of the 2000s have recently been revised[173]. These revised documents generally detail refined versions of methodologies from the documents they supersede, as opposed to any fundamental shift in approach or methodology. This indicates that the Irish methods remain comparable with assessment practices used in multiple jurisdictions internationally, though presently without the benefit of any significant formal revisions in methodology since WEDG06 was issued in 2006.

An indirect strength of current assessment practices is the early engagement of potential wind farm neighbours in the case where background noise monitoring at neighbouring dwellings is carried out during the early stages of a planning application.

8.3.3 Gaps and improvement opportunities

A number of practical issues have been identified as having the potential to provide improvement opportunities to the assessment of wind turbines in Ireland. These are outlined in Table 9.

Table 9: Noise assessment issues identified for further consideration

Item	Comment
Involved receivers	WEDG06 does not provide any direct discussions of how receivers that are involved in a wind farm development should be assessed. In addition, no comment is provided about what constitutes an involved receiver.
Noise limit values	There is some ambiguity in relation to daytime and night-time periods and the selection process for the fixed limit values as per the site specific assessment. Clarification could be helpful regarding how the noise limit values can be derived and what considerations can be taken into account in the setting of the lower absolute limits.
Cumulative noise limits	WEDG06 provides some guidance about methods for measuring background noise levels in the presence of existing, operational wind farms. However, there is no clarity about whether noise limits in general should apply per wind farm or to the total level of wind farm noise received.
Reverse sensitivity/ encroachment	WEDG06 does not provide discussion of encroachment or reverse sensitivity of noise sensitive development after the wind farm has received planning approval. For example, would construction of a wind farm preclude future residential development in the immediate area?

[173] Examples include NZS6808:2010 and SAG2009

Item	Comment
Prediction methods	There may be benefit in specifying suitable methods for prediction of wind farm noise and, possibly, also specifying suitable input variables for recommended models. This is a practice commonly used in Australia and New Zealand and, to the degree afforded by the IOA JS2009, the UK
Site measurements	The procedure for carrying out on-site measurements is not clearly defined. There are a number of issues in relation on-site assessment which can have a significant effect on the background noise measurement. ETSU-R-97 is commonly referenced in Ireland as an acceptable assessment procedure. Associated guidance updates by the Institute of Acoustics (IOA) in the UK, such as the IOA GPG, can be open to interpretation within the Irish system The implications of the updated guidance can have a significant effect on the limit values established on the site. Clarity on monitoring locations, wind shields, wind shear, and monitoring equipment would improve consistency across noise assessments.
Wind speed measurements	Additional comments regarding wind speed measurements may be of benefit. Historically wind speeds have been measured at 10m AGL. This can lead to problems in some cases if measurement results are compared directly with turbine sound power levels at 10m AGL without taking due consideration of wind shear effects. In many jurisdictions, current best practice involves referencing wind speed to turbine hub height.
Special audible characteristics	There is some indirect discussion of tonality in WEDG06. However, a broader discussion of special audible characteristics in general including approaches to regulation and methods of assessment is lacking. This is a point of difference with many guidance documents employed in other jurisdictions, where special audible characteristics are addressed to varying degrees. At present it is anticipated that ETSU-R-97 would act as the defacto assessment standard for special audible characteristics issues. Tonality is the special audible characteristic addressed in most detail in ETSU-R-97.
Commissioning	WEDG06 does not provide recommendations for compliance monitoring of operational wind farms.

8.4 Submissions review

Earlier in 2013, the DECLG announced that it was going to undertake an update of the guidance on noise (including separation distance) and shadow flicker in the WEDG06, in consultation with the DCENR. As the starting point to this process, submissions were invited as part of a preliminary public consultation process. Over 550 submissions were received from private individuals, the wind industry, professional institutes and local authorities.

Three key noise related topics have been identified as discussion points in the submissions:

- Setbacks
- A-weighted noise levels
- Special audible characteristics

For these three topics, a cross section of issues raised in the reviewed submissions is noted:

- *Setbacks*
  A significant number of submissions supported mandatory setbacks and where distances were mentioned they were generally significantly higher than the 500 m separation referenced in WEDG06. Some submissions suggested that setback distance be proportional to turbine size, for example, a separation equating to a certain number of rotor blade diameters or multiples of turbine blade tip height. Industry submissions were commonly not in favour of mandatory setbacks, suggesting that they did not provide a means of control which was directly linked to actual noise levels. These submissions also expressed concern that mandatory setbacks set at relatively high levels would prohibit the location of wind farms which were otherwise acceptable from the perspective of noise generated at dwellings or other noise sensitive locations. Some industry submissions stated that setting a fixed mandatory distance would not account for changes in the size or sound generation levels of turbines.

- *A-weighted noise levels*
  The suitability of A-weighted noise limits such as the nominal 43 dBA night-time noise limit applied by ETSU-R-97 was discussed in some submissions. In some cases the A-weighting was noted to not provide adequate emphasis on low frequency noise. In others the 43 dBA limit was considered to be inconsistent with recent changes in WHO recommended indoor noise levels.

- Special audible characteristics
  Infrasound and low frequency noise were mentioned in some submissions, with an emphasis on amenity and possible health impacts which could arise from these types of sound. A general point was that WEDG06 did not take these types of sound into account. Amplitude modulation was not commonly raised.

For further discussion of these issues, refer to Section 5.3 for setbacks, for a review of noise limits applied internationally and Section 3.4 and Section 5.5 for a discussion of special audible characteristics.

Other issues noted from the submissions include concerns raised in relation to the perceived deficiencies in the process of assessment of planning applications for wind farms by planning authorities. Issues were also raised in regard to noise measurement, a lack of information available to the public about proposed wind energy and developments and also a lack of adequate public consultation by wind farm developers. The potential negative health impacts from wind farms was a common issue of concern raised in a significant number of the submissions.

9.0 CONCLUSIONS OF DESKTOP STUDY (WORKPACKAGE 4)

This section provides a summary of the key conclusions of the desktop review of wind farm noise assessment practices.

9.1 Developments since 2006

In the broadest sense the approach to assessment of wind farm noise, particularly developments of a commercial scale, employed across a range of jurisdictions internationally has not changed drastically since the issue of Ireland's Wind Energy Development Guidelines (WEDG06) in 2006. Rather, the changes to assessment procedures largely amount to refinements and developments of existing methods. The most apparent example of this is in the UK where the 1996 document *The assessment and rating of noise from wind farms* (ETSU-R-97) has been retained as the primary tool for assessing wind farm noise while, to compliment the tool and provide supplementary guidance relevant to its application to modern wind farm developments, the UK Institute of Acoustics published the document *A good practice guide to the application of ETSU-R-97 for the assessment and rating of wind turbine noise* in May of this year.

Additional examples of refinements to wind farm noise assessment include:

- *Sources*
  IEC 61400-11 *Wind turbine generator systems - Part 11: Acoustic noise measurement techniques* was updated to Version 3.0 in 2012 from the previous Version 2.1 dated 2006. There are many refinements in the 3rd version, however the fundamental concepts have not changed and the key output from the tests carried out in accordance with the standard are sound power levels across a range of hub height wind speeds that are suitable for input into sound propagation prediction models.

- *Propagation*
  ISO9613-2:1996 *Acoustics - Attenuation of sound during propagation outdoors - Part 2: General method of calculation* remains a commonly used prediction method for wind farms, just as it was in 2006. Some recent guidance documents such as New Zealand Standard 6808:2010 *Acoustics – Wind farm noise* and the South Australian EPA document *Wind farms: Environmental noise guidelines* provide details of suitable input variables for wind farm sound prediction, such as standardised temperature and humidity effects.

- *Receivers*
  Practices for measuring and assessing background noise levels at noise sensitive locations have been refined. For example, wind speeds used in correlation analysis are now often referenced to turbine hub height, particularly for larger developments with turbines rated in excess of 1 MW, to better address variation in atmospheric conditions. Also, advances in sound level meter capabilities have expanded the quality and quantity of data that can be readily collected at site.

9.2 Approaches to wind farm noise assessment

There are no 'perfect' assessment methods for wind farm noise assessment, as demonstrated by the variation in approaches employed internationally which range from simple setback distances to complex limits with wind speed dependence and absolute and relative components.

As noted commonly in wind farm noise assessment documents, a key objective of an assessment methodology is to balance the potential noise impacts of a wind farm development on its neighbours with the wider national and regional benefits of increased wind energy capacity.

A balance is also required between the complexity of assessment inputs on the one hand and the accuracy and robustness of assessment outcomes on the other. For example, if a proposed wind farm is particularly remote and is a significant distance from any noise sensitive receiver then a comparatively simple noise assessment may adequately achieve the intended planning outcomes. Conversely, a proposed wind farm that is comparatively closer to noise sensitive locations would likely benefit from more detailed assessment to better establish the viability of the proposal. The complexity of inputs must also be considered with respect to the skills and expertise of those required to review the appropriateness of the assessment such as regulatory authorities and potential wind farm neighbours.

In addition, the degree of accuracy of the assessment, determined in part by inputs, should be weighted relative to the degree of accuracy of any commissioning works. For example, typical outdoor measurements may have an uncertainty of at least ±1 decibel due to equipment tolerances and variable propagation and ambient noise influences. For wind farm noise measurements, a greater tolerance is likely applicable on account of additional variability associated with changes in wind speed and general atmospheric conditions. In this sense, a planning assessment methodology with an accuracy finer than 1 decibel is perhaps not of critical importance as outcomes could not be measured to the same resolution in practice[174].

9.3 Noise limits

From the review of noise control methods, in particular noise limits, discussed in Section 5.0, there are three broad categories of noise control method[175] that are commonly cited in regard to wind farm noise assessment:

- Absolute limits,
  which nominate a single noise limit value to be applied across a range of assessable wind speeds.
- Relative or combined limits,
  which include provision for limit values that vary with background noise level and, commonly, wind speed.

[174] Refer to Section 2.0 for a discussion of changes in sound level and how these are perceived in practice.

[175] Refer to Section 5.0 for a discussion of types of noise control mechanism and what they entail.

- Setbacks,
  which specify a minimum separation distance between a turbine and the nearest noise sensitive receiver.

9.3.1 Absolute noise limits

A range of advantages and disadvantages are provided in Table 10 below.

Table 10: Absolute noise limit pros and cons

Stakeholder	Pros	Cons
Regulator	Simpler to assess at planning application stage	Potential difficulty assessing compliance at the operational stage
Wind farm neighbour	Easier to understand than wind-speed dependent, background noise dependent limits	A more time consuming compliance assessment process compared with setbacks. Compliance assessment typically involves measurements at receiver locations which can take time to carry out, process and report on.
Wind farm developer	Reduced assessment burden for projects at planning application stage, as background noise measurements would not be required as part of the initial planning submission[176].	Potentially some lost wind generation capacity in areas of elevated background noise
		Some refinement possibly required to cope with high background noise areas such as near motorways.

[176] Background noise measurements would still likely be necessary prior to wind farm construction. However, as the background noise levels need not directly inform noise limits, they could be arranged once a project's initial submission is approved, at which point there is comparatively more certainty of the project going ahead.

9.3.2 Relative or combined noise limits

A range of advantages and disadvantages are provided in Table 11 below.

Table 11: Relative or combined noise limits pros and cons

Stakeholder	Pros	Cons
Regulator	Consistent with the current Irish assessment approach as well as that used in the UK	Assessment of complex planning applications
		Potential difficulty assessing compliance at the operational stage
Wind farm neighbour	-	A more time consuming compliance assessment process compared with setbacks. Compliance assessment typically involves measurements at receiver locations which can take time to carry out, process and report on.
Wind farm developer	Copes more readily with active stall turbines which are characterised by noise levels that continue to increase above the wind speed of rated power.	A more involved pre-planning application scope of works, when compared with absolute limits, to carry out background noise measurements.

9.3.3 Setbacks

A range of advantages and disadvantages are provided in Table 12 below.

Table 12:Setbacks pros and cons

Stakeholder	Pros	Cons
Regulator	Easy to assess compliance at planning application and operation stages	No direct facility to address complaints as there is no assessment standard for noise output.
Wind farm neighbour	Easy to understand	A coarse tool which does not necessarily correlate with noise levels and may result in high levels of wind farm sound at noise sensitive receivers in some cases.
		Developers have no direct, regulatory disincentive for the use of turbines with undesirable sound characteristics
Wind farm developer	Reduced assessment burden for projects at planning application and operational stages of development	Potential for significant lost wind generating capacity.
	No noise related incentive to use more expensive turbines with lower sound emissions	

9.4 Measurements

Noise measurements for a wind farm can be carried out for a range or reasons including:

- Sound power level testing for warranty assessment and noise prediction model verification
- Background noise measurements at receptor locations prior to a wind farm development, to quantify existing ambient noise levels
- Post-construction noise measurements to assess whether wind farm operational noise complies with applicable requirements

The key challenge for noise measurements is acquiring robust and accurate noise level data during periods with moderate to high wind speeds.

Sound power level testing is normally carried out in accordance with International Standard IEC61400-11:2006[177].

[177] IEC61400-11:2006 Wind turbine generator systems - Part 11: Acoustic noise measurement techniques, (International Electrotechnical Commission, 2006)

There are no universally accepted methods for quantifying background noise levels at receptor locations around either proposed or operational wind farms. Common to several approaches[178], however, is the unattended measurement of noise levels using logging equipment for a period of a week or more. The background noise levels, typically L_{A90} or L_{A95}, are generally measured across a series of consecutive 10 minute periods for a number of days or weeks to collect a minimum number of data points, often at least 1500 to 2000. While unattended measurement methods are well documented in a number of jurisdictions, the robustness and accuracy of results can be influenced by many factors such as equipment noise floor and wind screen performance. The results of unattended monitoring can often be disputed during the planning application stage of a development.

A significant further challenge with unattended post-construction noise measurements is that noise levels from an operating wind farm at a receptor are often similar to levels of ambient noise. Distinguishing the relative contributions of wind farm and ambient noise to any given measured level is therefore very difficult. Additional post-construction noise commissioning measurement methods which have been developed to try and overcome this issue include:

- Attended measurements at receptor locations
- Measurements at derived or intermediate points
- Sound power level testing and noise prediction model verification

9.5 Special audible characteristics

The following special audible characteristics have been considered in this report:

- Amplitude modulation
- Impulsiveness
- Infrasound
- Low frequency noise
- Tonality

In some jurisdictions special audible characteristic assessment methods and criteria have been developed for application to general noise sources such as industrial or commercial noise and have been applied for wind farm noise assessment, though some refinement of methods can be necessary to cope with changes in wind speed.

The occurrence of one or more special audible characteristics typically results in a penalty being applied to an assessment of wind farm noise. For example, a 5 decibel penalty is often required to be added to measured wind farm noise levels.

[178] ETSU-R-97, NZS6808:2010, AS4959:2010, SAG2009

With the exception of tonality, special audible characteristics are not commonly directly predicted or assessed during the preparation of a planning application for a wind farm. As noted in Section 6.3.1 in relation to amplitude modulation and impulsiveness, this approach has likely evolved pragmatically, reflecting the limited documentation of occurrences at operating wind farms. In some jurisdictions low frequency noise and infrasound predictions have begun to be included in planning application stage assessments despite any well documented evidence in those jurisdictions to indicate these issues have been problematic[179].

Operational stage assessments of special audible characteristics can also be variable. Methods of assessing tonality are comparatively well established. Similarly, there are methods available for assessing infrasound and low frequency noise although measurement techniques must be carefully considered to eliminate undue influence of the wind, particularly when measuring outdoors. Methods of measurement and criteria for excessive amplitude modulation and impulsiveness are less well established and there is evidence to suggest that they can be significantly influenced by extraneous noise.

9.6 Irish guidance

As essentially the key guidance document for wind farm noise assessment, WEDG06 provides broad high level guidance on general issues associated with noise from wind farms during construction and operation. As discussed in detail in Section 8.3, WEDG06 would benefit from greater clarity regarding noise assessment methods and applicable noise limits.

The ambiguity of some of the existing comments in the guidelines has the potential to result in a higher rate of variability of assessment outcomes across projects owing to different interpretations of a common point or points of guidance. In the extreme, it is quite conceivable that two independent assessments of a single wind farm, both using WEDG06, could result in different outcomes despite each assessment essentially complying with the intent and requirements of WEDG06.

An example of where this may occur is through the application of noise limits. WEDG06 recommends that in low noise environments where the background noise level is less than 30 dBA, the absolute component of the noise limits should be within 35-40 dBA. Because no guidance is provided for selecting an appropriate absolute limit from this range, two different assessments of a single wind farm could both justifiably apply absolute noise limits that are up to 5 decibels different from each other. This could in turn require wind farm noise predictions for one of the assessments to be 5 decibels lower: a significant difference in the context of wind farm development, which could result in significant lost energy yield or bring the viability of the project into question[180].

In practice, the two assessments in this example have the potential to arrive at a consistent outcome if they both referenced ETSU-R-97 for guidance on selecting suitable absolute noise limits. ETSU-R-97 is currently a common point of reference for Irish wind farm noise assessment and in many senses is a default detailed assessment methodology for the implementation of the requirements of WEDG06.

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[179] (NSW Department of Planning and Infrastructure, 2011)

[180] (Adcock, Bullmore, Jiggins, & Cand, 2007)

10.0 RECOMMENDATIONS (WORK PACKAGE 4)

This section presents recommendations regarding existing Irish guidance for assessing wind farm noise, in particular the Wind Energy Development Guidelines 2006 (WEDG06).

10.1 Key recommendations

Should WEDG06 be updated or replaced?

Yes.

As discussed above, it is considered that the noise guidance provided in WEDG06 would benefit from greater clarity, particularly regarding applicable noise limits and associated assessment methods.

It is recommended therefore that the noise related discussions in WEDG06 be either revised or replaced.

Should the discussion of noise limits be revised?

Yes.

The current advice regarding noise limits is ambiguous and is a potential source of doubt for wind farm developers, potential neighbours and local regulatory authorities.

It is recommended therefore that the discussion of noise limits in WEDG06 be either revised or replaced.

The revised text should provide clear and direct advice about appropriate noise limits for wind farm developments. Work involved in updating WEDG06 should include not only a review of suitable noise limit values but also of the broader style of noise control method or limit that is applied. See Section 10.2 below for further discussion.

What else needs to be included?

It is recommended that any revision of WEDG06 include additional guidance about a number of noise related issues, including:

- Wind farm noise prediction methods
- Special audible characteristics
- Commissioning requirements
- Cumulative noise from more than one wind farm

These issues are discussed further in pursuant sections.

These additional issues could be discussed directly in updated guidance or, alternatively, developed into a supplementary document or appendix, similar to WEDG06 Appendix 3 which provides comparatively detailed advice relating to landscape impact assessment.

Any discussions should have due regard to the revision of noise limits noted above.

10.2 Noise limits

Review of noise control methods

As discussed in Section 5.0 and Section 9.0, there are three broad categories of noise control method[181] that could be considered for wind farm noise assessment in Ireland:

- Relative or combined limits, which include provision for limit values that vary with background noise level and, commonly, wind speed.
- Absolute limits, which nominate a single noise limit value to be applied across a range of assessable wind speeds.
- Setbacks, which specify a minimum separation distance between a turbine and the nearest noise sensitive receiver.

Deciding on a suitable noise control method involves factors that extend well beyond noise assessment, such as community perception, expected rates of noise annoyance and priorities of the regulatory authority. Notwithstanding these considerations, a limited discussion is provided here to help inform the DECLG and the DCENR of relevant noise assessment considerations during their review of broader issues.

From the review of these noise control methods as detailed in this report:

- Relative or combined noise limits have been employed in many jurisdictions internationally suggesting that they offer a reasonably robust means of assessing wind farm noise. However, there is significant complexity associated with accurately quantifying ambient noise environments, particularly across a range of wind speeds. This can lead to onerous noise measurement and assessment requirements during preliminary stages of a proposed wind farm. It may also lead to reduced certainty for wind farm neighbours if noise limits at their dwellings are based on complex and inherently variable background noise levels. Given the current trend towards pitch-controlled wind turbines for larger developments, whose sound power levels tend to plateau at wind speeds above rated power, the net value of having limits based on wind speed dependent background noise levels is questionable.
- Absolute limits have also been employed in a number of jurisdictions internationally suggesting that they offer a reasonably robust means of assessing wind farm noise. Absolute limits would be expected to provide a comparable or better degree of amenity protection than combined noise limits.[182] Concurrently, they would offer a streamlined assessment of wind farm noise during the planning stage. In particular, there would be no explicit requirement to measure background noise levels prior to preparing a planning application. These measurements may, however, ultimately be required either to address environmental impact requirements or to inform post-construction noise commissioning assessments.

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[181] Refer to Section 5.0 for a discussion of types of noise control mechanism and what they entail.

[182] Assuming that the absolute component of the combined noise limits is maintained and applied to all wind speeds in the nominated assessable range.

- The relationship between distance from a wind turbine or wind farm and noise effects is significantly variable[183], and there is little means of future proofing when specifying minimum set back distances. In this respect, setbacks therefore have the potential to either over-protect or under-protect wind farm neighbours. It is therefore recommended that setbacks are not used as a control method. Further discussion of setbacks is provided in Section 5.3.

On balance, it is considered that absolute noise limits offer the potential to provide comparable or better levels of amenity protection than the combined noise limits discussed in WEDG06. Concurrently, they offer the opportunity for a simpler planning stage assessment, with background noise level measurements only required if a proposed project receives planning approval.

On this basis, it is recommended that absolute noise limits be strongly considered for incorporation into revised noise assessment guidance. This should include a review of relative wind generating capacity of existing combined noise limits and any proposed absolute limits.

Absolute limits in practice

An absolute limit would nominate a single noise limit value to be applied across a range of assessable wind speeds. In practice this could mean that the most significant pre-construction site noise survey works, that is background noise measurements, are deferred to a time when there is more certainty about the status of the project.

The use of absolute noise limits need not affect the rigour of the noise assessment as background noise measurements, including correlation with wind speed data and subsequent regression analysis, would still generally be required to inform post-construction commissioning works[184].

Also, in the absence of these background measurements, which typically involves early engagement with potential wind farm neighbours, it would be important to ensure that potential neighbours are engaged in the development process at an early stage.

Noise limit values

The selection of appropriate numerical values for noise limits, whether for absolute or combined limits, should take due regard of the balance a regulator wishes to achieve between rates of wind farm development on the one hand and the degree of amenity protection offered to wind farm neighbours on the other. Concurrently, the limit value should be balanced with the measurement and assessment methods that it is paired with.

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[183] Depending on the details of the wind farm including the number of turbines and their spacing as well as the topography of the wind farm site and surrounding area.

[184] As detailed in Section 7.2.1, pre-construction background noise levels can be used to correct for the influence of ambient noise during post-construction commissioning measurements.

Providing a noise limit range from which a suitable numerical value can be selected, as is the case in WEDG06 where a limit range of 35-40 dBA is nominated, may offer sensitivity to local planning requirements and ambient environments. Conversely, selecting a single numerical limit value reduces the risk of ambiguity during wind farm noise assessment, particularly for non-involved receivers as there would be clarity about what limit value applies at their property.

The review of noise limits across a range of jurisdictions internationally indicates that limit values in the range of 35-45 dBA are commonly employed where there is an intention by the relevant regulatory authority to reasonably limit sleep disturbance such as where limits are specified for a night-time period. Limit values at the upper end of this range, around 45 dBA, are often only applied for involved receivers, as is the case with ETSU-R-97. Limit values at the lower end of this range, 35 dBA, are in some cases identified as only applying as a special case to areas that are particularly sensitive to noise and not to general rural areas where, for example, agricultural industries are priorities. NZS6808:2010 and SAG2009 offer two such examples of this approach.

10.3 Prediction methods

It is considered essential that revisions of the noise related content in WEDG06 include a discussion of wind farm noise prediction methodologies to reduce the opportunity for inconsistency and dispute to arise during the modelling process.

At a minimum, the discussion should indicate the types of standards and prediction methods that are considered appropriate. Further, prescriptive advice on specific prediction details would help promote assessment consistency and avoid protracted dispute. For example, the UK Institute of Acoustics IOA GPG[185] references ISO 9613-2:1996[186] as a suitable prediction method and provides a discussion of suitable modelling parameters and approaches such as recommended values for humidity and temperature[187], limits on barrier attenuation and suitable values of ground factor.

In the interest of allowing for improvements in technical methods, or simple cases where detailed methods are not required, it may be desirable to allow alternative prediction methods to be used where adequate technical justifications are provided.

[185] *A good practice guide to the application of ETSU-R-97 for the assessment and rating of wind turbine noise,* (Cand, Davis, Jordan, Hayes, & Perkins, 2013)

[186] ISO 9613-2:1996 Acoustics - Attenuation of sound during propagation outdoors - Part 2: General method of calculation, (International Standards Organisation, 1996)

[187] Which can influence the amount of air absorption is predicted by the model.

10.4 Special audible characteristics

It is recommended that revisions of WEDG06 include commentary regarding the following special audible characteristics:

- Amplitude modulation
- Impulsiveness
- Infrasound
- Low frequency noise
- Tonality

The comments should include details of any penalties to be applied where special audible characteristics are identified and, if necessary, how such penalties should be incorporated into a compliance assessment for either a proposed or operational wind farm, particularly if the assessment involves regression analysis[188].

A key benefit of providing such a discussion is a clear and well documented assessment path for evaluating special audible characteristics should their presence be suspected at a planned or operational wind farm. In the absence of any guidance, significant effort can be required from all stakeholders to establish suitable assessment methods on a case-by-case basis.

The extent of the special audible characteristics discussions can be a balance of a range of factors. For example, special audible characteristics are not unique to wind farms and can be a readily occurring characteristic of many types of noise. Often a jurisdiction will have existing regulations or methods in place to assess such characteristics such that the discussion in a wind farm guidance document need only refer to the existing information, perhaps with additional comments about how to address variations with wind speed[189].

The types of potential special audible characteristics for which assessment methods are provided could be weighted toward the considered risks of such characteristics occurring in practice at operational wind farms. For example tonality has been documented to be a feature of some turbines and some wind farms from time to time whereas available literature in relation to impulsiveness and infrasound suggest that they do not commonly occur at problematic levels.

[188] For example, if a regression analysis involves 1000-2000 measured noise levels, should a penalty for, say, tonality, be applied to: individual measured levels prior to determining the regression curve; all measured noise levels at relevant wind speed and wind direction conditions prior to determining the regression curve, or; directly to levels determined from the regression curve?

[189] For example, ISO1996-2:2007 *Acoustics - Description, measurement and assessment of environmental noise - Part 2: Determination of environmental noise levels* is often reference for tonality assessment of general noise sources and with appropriate supplementary guidance it could also be used to facilitate an assessment of tonality for wind farm noise.

Similarly, the magnitude of any special audible characteristics penalties could be weighted in recognition of chosen limit values. For example, if comparatively relaxed noise limit values were selected it may be appropriate to apply special characteristics penalties cumulatively[190] whereas a single penalty[191] may be more appropriate if applied in conjunction with comparatively onerous noise limits values.

Also, it may be worth affording flexibility in any prepared comments that allow for advances in the state of the art. This style of approach has been adopted in NZS6808:2010 *Acoustics – Wind turbine noise* where the assessment method for amplitude modulation has been identified as "interim".[192]

10.5 Commissioning

It is recommended that revisions of WEDG06 include a discussion of commissioning measurements and assessment requirements including when commissioning work is considered necessary and how it is to be carried out.

The discussion should detail methods to assess levels of operational wind farm noise in response to complaint. The methods should describe requirements for any un/attended monitoring, what sound levels are to be recorded, how they are to be correlated with wind speeds etc.

Additionally, there could be merit in requiring an amount of pro-active compliance monitoring once a new wind farm development becomes operational, to confirm that any conditions on planning permissions are being adhered to.

10.6 Additional issues

A number of additional issues have been identified as warranting further discussion in any revision of WEDG06. These issues are discussed in Table 13.

[190] That is, the inclusion of a separate penalty for each special audible characteristic that is identified.

[191] That is, a single penalty applying whether one or several special audible characteristics is identified.

[192] Section B3.2 of NZS6808:2010 notes the following:
This method is considered to be an adequate interim test that has been used in New Zealand. It is envisaged that appropriate objective tests for modulation special audible characteristics will be developed in future to replace B3.2 or provide a more robust objective method than B3.2.

:nded for inclusion in wind farm noise assessment guidance

Comment	Example resolution
egarding involved receivers including a definition of suitable noise limits for involved receivers and what lace between the receiver and wind farm developer to gotiated adjustments to noise limits.	A higher absolute limit, as is commonly applied for involved receivers in many jurisdictions, could be nominated. In addition, requiring a contract or written agreement between a receiver and wind farm developer of any variation to noise limits could prevent confusion and ambiguity about when an adjustment in noise limits should apply.
ıe in separate noise limits for daytime and night-time periods. can theoretically have the benefit of enhanced amenity tional flexibility, depending and what limit values are :erms, a common limit for day and night may provide a ' of assessment and simplicity of interpretation.	A common noise limit could be adopted for daytime and night-time periods, with the limit value selected to address the most noise sensitive time of day (typically night-time).
tential cumulative noise impacts from more than one ınd how they should be assessed.	Noise limits at a given noise sensitive location could apply to the total level of wind farm noise rather than on a 'per wind farm' basis. This approach to limits could be supported by additional guidance on how to identify receivers for assessment and how to coordinate predictions of multiple wind farm schemes.
guidance about reverse sensitivity and encroachment, :ntial dwellings or other noise sensitive land uses are ty to an approved or operating wind farm. :ial developments are not permitted within a certain the wind farm. This is comparable to the mechanisms croachment around other types of noise-generating ɔf such methods depends on the planning framework ʼed in a particular jurisdiction.	A requirement for the wind farm developer to provide the local regulatory authority with information about noise levels from a wind farm in the form of predicted or measured noise contours. This information could be used for the regulatory authority and perspective developers of land neighbouring the wind farm, to evaluate the suitability of a particular property and development plan.

ıeighbouring a wind farm development and who have an involvement in the project, often including financial involvement.

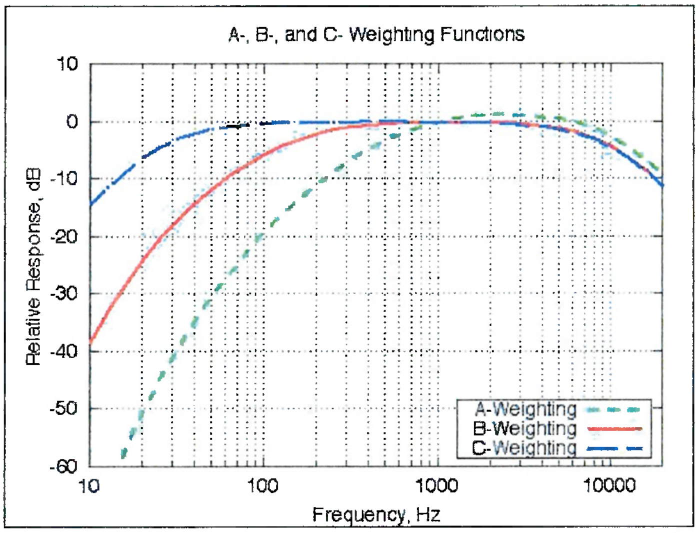
10.7 Discussion

The SEAI's stated objective for this desktop study of onshore wind farm noise is to obtain evidence upon which to evaluate the appropriateness of WEDG06 in relation to noise impacts and if considered necessary suggest changes.

The recommendations detailed above include reviewing the noise control methods currently used for wind farm developments in Ireland. As noted in Section 10.2, deciding on a suitable noise control method involves factors that extend well beyond noise assessment. If a new noise control method is nominated as an outcome of the technical update of WEDG06 noise issues, it is recommended that the proposed method be reviewed by the relevant authority with due consideration of the wider planning context including rates of renewable energy development, community perception, rates of noise.

A number of the recommendations detailed above, such as those relating to special audible characteristics and commissioning work, will involve provision of new content in the form of detailed guidance and methodologies. If these recommendations are adopted as part of the technical update of WEDG06 noise issues it is recommended that they be externally reviewed prior to being finalised.

APPENDIX A GLOSSARY OF TERMINOLOGY

AGL	Above Ground Level
Ambient	The ambient noise level is the noise level measured in the absence of the intrusive noise or the noise requiring control. Ambient noise levels are frequently measured to determine the situation prior to the addition of a new noise source.
Amplitude modulation	*Amplitude modulation special audible characteristics occur when there is significant amplitude modulation of the aerodynamic sound from one of more wind turbines such that there is a greater than normal degree of fluctuation as a function of the blade passing frequency (typically about once per second for larger turbines.)*[193] Refer to Section 3.4 for further details.
A-weighting	The A-weighting approximates the response of the human ear, particularly for sounds of moderate and low levels.
C-weighting	The C-weighting approximates the response of the human ear, particularly for sounds at high noise levels (typically greater than 100 dB).
Comparison of A and C weightings	
dB	Decibel. The unit of sound level. A measurement of sound level expressed as a logarithmic ratio of sound pressure P relative to a reference pressure of Pr=20 μPa i.e. dB = 20 x log(P/P_r)
Frequency	Frequency is the number of pressure fluctuation cycles per second of a sound wave. Measured in units of Hertz (Hz). Sound can occur over a range of frequencies extending from the very low, such as the rumble of thunder, up to the very high such as the crash of cymbals.
Impulsiveness	*Transient sound having a peak level of short duration, typically less than 100 milliseconds.*[193] Refer to Section 3.4 for further details.

Hertz (Hz)	Hertz is the unit of frequency. One hertz is one cycle per second. One thousand hertz is a kilohertz (kHz).
L_{Aeq}	The equivalent continuous (time-averaged) A-weighted sound level. This is commonly referred to as the average noise level.
L_{A90}	The A-weighted noise level equalled or exceeded for 90% of the measurement period. This is commonly referred to as the background noise level.
L_{Ceq}	The equivalent continuous (time-averaged) C-weighted sound level.
L_{C90}	The C-weighted noise level equalled or exceeded for 90% of the measurement period.
Low Frequency noise	*Sound below about 200Hz.*[193] Refer to Section 3.4 for further details.
Masking Noise	Background noise that is not disturbing, but due to its presence causes other unwanted noises to be less intelligible, noticeable and distracting.
Octave Band	Sound, which can occur over a range of frequencies, may be divided into octave bands for analysis. For environmental noise assessments, sound is commonly divided into 7 octave bands. The octave band frequencies are 63Hz, 125Hz, 250Hz, 500Hz, 1kHz, 2 kHz and 4kHz.
Sound Pressure Level (L_P)	A logarithmic ratio of a sound pressure measured at distance, relative to the threshold of hearing (20 µPa RMS) and expressed in decibels.
Sound Power Level (L_W)	The level of total sound power radiated by a sound source. A logarithmic ratio of the acoustic power output of a source relative to 10^{-12} Watts and expressed in decibels.
Special audible characteristics	Distinctive characteristics of a sound which are likely to subjectively cause adverse community response at lower levels than a sound without such characteristics. Examples are tonality (e.g. a hum or a whine) and impulsiveness (e.g. bangs or thumps).
Tonality	*Noise containing a discrete frequency component*[193]. Refer to Section 3.4 for further details.

[193] (Standards New Zealand, 2010)

APPENDIX B WIND FARMS: ANCILLARY SOURCES OF NOISE

Whereas wind turbine noise is strongly wind-speed dependant and so requires special methods of assessment, other noise sources within the farm are either not dependant on the wind (such as fans at a service building) or passively wind-related (such as noise from transmission lines). These sources can be assessed using conventional noise rules.

B1 Substations and Transformers

While the transformer located at the base of each turbine may be considered as part of the turbine noise emissions, the switching and substation facilities which are usually located within the wind farm are an additional source of noise. Substations are well understood, and are the subject of measurement and assessment standards such as IEC 60076-10[194]. Transformer noise generally occurs at two times the line frequency, for example 100 Hz for a 50 Hz electrical network, and harmonics of that frequency (e.g. 200, 300, 400 Hz). As such, transformer noise is often tonal and readily discerned in the environment.

B2 Transmission Lines

Transmission lines can produce noise as the wind blows through them (Aeolian noise) and in the case of high-voltage lines (e.g. above 200 kV) by the crackling that occurs especially in humid conditions (corona discharge).

Both of these effects are relatively low in sound level, and are usually only an issue when these lines pass in close proximity to a dwelling.

B3 Meteorological Masts

Meteorological masts are used both before and during the operation of a wind farm to collect wind data. Masts are often erected at similar heights to the turbines used in the wind farm. While they are of much lighter construction than a wind turbine, they are often held in place with multiple guy wires which can produce wind tones especially in the high winds associated with wind farm sites. These should be considered as a significant noise source if located near to dwellings.

B4 General Activity Noise

Noise produced from vehicles, building services, and other installations should be included in an assessment of noise effects. There is generally no special consideration that needs to be given to these as a result of being associated with a wind farm.

[194] (International Electrotechnical Commission, 2005)

APPENDIX C WIND SPEED PROFILES

C1 Wind shear

Wind shear describes variations in wind speed with height above ground level.

The rate of change of wind speed with height is influenced by a range of factors including the type of ground coverage, the complexity of the terrain profile, and atmospheric conditions[195].

The following equation can be used to estimate the difference in wind speed between two different heights, based on wind shear conditions that are characterised by the variable roughness length, Z_0 (m). The equation describes a logarithmic wind speed profile. Examples of wind speed profiles calculated using this equation are shown in Figure 18 for four different values of roughness length.

$$V_1 = V_2 \cdot \frac{\ln\left(\frac{h_1}{z_0}\right)}{\ln\left(\frac{h_2}{z_0}\right)}$$

(Equation 2)[196]

Where:

V_1 = wind speed at height h_1 in m/s

V_2 = wind speed at height h_2 in m/s

Z_0 = the surface roughness length

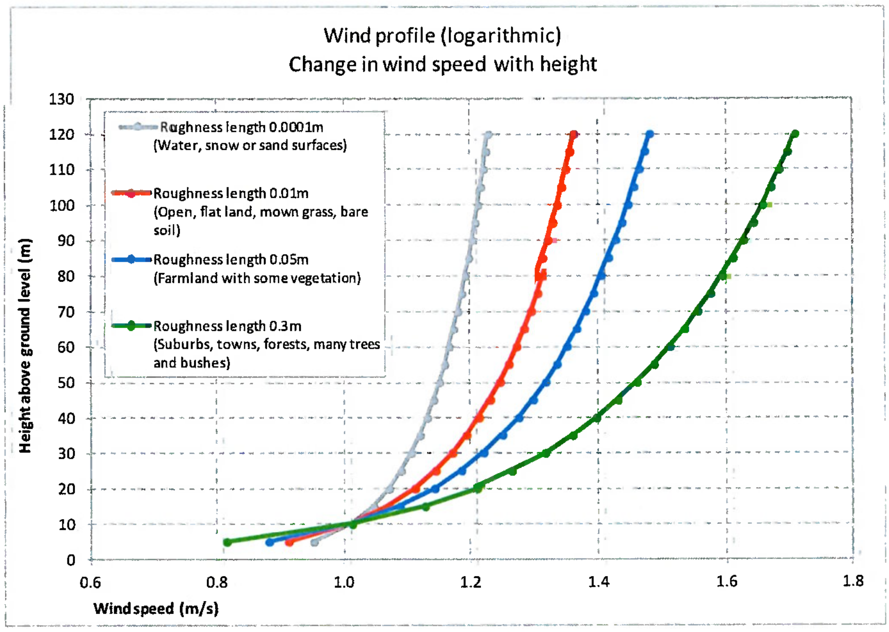


Figure 18: Example wind profiles

[195] (van den Berg, Effects of the wind profile at night on wind turbine sound, 2004)

[196] (International Electrotechnical Commission, 2012)

C2 Application to wind farm noise

Some methods of wind farm noise assessment, such as those detailed in ETSU-R-97, rely on a common 10m wind speed reference for both the measured background noise levels and the turbine noise emission data. In relation to background noise surveys, the 10m measurement height represented a practical requirement for the installation of temporary anemometry during the noise survey period. The 10m height wind speeds also generally tended to correspond more closely with wind conditions at surrounding receptor locations, enabling improved correlations between measured wind speeds and background noise levels, where these are necessary.

In relation to turbine emission data however, the reliability of a 10m height wind speed is dependent on an assumed shear profile. Specifically, manufacturers' noise emission data assessed according to IEC61400-11 must be referenced to 10m height wind speed and assumes a standard relationship between wind speeds at hub-height and 10m height. This relationship uses a reference surface roughness length (z_0) of 0.05m which equates to a wind profile near ground level for relatively open farmland with limited tree coverage and mild undulating terrain. The benefit of this method is a standardised reference which enables the comparison of noise emissions from different turbines with varying hub-heights.

The reliability of the 10m referenced turbine data is reduced if actual wind shear conditions where the turbine is installed significantly differ from the assumed wind shear applied to manufacturers' data. For example, if wind shear is lower than assumed by the standardised reference roughness length, as may occur during the day at sites with very flat ground and little or no tree coverage, the turbine's noise emissions will occur at relatively higher wind speeds than indicated by the 10m height standardised data, leading to potentially lower noise levels than expected for a given wind speed. Conversely, if wind shear is higher than assumed by the standardised reference roughness length, the turbine's noise emissions will occur at relatively lower wind speeds than indicated by the 10m standardised height, leading to potentially higher noise levels for a given wind speed.

Higher wind shear conditions than assumed manufacturers' IEC61400-11 noise emission data can occur as a result of increasing terrain complexity and ground coverage, or importantly as a result of wind shear conditions being dominated by atmospheric stability effects rather than ground roughness effects[197]. Stable atmospheric conditions may occur for a range of reasons such as the relative cooling of the air near ground level at night. The effect of stable atmospheric conditions and increased wind shear can therefore lead to situations where an assessment referenced to 10m wind speed heights will underestimate the level of turbine noise expected at surrounding locations for a given wind speed, a phenomenon reported in measurements published by Frits van den Berg[195] , and since occasionally referred to as the "van den Berg effect". The influence of increased wind shear was particularly relevant for older types of turbine design which utilised stall based speed regulation systems, characterised by noise profiles that continued to increase with wind speed. In contrast, modern pitch regulated machines tend to increase noise emissions up to a particular wind speed, above which noise levels do not generally increase with wind speed.

[197] (van den Berg, Effects of the wind profile at night on wind turbine sound, 2004)

In some jurisdictions, current industry practice is to base wind farm noise assessments on hub-height wind speeds rather than the 10m height wind speeds. For example, the use of hub-height wind speed data has been detailed in recent guidance from Australia[198] and New Zealand[199] as it is considered to better account for the influence of site-specific wind shear conditions in the noise assessment.

Conversely, wind speeds continue to be referenced to 10m AGL in the UK. However, following criticism of assessments based on direct measurement of wind speeds at a height of ten metres, current good practice in the UK[200] recommends that all ten metre wind speed data is calculated from hub height wind speed assuming reference conditions.

[198] SAG2009, AS4959:2010

[199] NZS6808:2010

[200] (Cand, Davis, Jordan, Hayes, & Perkins, 2013)

APPENDIX D GENERAL NOISE CONTROL METHODS

Most development, whether it involves construction of new dwellings or improving essential infrastructure, will generate noise.

General noise policies for infrastructure developments must therefore provide an acceptable level of amenity protection, whilst providing a viable framework that allows for essential development.

D1 Methods for policy control

The intent of many noise policies is to adequately control the effects that noise from one location has at another location. Most commonly, the control method is in the form of a *noise limit*, being the level of the sound that should not be exceeded at some location, typically that of the nearest noise sensitive receiver. There is, however, a range of control methods available, including several varying approaches to the use of a noise limit. These approaches are discussed briefly in Table 14.

Table 14: Summary of types of noise control method

Method		Comments
A	*Land Use Planning*	In the broadest terms, land use planning concerns the compatible and efficient arrangement of a variety of land uses: in a sense it's the starting point for any form of noise management. When the planning system achieves ideal outcomes, specific impact assessments aren't needed and land use planning can effectively address all possible issues relating to impact and effects. For example, zoning of land around airports often precludes/excludes potential development of residences as this type of noise sensitive land use is contradictory to the primary activities of an airport and the adverse noise impacts that it can potentially generate. By incorporating this style of buffer zone around an airport, the broader financial, social and in some cases security benefits of efficiently functioning airports can be better realised.
B	*Compensation to affected receivers*	In some cases it may not be possible to adequately control external noise levels at surrounding receptor locations. An alternative approach in these cases can be to compensate the affected receivers. For example, negotiating a mutually agreed outcome with the affected receptor(s). For example, building sound insulation upgrades could be provided as compensation for a property owner allowing higher noise limits at the property.
C	*Compulsory acquisition of affected receivers*	During major infrastructure projects, regularity bodies can in some cases have an option to acquire land in the vicinity of a project. This method is usually considered a last resort and only considered should other options not be viable. Generally, there is no set condition or rule which triggers the need for compulsory land acquisition. Rather, it involves weighing all relevant factors such as project benefits to the community, costs of acquisition, alternative site selection etc.

Method		Comments
D	*Minimum separation distances*	Requires a minimum separation distance between a noise source and noise sensitive receiver. For example the Ontario Ministry of the Environment's minimum setback between a wind project and a noise sensitive receiver of 550m. Setbacks allow a simple way of separating noise generating and noise sensitive development. However, they do not necessarily provide a consistent level of amenity protection. In some cases setbacks can be overly onerous as they fail to take account of terrain, shielding and meteorological affects on sound propagation. Conversely, unless the separation distance is impractically large, it fails to cope with any changes in source characteristics such as higher sound levels. Setbacks are addressed further in Section 5.2.4.
E	*Voluntary acquisition of affected receivers*	In some cases, typically involving major changes to an existing item of infrastructure which is going to cause adverse noise impacts, there can be an option to offer to acquire any affected properties.
F1 F2 F3	*Noise limits*	A cap on noise levels from one location received at another location, typically in the form of numerical noise limit values. Refer to Section 5.1 for further details.

D2 Noise control methods: Summary of advantages and disadvantages

Table 15 provides some key advantages and disadvantages of each noise limit derivation and regulatory approach.

Table 15: Advantage and disadvantages of each approach*

Method		Advantages	Disadvantages
A	Land use planning	Noise management based on (high level) consideration of different receiver sensitivities	There may not be enough land available for ideal land use planning at interfaces between zones. For example, ideal buffer between industrial and residential zones may not be realisable in practice.
B	Compensation to affected receivers	Shared financial benefit of the project.	Potentially costly and divisive
		Can allow a suitable internal amenity if building fabric is upgraded	Potential loss of amenity for neighbours irrespective of compensation received.
C	Compulsory acquisition of affected receivers	Prevents long term exposure to adverse noise impacts	Relocation of residents, additional cost

Method	Advantages	Disadvantages
D Separation distance	Transparency and ease of understanding	No account of shielding or meteorological affects
	Simple to implement	Can result in inefficient use of resources
		May not cope well with changes in technology
		Limited or no incentive to use low noise technology
		Dispersed housing can make identifying appropriate sites difficult
E Voluntary acquisition of affected receivers	Resident is provided with an option to relocate	Additional cost
		Residual impact on residents who chose not to move.
F1 Absolute noise limit	Easily derived	Doesn't take into account existing acoustic environment
F2 Relative noise limit	Takes into account existing acoustic environment	Requires a robust measurement procedure to establish representative ambient noise levels.
F3 Combination noise limit	Takes into account existing acoustic environment, provides a cap to limit continuing noise increase	See F2

* The extent of some of the advantages and disadvantages noted in the table will depend on the extent of control required by the relevant method. For example, the extent to which a separation distance may result in inefficient use of resources will depend on the magnitude of the setback or separation distance.

In relation to wind farms, as detailed in Table 16 in Appendix E, noise limits (F1, F2 & F3) are commonly encountered control methods in many jurisdictions. Alternatively methods of control such as acquisition (C, E) and setbacks (D) are much less commonly referenced in relation to wind farms.

APPENDIX E REVIEW OF WIND FARM NOISE REGULATIONS IN OTHER JURISDICTIONS

t	Period[202]	Comment
	All	New South Wales, Queensland, Tasmania and Western Australia typically reference either South Australian wind farm noise guidance or the New Zealand standard on wind farm noise for assessments.
	All	
	All	
	Night	
	All	Site measurement of background level at receivers is not required. An assumed background level for wind speeds in the range 4-10m/s at 10m AGL is provided in the relevant Ministry guidelines, which state that the "[...] *wind induced background sound level reference* [values] ... *was determined by correlating the A-weighted ninetieth percentile sound level (L90) with the average wind speed measured at a particularly quiet site.*
	All	
	All	
	Night	
	Day	
	Night	Base limit varies depending on housing density in the receiving environment. The lower stated limit applies in an area with 1 - 8 dwellings, increasing to +3 dB for 9-160 dwellings and to +6 dB in noise affected areas with greater than 160 dwellings.
	Day	
	Night	
	Day	
	Night	
	Day	

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the urban hum

to frequent aircraft flyovers"

requent aircraft flyovers"

t	Perio d[02]	Comment
	All All All Night	New South Wales, Queensland, Tasmania and Western Australia typically reference either South Australian wind farm noise guidance or the New Zealand sta ndard on wind farm noise for assessments.
	All All All Night Day	Site measurement of background level at receivers is not required. An assumed background level for wind speeds in the range 4 10m/s at 10m AGL is provided in the relevant Ministry guidelines, which state that the "[...] *wind induced background sound level reference* [values] ... *was determined by correlating the A-weighted ninetieth percentile sound level (L90) with the average wind speed measured at a particularly quiet site.*
	Night Day Night Day Night Day	Base limit varies depending on housing density in the receiving environment. The lower stated limit applies in an area with 1 - 8 dwellings, increasing to +3 dB for 9-160 dwellings and to +6 dB in noise affected areas with greater than 160 dwellings.

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the urban hum

to frequent aircraft flyovers"

requent aircraft flyovers"

t	Period[202]	Comment
	All	Limit applies at 6m/s at 10m AGL
	All	Limit applies at 8m/s at 10m AGL
	All	Limit applies at 6m/s at 10m AGL
	All	Limit applies at 8m/s at 10m AGL
	All	The relative thresholds inside dwellings apply across a range of single octave bands from 125 Hz to 4000 Hz.
	Day	A minimum setback distance of 500m also applies[220].
	Night	
	Day	Germany does not have wind farm specific noise limit, and legislative noise limits for general noise sources apply.
	Night	Peak limits also apply and the legislation states:
	Day	*Individual short-term noise peaks may exceed binding immission values during the day by not more than 30 dB(A), and at night by not more than 20 dB(A).*
	Night	
	Day	
	Night	
	Day	
	Night	
	Day	
	Night	
	All	
	All	Section 3.0 for further details.
ı)	All	

tutional, holiday home, camping or allotment purposes or areas designated in district plans or town planning regulations for noise-

·m), Joint Ministerial Gazette (GMBl) No. 26/1998, 26 August 1998, p. 503.

APPENDIX F EXAMPLE NOISE MODEL SUMMARY DETAILS

Table 17: noise model reference information

Item	Note									
Sound power level data L_{WA} (dB)	2.3MW turbine									
	Octave Band Centre Frequency (Hz),									
	31.5	**63**	**125**	**250**	**500**	**1000**	**2000**	**4000**	**8000**	**Overall**
	74.6	90.4	95.7	97.7	98.6	96.6	99.8	96.2	91.7	109.8
Sound power level data L_{WA} (dB)	3MW turbine									
	Octave Band Centre Frequency (Hz),									
	31.5	**63**	**125**	**250**	**500**	**1000**	**2000**	**4000**	**8000**	**Overall**
	83.1	95.7	95.6	103.2	104.9	101.7	102.3	95.4	85.9	105.8
Turbine wind speed	Nominally the wind speed of rated power									

Item	Setback example 1			Setback examples 2			Setback example 3		
Turbine layout data	**X**	**Y**	**Z (rel)***	**X**	**Y**	**Z (rel)***	**X**	**Y**	**Z (rel)***
	700	0	100	700	0	100	700	0	100
				1200	0	100	1200	0	100
				1700	0	100	1700	0	100
				2200	0	100	2200	0	100
				2700	0	100	2700	0	100
				700	-300	100	700	-300	100
				1200	-300	100	1200	-300	100
				1700	-300	100	1700	-300	100
				2200	-300	100	2200	-300	100
				2700	-300	100	2700	-300	100
				500	350	100	500	350	100
				1000	350	100	1000	350	100
				1500	350	100	1500	350	100
				2000	350	100	2000	350	100
				2500	350	100	2500	350	100
				0	700	100	0	700	100
				500	700	100	500	700	100
				1000	700	100	1000	700	100
				1500	700	100	1500	700	100
				2000	700	100	2000	700	100

Receiver layout data	Setback example 1			Setback example 2			Setback example 3		
	X	Y	Z (rel)*	X	Y	Z (rel)*	X	Y	Z (rel)*
	0	0	1.5	-86	-33	1.5	-121	142	1.5
Prediction methodology	ISO 9613-2 1996 *Acoustics – Attenuation of sound during propagation outdoors –Part 2: General method for calculation* (ISO 9613-2:1996) implemented in SoundPLAN v7.2.								
Prediction input parameters	• Ground conditions – mixed ground characterised by a ground factor of G = 0.5 • Ground contours: Examples 1,2 – Flat ground Example 3 – Turbines are elevated relative to the receiver • Temperature – 10°C • Relative humidity – 70% • Source heights – 100m • Receiver heights - 1.5m AGL • Barrier effects – ISO 613-2:1996 Equation 12, Dz limited to no more than 20								

* relative heights express the height above ground level. Where ground contours are included in the noise prediction model, comparative heights between sources and receivers will vary.

APPENDIX G TENDER LITERATURE REVIEW DOCUMENTS

For informative purposed, brief comments are provided herein regarding each of the documents noted in Annex A of the *Request to Tender* documentation from SEAI[236].

Item	
1	Nissenbaum MA, Aramini JJ, Hanning CD (2012).Effects of industrial wind turbine noise on sleep and health. Noise Health;14:237-43 • Considers sleep and general health outcomes of people living close to wind turbines • A cross-sectional study involving two sites: Mars Hill (linear arrangement of 28 General Electric 1.5 megawatt turbines)and Vinalhaven (of three similar turbines sited on a low-lying, tree-covered island), Maine, USA. • A questionnaire was offered to all residents meeting the participant-inclusion criteria and living within1.5 km of an industrial wind turbine (IWT) and to a random sample of residents, meeting participant inclusion criteria, living 3 to 7 km from an IWT between March and July of 2010. • Validated questionnaires were used to collect information on sleep quality (Pittsburgh Sleep Quality Index - PSQI), daytime sleepiness (Epworth Sleepiness Score - ESS), and general health (SF36v2), together with psychiatric disorders, attitude, and demographics. • Participants living within 1.4 km of an IWT had worse sleep, were sleepier during the day, and had worse SF36 Mental Component Scores compared to those living further than 1.4 km away. Significant dose-response relationships between PSQI, ESS, SF36 Mental Component Score, and log-distance to the nearest IWT were identified after controlling for gender, age, and household clustering. The adverse event reports of sleep disturbance and ill health by those living close to IWTs are supported.
2	Colby, WD.,.Dobie, R.; Leventhall, G.; Lipscomb, D M ,. McCunney, R.J.,Seilo, Søndergaard, B.,(2009) Wind Turbine Sound and Health Effects, An Expert Panel Review. American Wind Energy Association and Canadian Wind Energy Association. • Considers health impacts of wind turbines • Study based on literature review • There is no evidence that the audible or sub-audible sounds emitted by wind turbines have any direct adverse physiological effects. • The ground-borne vibrations from wind turbines are too weak to be detected by, or to affect, humans. • The sounds emitted by wind turbines are not unique. There is no reason to believe, based on the levels and frequencies of the sounds and the panel's experience with sound exposures in occupational settings, that the sounds from wind turbines could plausibly have direct adverse health consequences

[236] It should be noted that the wider literature review included many more documents than the eight listed above. Refer to the Bibliography for a list of relevant literature.

3 IEA Task 28 relevant projects, http://www.socialacceptance.ch/WPrList.aspx?TR=E

Searched for 'abstract: noise' which identified the following documents:

A. Jeffrey M. Ellenbogen / Sheryl Grace / Wendy J Heiger-Bernays (Massachusetts Department of Environmental Protection), Wind Turbine Health Impact Study: Report of Independent Expert Panel January 2012, Prepared for: Massachusetts Department of Environmental Protection Massachusetts Department of Public Health

- Considers health impacts of wind turbines
- Study based on literature review
- There is limited evidence from epidemiologic studies suggesting an association between noise from wind turbines and sleep disruption.
- Whether annoyance from wind turbines leads to sleep issues or stress has not been sufficiently quantified. While not based on evidence of wind turbines, there is evidence that sleep disruption can adversely affect mood, cognitive functioning, and overall sense of health and well-being.
- There is insufficient evidence that the noise from wind turbines is directly (i.e., independent from an effect on annoyance or sleep) causing health problems or disease.

B. Delta, Low frequency noise from large wind turbines (Journal no. AV 1272/10, Project no. A401929, 21 November 2010)
http://www.madebydelta.com/delta/Business_units/TC/Services+by+technology/Acoustics/Low+frequency+noise/Low+frequency+noise+from+large+wind+turbines.page

- **Noise emission from wind turbines**

The emitted sound power from the wind turbines increases with the nominal power of the turbines. The increase in total A-weighted noise emission is slightly less than the increase in electrical power. In short, larger wind turbines are slightly quieter than smaller wind turbines, per kW of generated power.

- **Indoor noise levels at adjacent residences**

Calculation scenarios at the adjacent residences to wind turbines with determination of low frequency noise levels indoor have shown that the general differences between small and large wind turbines are small. For scenarios where the results for the total outdoor noise is close to the existing noise limits, the levels calculated for the indoor low frequency noise are close to the guidance limits applicable for industry in Denmark.

- **Annoyance from wind turbine noise**

Listening tests were carried out at the University of Salford. Here it was found that tones at lower frequencies in wind turbine noise was not perceived as more annoying than tones at higher frequencies when heard at the same prominence. This is a rather important result as when present, tones in noise from large wind turbines tend to occur at lower frequencies than for small wind turbines.

- **Infrasound**

A theoretical study from RISØ DTU together with the findings from the measurements on large wind turbines and a literature study, confirms that infrasound is imperceptible for this type of wind turbines. Even close to the wind turbines the sound pressure level is much below the normal hearing threshold. Thus infrasound is not considered a problem

C. Geoff Leventhal, *Infrasound From Wind Turbines – Fact, Fiction or Deception*, Canadian Acoustics Issue 29, Vol 34 no.2 (2006)

- A literature review with the following key findings:
  Infrasound from wind turbines is below the audible threshold and of no consequence.
  Low frequency noise is normally not a problem, except under conditions of unusually turbulent inflow air.
  The problem noise from wind turbines is the fluctuating swish

D. Eja Pedersen, Högskolan i Halmstad (Swedish EPA) , Noise annoyance from wind turbines a review (2013)

- Considers Noise annoyance from wind turbines
- Key findings include:
  Noise from wind turbines is not at all as well studied as for instance noise from road traffic. As the number of studies is low no general conclusions could be drawn. ...
  The reviewed studies above indicate that annoyance from wind turbine noise
  + Is to a degree correlated to noise exposure.
  + Occurs to a higher degree at low noise levels than noise annoyance from other sources of community noise such as traffic.
  +Is influenced by the turbines' visual impact on the landscape.
- It is also noted that wind turbine noise does not directly cause any physical health problems.
  There is not enough data to conclude if wind turbine noise could induce sleep disturbance or stress-related symptoms.
  Wind turbine noise is, due to its characteristics, not easily masked by background noise.
  Wind turbine noise is particularly poorly masked by background noise at certain topographical conditions.

E. EJA Pederson, Human response to wind turbine noise – perception, annoyance and moderating factors (Department of Public Health and Community Medicine, Göteborgs 2007)

- Considers noise annoyance from wind turbines
- Cross-sectional study carried out in a flat mainly rural area in Sweden. Examination of dose response relationship between wind turbine sound pressure levels and annoyance
- 513 surveys were collected with a response rate of 68%
- Key findings include:
  Dose response relationships were identified for perception and annoyance
  Risk of annoyance was enhanced by being able to see turbines and by resident living in as rural cf. Suburban area
  Noise was appraised as an intrusion to privacy
  Amplitude modulated sound was described as most annoying

4	UK institute of Acoustics relevant projects, http://www.ioa.org.uk/about-us/news-article.asp?id=260 Refer to comments about the IOA GPG throughout the body of this report.
5	Irish Wind Energy Association (2012) Noise Research Paper This document was not retrievable online and has not been reviewed.

6	Hanning, CD.,Evans, A., (2012) British Medical Journal – Editorial and letter of response. Wind Turbine Noise, British Medical Journal Editorial. (Wind turbine noise Seems to affect health adversely and an independent review of evidence is needed Christopher D Hanning honorary consultant in sleep medicine 1, Alun Evans professor emeritus) • Considers sleep disturbance caused by wind turbine noise • Key findings *A large body of evidence now exists to suggest that wind turbines disturb sleep and impair health at distances and external noise levels that are permitted in most jurisdictions, including the United Kingdom. Sleep disturbance may be a particular problem in children, and it may have important implications for public health. When seeking to generate renewable energy through wind, governments must ensure that the public will not suffer harm from additional ambient noise. Robust independent research into the health effects of existing wind farms is long overdue, as is an independent review of existing evidence and guidance on acceptable noise levels.*
7	Referenced studies by Simon Chapman in his letter of response to the BMJ Editorial http://www.bmj.com/content/344/bmj.e1527/rr/572780 The following papers are referenced: A. Hanning CP, Evans A. Wind turbine noise. BMJ 2012;344:e1527 doi: 10.1136/bmj.e1527 (Published 8 March 2012) • See Item 6 of this table for comments. B. Chapman S, Simonetti T. Summary of main conclusions reached in 17 reviews of the research literature on wind farms and health. School of Public Health, University of Sydney. 30 Jan 2012 http://www.scribd.com/doc/79506148/Summary-of-main-conclusions-reached-in-17-reviews-of-the-research-literature-on-wind-farms-and-health • Key finding: insufficient evidence that the noise from wind turbines is directly causing health problems or diseases C. Chapman S, Simonetti T. Is there anything not caused by wind farms? A list of diseases and symptoms in humans and animals said to be caused by wind turbines. School of Public Health, University of Sydney. http://tobacco.health.usyd.edu.au/assets/pdfs/publications/WindfarmDiseases.pdf • Key finding: 216 difference diseases/symptoms claimed to be caused by exposure to wind turbine noise (intention to ridicule claims) D. Bartholomew RE, Wessely S. Protean nature of mass sociogenic illness: From possessed nuns to chemical and biological terrorism fears. Br J Psychiatry 2002 180: 300-306. http://bjp.rcpsych.org/content/180/4/300.full.pdf+html Issues considered • Considers mass sociogenic illness issues by way of literature review • Key finding: There has been a significant shift in the presentation of mass sociogenic illness E. Boss LP. Epidemic hysteria: a review of the published literature. Epidem Reviews 1997;19:233-243 • Literature review concerning reported instances of mass hysteria and mass psychogenic illness

F. Krogh CME. Industrial wind turbine development and loss of social justice. Bull Science, Technol and Society 2011;31:321-333.

- Argues that there has been a lack due diligence on the part of governments to investigate adverse health impacts of noise from wind turbines. In turn, the author contends that this demonstrates a failure to provide social justice.

8 **Submission by Simon Chapman to NSW Windfarm Guidance**

- Contends that "*...the sheer weight of evidence as adjudicated now in 17 separate reviews (see Appendix 1) underlines that claims that wind turbines can adversely affect health are not evidence-based.*"
- Analysis and discussion addresses: Nina Pierpont and Wind turbine syndrome; Sarah Laurie, *Waubra Foundation;* Vibro-acoustic disease
- Also cites:

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APPENDIX H BIBLIOGRAPHY

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ETSU-R-97

The Assessment & Rating of NOISE from Wind Farms

ETSU

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Department of Trade and Industry

ETSU-R-97

THE ASSESSMENT AND RATING OF NOISE FROM WIND FARMS

The Working Group on Noise from Wind Turbines

Final Report
September 1996

PREFACE

This report describes the findings of a Working Group on Wind Turbine Noise. The aim of the Working Group was to provide information and advice to developers and planners on the environmental assessment of noise from wind turbines. While the DTI facilitated the establishment of this Noise Working Group this report is not a report of Government and should not be thought of in any way as replacing the advice contained within relevant Government guidance.

The report represents the consensus view of the group of experts listed below who between them have a breadth and depth of experience in assessing and controlling the environmental impact of noise from wind farms. This consensus view has been arrived at through negotiation and compromise and in recognition of the value of achieving a common approach to the assessment of noise from wind turbines.

Members of the Noise Working Group:

Mr R Meir, Chairman	DTI
Dr M L Legerton, Secretary	ETSU
Dr M B Anderson	Renewable Energy Systems
Mr B Berry	National Physical Laboratory
Dr A Bullmore	Hoare Lea and Partners
Mr M Hayes	The Hayes McKenzie Partnership
Mr M Jiggins	Carrick District Council
Mr E Leeming	The Natural Power Company Ltd
Dr P Musgrove	National Wind Power Ltd
Mr D J Spode	North Cornwall District Council
Mr H A Thomas	Isle of Anglesey County Council
Ms E Tomalin	EcoGen Ltd
Mr M Trinick	Bond Pearce Solicitors
Dr J Warren	National Wind Power Ltd

EXECUTIVE SUMMARY

INTRODUCTION

1. This document describes a framework for the measurement of wind farm noise and gives indicative noise levels thought to offer a reasonable degree of protection to wind farm neighbours, without placing unreasonable restrictions on wind farm development or adding unduly to the costs and administrative burdens on wind farm developers or local authorities. The suggested noise limits and their reasonableness have been evaluated with regard to regulating the development of wind energy in the public interest. They have been presented in a manner that makes them a suitable basis for noise-related planning conditions or covenants within an agreement between a developer of a wind farm and the local authority.

2. The noise limits suggested have been derived with reference to:

- existing standards and guidance relating to noise emissions
- the need of society for renewable energy sources to reduce the emission of pollutants in pursuance of Government energy policy
- the ability of manufacturers and developers to meet these noise limits
- the researches of the Noise Working Group in the UK, Denmark, Holland and Germany
- the professional experience of members of the Working Group in regulating noise emissions from wind turbines and other noise sources
- the discussion of the issues at meetings of the Noise Working Group and with others with appropriate experience.

3. The Noise Working Group has sought to protect both the internal and external amenity of the wind farm neighbour. Wind farms are usually sited in the more rural areas of the UK where enjoyment of the external environment can be as important as the environment within the home.

4. The guidance contained within this report refers to the operation of the wind farm and is not appropriate to the construction phase.

NOISE LIMITS

5. The Noise Working Group recommends that the current practice on controlling wind farm noise by the application of noise limits at the nearest noise-sensitive properties is the most appropriate approach. This approach has the advantage that the limits can directly reflect the existing environment at the nearest properties and the impact that the wind farm may have on this environment.

6. Given that one of the aims of imposing noise limits is to protect the internal environment, one might consider it appropriate to set these limits and hence monitoring locations at positions within the building. There are, however, some practicalities to take into consideration which lead us to believe that the current practice of setting external limits on noise is the more sensible approach; these factors are described in detail in Chapter 6 of the full report.

7. The noise limits applied to protect the external amenity should only apply to those areas of the property which are frequently used for relaxation or activities for which a quiet environment is highly desirable.

8. The Noise Working Group considers that absolute noise limits applied at all wind speeds are not suited to wind farms in typical UK locations and that limits set relative to the background noise are more appropriate in the majority of cases.

9. Only by measuring the background noise over a range of wind speeds will it be possible to evaluate the impact of turbine noise, which also varies with wind speed, on the local environment.

10. The Noise Working Group is of the opinion that one should only seek to place limits on noise over a range of wind speeds up to 12m/s when measured at 10m height on the wind farm site. There are four reasons for restricting the noise limits to this range of wind speed:

- Wind speeds are not often measured at wind speeds greater than 12m/s at 10m height

- Reliable measurements of background noise levels and turbine noise will be difficult to make in high winds

- Turbine manufacturers are unlikely to be able to provide information on sound power levels at such high wind speeds for similar reasons

- If a wind farm meets noise limits at wind speeds lower than 12m/s it is most unlikely to cause any greater loss of amenity at higher wind speeds

11. The recommendation of the Noise Working Group is that, generally, the noise limits should be set relative to the existing background noise at nearest noise-sensitive properties and that the limits should reflect the variation in both turbine source noise and background noise with wind speed. We have also considered whether the low noise limits which this could imply in particularly quiet areas are appropriate and have concluded that it is not necessary to use a margin above background approach in such low-noise environments. This would be unduly restrictive on developments which are recognised as having wider national and global benefits. Such low limits are, in any event, not necessary in order to offer a reasonable degree of protection to the wind farm neighbour.

12. Separate noise limits should apply for day-time and for night-time. The reason for this is that during the night the protection of external amenity becomes less important and the emphasis should be on preventing sleep disturbance. Day-time noise limits will be derived

from background noise data taken during quiet periods of the day and similarly the night-time limits will be derived from background noise data collected during the night.

Quiet day-time periods are defined as:

All evenings from 6pm to 11pm,
plus Saturday afternoon from 1pm to 6pm,
plus all day Sunday, 7am to 6pm.

Night-time is defined as 11pm to 7am.

13. Consideration has also be given to circumstances where a more simplified approach, based on a fixed limit, may be appropriate.

14. The Noise Working Group is agreed that the $L_{A90,10min}$ descriptor should be used for both the background noise and the wind farm noise, and that when setting limits it should be borne in mind that the $L_{A90,10min}$ of the wind farm is likely to be about 1.5-2.5dB(A) less than the L_{Aeq} measured over the same period. The use of the $L_{A90,10min}$ descriptor for wind farm noise allows reliable measurements to be made without corruption from relatively loud, transitory noise events from other sources.

15. The limits to be proposed relate to free-field (except for ground reflections) measurements in the vicinity of noise-sensitive properties.

16. The Noise Working Group is of the opinion that absolute noise limits and margins above background should relate to the cumulative effect of all wind turbines in the area contributing to the noise received at the properties in question. It is clearly unreasonable to suggest that, because a wind farm has been constructed in the vicinity in the past which resulted in increased noise levels at some properties, the residents of those properties are now able to tolerate higher noise levels still. The existing wind farm should not be considered as part of the prevailing background noise.

17. Wind turbines operate day and night dependent upon wind speeds. It will be necessary to acquire background noise data for both day- and night-time periods because:

- the absolute lower limit is likely to be different for day- and night-time operation
- the noise limits are to be related to the background noise levels
- background noise levels may be different in the day than during the night.

18. It is proposed that the background noise levels upon which limits are based and the noise limits themselves are based upon typical rather than extreme values at any given wind speed. An approach based upon extreme values would be difficult to implement as the difference in measurements between turbine noise and background would depend upon the length of time one is prepared to take data. A more sensible approach is to base limits upon typical or average levels but to appreciate that both turbine and background noise levels can vary over several dB for the same nominal conditions.

19. The variation in background noise level with wind speed will be determined by correlating $L_{A90,10min}$ noise measurements taken over a period of time with the average wind speeds measured over the same 10-minute periods and then fitting a curve to these data.

20. The wind farm noise limits proposed below refer to rating levels in a similar manner to that proposed in BS 4142 in respect that additions are made to the measured noise to reflect the character of the noise.

21. Noise from the wind farm should be limited to 5dB(A) above background for both day- and night-time (with the exception of the lower limits and simplified method described below), remembering that the background level of each period may be different.

22. In low noise environments the day-time level of the $L_{A90,10min}$ of the wind farm noise should be limited to an absolute level within the range of 35-40dB(A). The actual value chosen within this range should depend upon a number of factors:

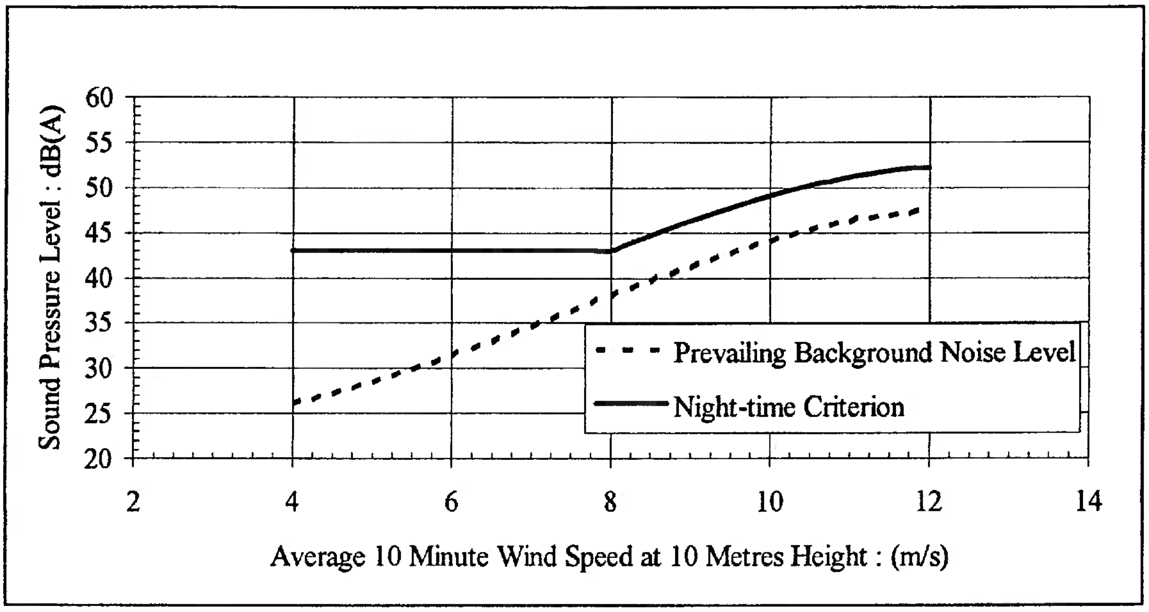
- the number of dwellings in the neighbourhood of the wind farm
- the effect of noise limits on the number of kWh generated
- the duration and level of exposure.

23. The Noise Working Group recommends that the fixed limit for night-time is 43dB(A). This limit is derived from the 35dB(A) sleep disturbance criteria referred to in Planning Policy Guidance Note 24 (PPG 24). An allowance of 10dB(A) has been made for attenuation through an open window (free-field to internal) and 2dB subtracted to account for the use of $L_{A90,10min}$ rather than $L_{Aeq,10min}$.

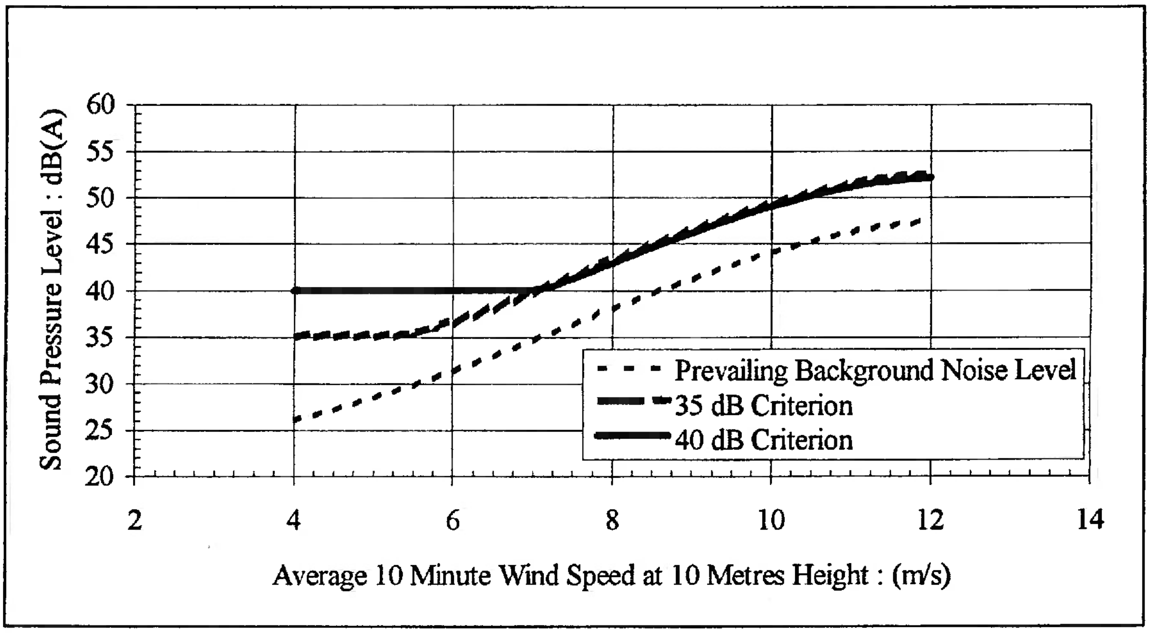
24. The Noise Working Group recommends that both day- and night-time lower fixed limits can be increased to 45dB(A) and that consideration should be given to increasing the permissible margin above background where the occupier of the property has some financial involvement in the wind farm.

25. For single turbines or wind farms with very large separation distances between the turbines and the nearest properties a simplified noise condition may be suitable. We are of the opinion that, if the noise is limited to an $L_{A90,10min}$ of 35dB(A) up to wind speeds of 10m/s at 10m height, then this condition alone would offer sufficient protection of amenity, and background noise surveys would be unnecessary. We feel that, even in sheltered areas when the wind speed exceeds 10m/s on the wind farm site, some additional background noise will be generated which will increase background levels at the property.

26. Graphical representations of the recommended limits appear in the figures overleaf based upon a fairly typical background noise curve. Both background levels and turbine noise are determined by best-fit curves through representative data.



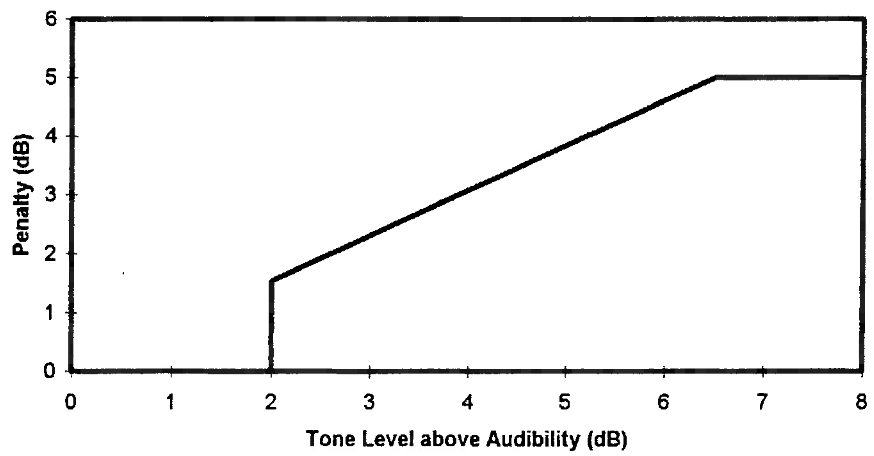
Example of night-time noise criterion



Example of day-time noise criterion

27. The noise levels recommended in this report take into account the character of noise described as blade swish. Given that all wind turbines exhibit blade swish to a certain extent we feel this is a common-sense approach given the current level of knowledge.

28. The Noise Working Group recommends that a tonal penalty is added to the measured noise levels in accordance with the figure below. The penalty incurred is related to the audibility of any tones produced by the wind turbines when measured using a prescribed method as represented graphically below.



Penalties for tonal noise

29. The Noise Working Group thought that it would be beneficial to present its recommendations in a form which might be useful to developers and planners. We therefore considered drafting planning conditions, but came to the conclusion that the necessary definitions of terms which would be required would make planning conditions too complicated. Therefore, it was decided to produce covenants for inclusion within an Agreement between a developer and a local authority. Conditions and Agreements (known as Planning Obligations) are discussed in Chapter 2. The Planning Obligation produced by the Noise Working Group is reproduced in Chapter 8 where it is supplemented by some Guidance Notes to which it refers. These Guidance Notes also serve as a useful summary of the proposed measurement procedure.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

1. INTRODUCTION

A Planning Policy Guidance Note on Renewable Energy, PPG 22 [1], was published by the Department of the Environment and the Welsh Office on 3 February 1993. PPG 22 contains an Annex on Wind Energy which includes some discussion on noise from wind turbines. This annex includes a description of the sources of noise from wind turbines, a discussion on the limitations on the use of BS 4142: 1990, "Method for rating industrial noise affecting mixed residential and industrial areas" [2], and advice on noise-related information that could usefully accompany a planning application. At the time of writing there was insufficient relevant experience of noise from wind farms in the UK environment and public reaction to the noise to be able to provide more specific guidance.

A literal interpretation of how BS 4142 should be applied to wind turbine noise assessment is difficult and its use may be inappropriate and problematical. These difficulties are discussed in Chapter 6 of this report.

With no generally agreed procedure for determining noise levels that provide acceptable protection to the amenity of local residents, planners and developers have been required to use their own experiences to bring forward workable solutions by reference to the particular character and sensitivity of the area. Many wind farms, though not all, have had conditions relating to noise levels from the wind farm specified in the planning consents. These have varied in noise level and measurement units (eg L_{A90} or L_{A50}) from site to site but generally fall in to two classes: either an absolute noise level which shall not be exceeded at the nearest residences or a margin above the existing background noise which shall not be exceeded.

It was, however, recognised that there was still a degree of uncertainty among planners and developers. Planners did not have much experience of noise from wind turbines in rural areas. Developers had no noise targets for guidance when selecting sites for wind farms or deciding upon turbine layout. Therefore, in August 1993, the DTI facilitated the establishment of a Working Group on Noise from Wind Turbines, consisting of experts with experience in the environmental assessment of noise from wind turbines. The objectives of the Noise Working Group were:

- To review recent experience in the field of wind turbine noise. This was to include an attempt to relate measured data to complaints and provide an expert assessment of the issues relating to wind turbine noise.

- To define a framework which can be used to measure and rate the noise from wind turbines. This was to include parameters to be measured, measurement methods, units and measurement periods and was to fulfil all the necessary criteria required for planning conditions or covenants within Planning Conditions.

- To provide indicative noise levels thought to offer a reasonable degree of protection to wind farm neighbours and encourage best practice in turbine design and wind farm siting and layout.

- To encourage the widespread adoption of the Working Group's recommendations.

The Working Group was asked to address the issues of broadband noise, tonal content and blade swish (the modulation of broadband noise at blade passing frequency). The following report describes the findings and recommendations of the Noise Working Group. These recommendations are intended to serve as an informative guide to assessing the environmental impact of the noise from wind turbines.

The report was drafted in the light of the best information available at the time. However it is acknowledged that as more experience and information become available and as circumstances develop it may become necessary to revise and improve the contents of this report. The Noise Working Group therefore suggests this report and its recommendations are reviewed in two years time. To this end, any comments on the usefulness of the report would be most welcome, including any suggestions for improvement with any supporting evidence where possible. Any such suggestions should be sent to the Noise Working Group Secretariat at the following address:

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2. THE PHILOSOPHY AND PRACTICE OF NOISE EMISSION CONTROL

Introduction

The way in which a society controls man-made noise sources reflects a variety of complex influences. These influences are social, economic, intellectual and political. They also reflect the limits of technical ability in the measurement of the noise source in question.

That the position is complex is reflected by the way in which those in the UK who live close to wind farms have reacted to noise generated by the wind turbines. An individual's reaction to the receipt of noise may reflect, at the same time, physical sensitivity to noise, local political attitudes to wind turbines, perceptions of the economic worth of wind energy generation, attitudes to wind energy development and development in the countryside, and the individual's own perception of wind turbines.

These complexities are not unique to the UK. Attitudes to noise emissions vary between and throughout all countries. However, certain patterns emerge both within Europe and within the UK. From the researches of the Working Party it seems that attitudes towards noise emissions, particularly with regard to wind turbines, are generally more rigorous in the northern countries of Europe where the most extensive deployment of wind turbines has taken place. In particular, Swedish and Dutch attitudes to the control of noise from wind turbines are strict, and the same could probably be said of the UK. Again, in Denmark there is a Statutory Order which specifically regulates noise from wind turbines, although perhaps less strictly than in Holland.

History of noise emission control in the UK

Modern noise control in the UK derives in spirit from the Wilson Report of 1964 [3]. One of the fundamental findings of the Wilson Report was that as a guiding principle noise regulation authorities should seek to control existing ambient noise at current levels. The existing noise environment should be maintained. This principle can be seen in DOE Circular 10/73 [4], now withdrawn in England in favour of Planning Policy Guidance: Planning and Noise, PPG 24, [5] issued in September 1994.

There can be little surprise at the findings of the Wilson Report or at the way it became transmitted into formal Government advice. The UK is relatively densely populated. Intensive and extensive developments in and adjoining towns and cities have over the years produced ambient noise levels much higher than might be desirable by any objective standard. At the same time, perhaps because of noise-generating development in towns and cities, those able to do so have sought the peace and quiet of the countryside for their leisure time. They have become commuters. It is to be expected that such persons will be exceptionally sensitive to any intrusions on the peace and quiet which they have obtained by moving to live in the countryside, whatever the reasons for the noise-generating activity which may prove to be such an intrusion.

Given the findings of the Wilson Report, and the advice in DOE Circular 10/73, it was logical that control of new noise emissions should have developed on the basis of a level of exceedence over the background noise level existing prior to the introduction of the new noise source. This approach is reflected in a well known advisory document on noise control, BS 4142. BS 4142 was first issued in 1967 and was most recently reissued in revised form in 1990. At the date of this report a further revision is in train.

PPG 24 and other advisory documents which include BS 4142: 1990 seek to control the noise environment by limits on the levels by which new development may cause the background noise level to be exceeded. However, there is a recognition that new development must take place because of the needs of the economy and of society. The aim of the guidance contained within PPG 24, as stated in the opening paragraph, is:

> *"..... to provide advice on how the planning system can be used to minimise the adverse impact of noise without placing unreasonable restrictions on development or adding unduly to the costs and administrative burdens of business."*

In the context of wind energy, the planning system must therefore seek to control the environmental impact from wind farms whilst at the same time recognising the national and global benefits that will arise through the development of renewable energy sources, and not be so severe that wind farm development is unduly stifled.

Special considerations are given to some types of development, such as road, rail and airport developments where the balance advised in PPG 24 is particularly difficult to achieve. In recognition that such developments must take place, but that they will cause significant changes to the noise environment of neighbours, a statutory compensation code has been developed. The statutory framework for this code is within the Land Compensation Act 1973. Developments covered by this Act possess a statutory immunity from action by regulatory authorities or by citizens who feel aggrieved at the noise created. Instead, citizens can claim compensation under the Act. The provisions of the Land Compensation Act 1973 do not apply to anything other than the sort of infrastructural development recorded in the previous paragraph.

The Government and planning authorities have also had to produce advisory standards for noise-generating developments which in the interests of the economy, society, and indeed the environment must take place. An example of a form of development falling into this category is mineral exploitation. Specific advice on noise emissions from mineral operations is contained in Mineral Planning Guidance Note 11 [6]. It is perhaps no coincidence that the Mineral Planning Guidance Notes issued by the Secretaries of State form an entirely separate body of advice from general Planning Policy Guidance Notes. Minerals are recognised in a variety of ways, not least noise emissions, to be a special case. Society requires a variety of minerals, and there is an inevitable environmental cost in their extraction and distribution.

Turning to wind energy, the Government has advised in a variety of documents, most recently Planning Policy Guidance Note 22 (February 1993) [1] and DTI Energy Paper 62 (March 1994) [7], that its policy is to encourage the exploitation of renewable energy resources in appropriate circumstances. The reasons for this advice relate to the need to promote a diversity of energy resources and to assist in meeting the UK's international environmental obligations. The Government's policy towards renewable energy development has been evidenced in the case of wind by over 30 planning permissions for wind farms, with many more planning permissions for single wind turbines. These developments have been permitted in rural areas where more established forms of development, except perhaps for mineral extraction, would be unlikely to be permitted.

No development is without an external cost. The external cost of wind energy generation derives mainly from the visual effect of the turbines, and such noise emissions that impact to any degree on those who live and work nearby.

Methods of noise control in the UK

While the Wilson Report was issued over 30 years ago, the emergence of noise emissions as a core environmental concern is relatively recent. While quite separate law relating to statutory nuisance derives from the Public Health Act 1936, the first relevant advice in a planning context can be seen within DOE Circular 10/73. At a statutory level the Control of Pollution Act 1974 contained detailed provisions concerning statutory nuisances. European Community (EC) Directives of the mid-1980s, and rapidly increasing concerns about a wide variety of environmental issues, culminated in the Environmental Protection Act 1990. Part I of the 1990 Act contains provisions (formerly within the Control of Pollution Act 1974) relating to the statutory nuisances which include noise. At the advisory level Planning Policy Guidance Note 24: Planning and Noise has replaced DOE Circular 10/73. In terms of renewable energy development the wind annex to Planning Policy Guidance Note 22 contains some fairly general thoughts on noise emissions.

Chapters 4 and 6 of this report include discussion on the difficulties in theory and in practice of applying the advisory documents recorded in the paragraph above to wind energy development.

There are three principal methods available to local authorities and to citizens who wish to control noise emissions from wind generators. Local authorities may secure compliance with planning conditions by serving a planning Enforcement Notice, by serving a Breach of Condition Notice, or by taking injunctive action in the Courts. Local authorities can enforce covenants given within Planning Obligations by taking injunctive action. Both local authorities and citizens can pursue complaints in the Magistrates Courts alleging statutory nuisance.

Planning conditions

When a local authority grants planning permission for a development they may impose such planning conditions as they think fit. This discretion is not unlimited. To be valid a planning condition has to satisfy certain tests, and these are advised in paragraph 14 of DOE Circular 11/95 (Welsh Office Circular 35/95) [8]. These tests are:

- relevance to planning
- relevance to the development in question

- necessity
- precision
- enforceability
- reasonableness in all the circumstances.

There is no doubt that the control of noise is relevant to planning, almost certainly relevant to any wind energy development and, if only for this reason, very probably necessary. It remains for a local authority to ensure that the condition as drafted is precise, enforceable and reasonable. If a planning condition fails any one of these three tests the local authority would have little prospect of successful enforcement.

The invalidity of a planning condition because of a failure to comply with any of the tests outlined above helps neither the developer nor the local authority if a problem should arise. With a well drafted and enforceable condition both parties know where they stand both against each other and, within the planning jurisdiction, with regard to any complainant. If a noise condition has been carefully thought out, correctly phrased, and is in all other respects valid then two beneficial consequences follow. Firstly, the wind farm operator will be able to establish if he is in breach of the condition, and what he has to do in order to secure compliance. Secondly, if despite a well drafted and reasonable condition, and compliance with that condition, a citizen brings a complaint before the Magistrates Court under the Environmental Protection Act 1990, the fact of compliance with a reasonable and well thought out condition may prove to be an effective defence to an action in the Magistrates Court. The defence of best practicable means is discussed below.

On the other hand, if the planning condition drafted does not secure the proper control of noise emissions, and could readily be perceived to be unfair to neighbouring occupiers, the Magistrates Court might have little hesitation in imposing a noise regime, through an abatement notice, under the statutory nuisance provisions of the Environmental Protection Act 1990. This regime would take precedence over the planning condition and would then be enforceable in the Courts even if more onerous than the planning condition.

Returning to the enforcement powers available to local planning authorities, the Enforcement Notice is a well established instrument used to proceed against breaches of planning control, including breaches of planning conditions. There is a right of appeal, and the appeal process may take a year or more. This position has for some years been extremely unsatisfactory for local authorities because irresponsible developers can flout the planning system, knowing that a considerable period of grace can be obtained by the lodging of an appeal.

It was and still is open to local authorities to serve Stop Notices. These require the immediate cessation of the activity alleged to be unlawful, but the Stop Notice has to be accompanied by an Enforcement Notice, and there is a right of appeal. Compensation for certain economic losses may be payable if the Stop Notice is withdrawn or quashed on appeal (unless quashed on the basis that the planning permission, which permitted increased noise levels, is granted).

Therefore local authorities very rarely use Stop Notices unless they are convinced of winning the appeal that may follow.

The Planning and Compensation Act 1991 introduced the Breach of Condition Notice. If local authorities detect a breach of a planning condition they can serve a notice requiring the developer to remedy the breach within the minimum period of 28 days. There is no right of appeal, and the only option for the developer is to make an application to vary or discharge the planning condition. This is a very effective means of control, and emphasises the need for developers to negotiate conditions that are not only comprehensible and valid, but to which they can adhere. Developers need to bear in mind the economic consequences of shutting down or restricting the operation of a wind farm in order to secure compliance with a Breach of Condition Notice.

Finally, local authorities may take injunctive action to secure a remedy for any breach of planning control, and therefore they may in theory take such action to secure an end to a breach of a planning condition. The principles for deciding such actions in the Court will broadly follow those in an action relating to breach of a covenant described below, but it is unlikely that the local authority would take injunctive action to prevent a continuing breach of the planning condition given the alternative, cheaper and equally effective remedies available, which are discussed above.

Planning Obligations

A Planning Obligation made under Section 106 Town and Country Planning Act 1990 (as amended) is a contractual document in which a developer gives covenants which are enforceable by the local planning authority. A Planning Obligation may take the form of an agreement between a developer and the local authority, or, a unilateral undertaking given by the developer to the local authority. The scope of a Planning Obligation is defined in Section 106 and guidance on the use of Planning Obligations is given in DOE Circular 16/91 (WO Circular 53/91). This Circular is under review at the time of writing. The present Circular 16/91 advises that Planning Obligations should be sought only where they are necessary to the granting of planning permission, relevant to planning, and relevant to the development to be permitted. Where a local planning authority seeks a Planning Obligation from a developer Circular 16/91 advises on the tests of the reasonableness of seeking a Planning Obligation.

If the developer breaches the covenants within the agreement then the local authority can take action through the Courts to secure an injunction requiring him to adhere to the terms of the Obligation. In such an action the burden of proof is on the planning authority to prove the breach alleged. However, once the breach has been proved there are severe limits to the mitigating circumstances which the developer can advance, and which may persuade the Court to stay its hand and refrain from granting an injunction. There is a substantial body of law relating to the limits of the Court's discretion in deciding whether or not to grant an injunction following an initial finding that a breach of covenant has occurred.

Statutory nuisance

As to the jurisdiction of the Environmental Protection Act any citizen who feels himself to be adversely affected by noise emission can bring an action in the Magistrates Court in order to secure what is known as a noise abatement order. Again, a local authority can act directly as a prosecutor and issue a noise abatement notice. An abatement notice or order may require the abatement of the alleged noise nuisance or prohibit or restrict its occurrence or recurrence. It may also require the execution of specified works and the taking of other specified steps. The abatement notice or order will specify the time within which the requirements are to be complied with. The wind farm operator can appeal, on specified grounds, to the Magistrates Court, and ultimately to the Crown Court and higher Courts, against noise abatement orders and notices.

It is not the role of this report to discuss in detail the defences available to a developer faced with an allegation of statutory nuisance under the Environmental Protection Act which has resulted in the issue of a noise abatement order or notice. However, it can be noted that the defence of "best practicable means" is available, can be very effective and may be essential. If a wind farm operator cannot reduce noise emissions without jeopardising the viability of the operation, then the defence of best practicable means will be the last line of defence against potentially disastrous economic consequences.

In considering the merits of the defence of best practicable means the Magistrates Court will have regard to three principal factors: local circumstances, the technology being deployed by the developer, and some sort of cost-benefit analysis. With regard to the first factor, the Court cannot require the developer to take abatement action which will involve the use of land not under his control. An acoustic barrier may be appropriate in a particular case, but if it can only be placed on land belonging to a third party, and which is not within the control of the developer, and that third party is not willing to cooperate with its placement, then the Court cannot enforce the remedy because of this local circumstance.

As to the technology available to the developer, the Court will expect to hear some evidence that the best available technology is being deployed, subject to a consideration of the third factor identified, a cost-benefit analysis. The limits to the use of the cost-benefit analysis within a defence of best practicable means will vary from case to case, and no firm lessons can be derived from past cases. This is partly because each case will be decided on its facts, but also because cases within the Magistrates Courts are not regularly reported and therefore the findings of the Justices are not readily accessible. Even if such were the case it must be noted that the Magistrates Courts are not courts of record, and that the findings of the Magistrates do not form a body of legal precedent.

Against this background certain extremes can be identified. Provided that the developer was able to show that at the time of deployment of the machines the best available technology was used in the design, manufacture and erection of the turbines then the Magistrates Court would be most unlikely to find that the replacement of those turbines would be a reasonable option open to the developer. In any event, planning permission would be required. However, extensive sound-proofing measures might well be felt to be reasonable even though at considerable cost. The equation to resolve in all cases will be the benefit to be extracted from a particular step when set against the cost of that step.

Summary

In summary a variety of measures are open to local planning authorities and to citizens who perceive detriment to the amenities of neighbouring occupiers because of noise emissions. Because each case will differ in its facts no firm conclusions, particularly in relation to any rating levels, can be derived from case studies. However, it is very clear that well drafted and fair planning conditions will tell a developer what must be achieved, will provide local authorities with an objective initial yardstick if a complaint is received, and will provide the starting point for any evaluation of a defence of best practicable means.

Regulating noise emissions in the public interest

It was noted in the introduction to this chapter that reactions to noise emissions from man-made sources vary widely, depending in part on the physical ability of the receptor to hear the noise and his perceptions of the source. Such factors do not admit readily to objective analysis. A noise which is to one person unbearable can be almost inaudible to another.

The Courts have historically adopted the standpoint of the reasonable man or, as in the cliché, the man on the Clapham omnibus. The Courts have not been prepared to make decisions to accommodate extreme perceptions in controlling noise from legitimate sources. They have adopted, so far as is possible, a reasonable approach.

Planning law follows the Courts. Planning Policy Guidance Note 1 advises that the basis of planning law and practice is that the use and development of land should be regulated in the public interest: the purpose of the planning system is not to protect private rights. It follows from this that extreme private perceptions will not be protected by the planning system. The objective is to promote the current concept, from time to time, of the public good.

With the factors that have been identified in this chapter in mind, it can be seen that to attempt to devise an assessment and rating standard for noise emissions from wind energy development is a difficult exercise. Wind energy remains a new form of development : its symbolic content remains a matter of debate. Opinions of wind energy fluctuate widely between people and over time. Nevertheless, as with minerals, there is an urgent need to assist local planning authorities by suggesting rating standards which would seem to be reasonable. Reasonableness in this case derives from: established standards and advisory notes relating to noise emissions; the need of society for clean energy in pursuance of Government energy policy; what can be achieved by the manufacturers of wind turbines; the researches of the Working Party in the UK, Denmark, Holland and Germany; the professional and career experience of members of the Working Group; and discussions between the members and various others with appropriate experience.

The purpose of this chapter has been to define and analyse the complicated background against which members of the Noise Working Group set out to suggest rating standards for noise emissions from wind turbines, standards which may themselves change with time. Such changes may arise as a result of technical improvements in noise suppression by the manufacturers, because of developing perceptions of clean energy development, because of changing patterns of settlement in the countryside, and due to a host of other factors which cannot be anticipated at present. This acknowledgement of continuing dynamics does not undermine the production of rating standards. It is hoped that, at the same time, they represent well researched assistance to developers, manufacturers and planning authorities as well as a firm basis for further research and guidance.

3. DESCRIPTION OF NOISE EMISSIONS FROM WIND TURBINES

Noise emitted by wind turbines can be associated with two types of noise source. These are aerodynamic sources due to the passage of air over the wind turbine blades and mechanical sources which are associated with components of the power train within the turbine, such as the gearbox and generator and control equipment for yaw, blade pitch, etc. These sources normally have different characteristics and can be considered separately.

Aerodynamic sources

Aerodynamic noise is emitted by a wind turbine blade through a number of sources which have been identified and studied by Lowson [9] and Lowson and Fiddes [10]. The key sources have been categorised as:

1. Self noise due to the interaction of the turbulent boundary layer with the blade trailing edge.

2. Noise due to inflow turbulence (turbulence in the wind interacting with the blades).

3. Discrete frequency noise due to trailing edge thickness.

4. Discrete frequency noise due to laminar boundary layer instabilities (unstable flow close to the surface of the blade).

5. Noise generated by the rotor tips.

Noise due to aerodynamic instabilities, mechanisms 3 and 4, can be reduced to insignificant levels by careful design. The other mechanisms are an inescapable consequence of the aerodynamics of the turbine which produce the power and between them they will make up most if not all of the aerodynamic noise radiated by the wind turbine. The relative contribution of each source will depend upon the detailed design of the turbine and the wind speed and turbulence at the time. The mechanisms responsible for tip noise are currently under investigation but it appears that methods for its control through design of the tip shape may be available. Self noise, mechanism 1 above, is most significant at low wind speeds whereas noise due to inflow turbulence becomes the dominant source at the higher wind speeds. Both mechanisms increase in strength as the wind speed increases, particularly inflow turbulence. The overall result is that at low to moderate wind speeds the noise from a fixed speed wind turbine increases at a rate of 0.5-1.5 dB(A)/m/s.

The experience of some residents who neighbour wind farms in the UK would indicate that the assumption that aerodynamic blade noise sounds like the wind in the trees is perhaps an over-simplification, although the frequency content of this source can be similar to that of wind turbines. It is the regular variation of the noise with time that, in some circumstances, enables the listener to distinguish the noise of the turbines from the surrounding noise. Onomatopoeic descriptions of these noises include swishing, whooshing, chomping and thumping.

Blade swish is an amplitude modulation of noise in the frequency range which is associated with trailing edge noise radiated from the outer portion of the turbine blade and discrete frequencies associated with trailing edge thickness. This rhythmic swishing sound, dependent upon tip speed and blade profile, is normally centred around the 800-1000Hz region of the frequency band for trailing edge noise and at higher frequencies for trailing edge discrete frequencies depending on edge thickness. Measurements of the emitted sound power level of a wind turbine are normally performed using the A-weighting network and a time-averaging period of a minimum of 2 minutes, [11] [12]. This modulation might be expected to be clearly apparent when performing noise measurements close to wind turbines. However, the modulation of the A-weighted noise level is of the order of 2-3dB(A) for typical wind turbine configurations. Measurements performed in Denmark [13] and at some locations in the UK indicate that this level of amplitude modulation may be greater if analysis is performed using third octave or narrow band analysis of the radiated noise from a wind turbine. This modulation may be caused by directivity effects associated with the generation of the noise at the blade and is most apparent when standing close to a wind turbine, less than 50 metres from the base of a supporting tower.

As observer distance increases from the turbine, the rhythmic swishing becomes less pronounced. This may be due to a number of single effects or a combination. As distance increases, the modulation caused by the directivity of the radiated sound wave emitted by a turbine blade will become less significant. Therefore, it would be expected that any directivity effects which may be audible close to the turbine will be reduced in audibility. Atmospheric attenuation will cause a reduction of high frequency blade noise relative to lower frequency blade noise. This removes the high frequency "swish" spectral content which increases its distinguishing character. As the observer distance increases, the level of sound from the turbine incident at the observer position will decrease. However, in exposed locations, it should be expected that the background noise level will remain, in general, the same. Therefore, increased masking by the background noise will reduce the subjective impact of the turbine noise. This rhythmic swishing has been noted to vary between turbine types and between sites where similar turbines have been installed.

Current research projects aimed at more fully characterising the aerodynamic noise emissions from wind turbines are described in Chapter 9 on Further Work. These projects include measurements of blade swish and low frequency noise and vibration emissions.

Mechanical sources

Mechanical noise is normally perceived within the emitted noise from wind turbines as an audible tone(s) which is subjectively more intrusive than a broad band noise of the same sound pressure level. Sources for this noise are normally associated with: the gearbox and the tooth mesh frequencies of the step up stages; generator noise caused by coil flexure of the generator windings which is associated with power regulation and control; generator noise caused by cooling fans; and control equipment noise caused by hydraulic compressors for pitch regulation and yaw control.

Where complaints have been received due to the operation of wind farms, tonal noise from the installed wind turbines appears to have increased the annoyance perceived by the complainants and indeed has been the primary cause for complaint.

Mechanical noise may be radiated by the containing structure of the source, ie the gearbox casing, or by parts of the turbine structure which have a direct mechanical linkage to the source. Where gearbox noise has been perceived as a tonal noise problem, the acoustic energy has normally been found to be radiated by the supporting tower structure upon which the turbine nacelle containing the gearbox is mounted and/or by the wind turbine blades themselves. Vibrational energy is transmitted from the drive train within the gearbox and the drive shafts and enters the gearbox supporting structure. This then travels through the supporting structure and may be re-radiated as sound at any position where the structure is exposed to atmosphere. Supporting towers are normally large, between 25 and 45 metres in height, from which acoustic energy may be radiated. These large radiating surfaces can result in the efficient transmission of the vibrational energy into the external environment surrounding a wind turbine.

Most turbine manufacturers have started to ensure that sufficient forethought is given to the design of quieter gearboxes and the means by which these vibrational transmission paths may be broken. Through the use of careful gearbox design and/or the use of anti-vibration techniques, it is possible to minimise the transmission of vibrational energy into the turbine supporting structure. The benefits of these design improvements have started to filter through into wind farm developments which are using these modified wind turbines. It is possible to obtain turbines which do not emit any clearly distinguishable tones.

Vibrational energy that enters the wind turbine blade may be reduced by the placing of a resilient coupling on the low-speed shaft and/or by treating the blade itself. Foam filling of the blade would provide significant additional damping to the blade skin, thereby reducing the transmitted vibrational energy within the blade.

4. REVIEW OF CURRENT PRACTICE AND GUIDANCE

Introduction

Much work has been carried out and is still current in relation to the measurement of noise from wind generators. However, there is as yet no primary or secondary legislation in the UK relating specifically to the rating of noise from wind generators. This corresponds with the position in all European Community member states which have seen wind energy development, except Denmark where a statutory instrument of 1991 [12] specifically regulates maximum levels of noise emissions from wind generators. There are statutory noise controls in Holland and Germany but these are not specifically related to wind generators.

The only current advice in the UK specifically relevant to wind energy development is contained within the wind energy annex to Planning Policy Guidance Note 22 (PPG 22) [1] which advises on renewable energy development. However, there are numerous elements of advice more or less pertinent to the subject and these are recorded in this section of the report. Advice continues to emerge, and in particular it is noted that Planning Policy Guidance Note 24: Planning and Noise [5], which superseded DOE Circular 10/73 [4] in England (Welsh Office 16/73 is still in effect at time of writing), was issued in September 1994 and a revision to BS 4142: 1990 [2] relating to industrial noise in mixed residential and industrial areas is currently being prepared.

This chapter of the report records and discusses legislation and advice which is current, and either potentially or directly pertinent to noise emissions from wind generators. Chapter 6 of this report discusses the difficulties in theory and in practice of applying the advisory documents described in this chapter to wind energy development and proceeds to recommend a framework for the measurement and assessment of noise from wind farms.

The use of planning conditions

As a result of this lack of direct guidance for the assessment of wind turbine noise, several methods have evolved to limit the noise levels which are incident from a wind turbine or farm. These methods can be summarised as follows:

- The setting of noise limits (maximum limit not to be exceeded or limit at a specified wind speed, typically 5m/s at hub height, the cut-in wind speed for a wind turbine) which are independent of the existing background noise levels. This is like the planning condition for Rhyd-y-Groes on Ynys Mon/Anglesey and some sites in Dyfed.

- The setting of a limit based on measurements of the background noise before the construction of the wind farm. The planning conditions agreed for Four Burrows in Cornwall are of this type.

- The setting of a limit permitting the noise level of the wind farm to the exceed the prevailing background noise level when the wind farm is not operating by a specified amount. This is like the planning condition agreed for Carland Cross in Cornwall.

Furthermore, the methods by which these conditions or obligations are to be tested are different. Some propose the measurement of the L_{Aeq} of the background and incident turbine noise at a property, some propose the measurement of the L_{A90} of the background and incident noise from the wind turbines and some consider the noise in terms of the L_{A50}. The reasons for this can be summarised as follows:

- The use of L_{Aeq} follows the guidance that is contained within BS 4142: 1990 (Method for rating industrial noise affecting mixed residential and industrial areas) which was updated to align itself with ISO 1996: Parts 1 to 3. This proposes that measurements and an assessment of a new noise source be performed using the L_{Aeq} index.

- The use of L_{A90} was proposed by some local district councils in Cornwall because transitory, high-energy effects such as aircraft fly-overs and wind upon the microphone could increase the measured L_{Aeq} such that the measured noise levels from the turbines would be masked. As a wind turbine is a fairly constant noise source it was considered that the L_{A90} would be a reasonable approximation to the L_{Aeq} of a wind turbine. However, at a receiver position, where short-term, high-energy events may result in a higher L_{Aeq} than would be expected from just the operation of wind turbines, the L_{A90} was considered to be less affected by these transitory, high-energy events.

- The use of L_{A50} was adopted during early work by the CEGB at the demonstration test facility at Carmarthen Bay. The reasoning for the use of the L_{A50} follows that described in the previous paragraph.

Therefore, there currently exist several methods by which conditions and obligations have been written and by which developers have considered the effects of their developments upon neighbouring dwellings and noise-sensitive buildings. The purpose of this Working Group is to consider the merits of these and other methods with respect to existing primary and secondary legislation, Planning Policy Guidance Notes, Mineral Planning Guidance and British Standards. This investigation has also taken into account recommendations made by the World Health Organisation (WHO), the European Community (EC) and the Organisation of Economic Co-operation and Development (OECD). Reference has also been made to the experiences of other countries where the development of wind energy has already been underway for a number of years.

Primary and secondary legislation in the UK

The emergence of noise emissions as a core environmental concern is relatively recent. While quite separate law relating to statutory nuisances derives from the Public Health Act 1936, the first relevant advice in a planning context can be seen in the DOE Circular 10/73 (Welsh Office Circular 16/73), now replaced in England by Planning Policy Guidance Note 24. At a statutory level the Control of Pollution Act 1974 contained detailed provisions concerning statutory nuisances. EC Directives of the mid-1980s, and rapidly increasing concerns about a wide variety of environmental issues, culminated in the Environmental Protection Act 1990. A brief summary of relevant provisions in primary legislation of relevance to noise emission control is given below.

Planning juridictions

Section 70 Town and Country Planning Act 1990:

"Where an application is made to a local planning authority for planning permission

a) Subject to (other sections) they may grant planning permission, either unconditionally or subject to such conditions as they think fit; or

b) They may refuse permission."

Section 106 Town and Country Planning Act 1990:

"Any person interested in land in the area of a local planning authority may, by agreement or otherwise, enter into an Obligation (... "a Planning Obligation"):

a) restricting the development or use of the land in any specified way;

b) requiring specified operations or activities to be carried out in, on, under or over the land;

c) requiring the land to be used in any specific way; or

d) requiring a sum or sums to be paid to the authority on a specified date or dates or periodically."

Statutory nuisance

Section 80 Environmental Protection Act 1990:

"Where a local authority is satisfied that a statutory nuisance exists, or is likely to occur or to recur, in the area of the authority, the local authority shall serve a notice ("an abatement notice") imposing all or any of the following requirements -

a) Requiring the abatement of the nuisance or prohibiting or restricting its occurrence or reoccurrence;

b) Requiring the execution of such works, and the taking of such other steps, as may be necessary for any of those purposes, and the notice shall specify the time or times within which the requirements of the notice are to be complied with."

Section 82 Environmental Protection Act 1990:

"A magistrates court may act under this section on a complaint made by any person on the ground that he is aggrieved by the existence of a statutory nuisance. If the

magistrates court is satisfied that the alleged nuisance exists, or that although abated it is likely to recur on the same premises, the Court shall make an order for either or both of the following purposes -

a) Requiring the Defendant to abate the nuisance within a time specified in the order, and to execute any works necessary for that purpose;

b) Prohibiting a reoccurrence of the nuisance, and requiring the Defendant, within a time specified in the order, to execute any works necessary to prevent the reoccurrence,

and may also impose on the Defendant a fine not exceeding ..... on the standard scale."

Town and Country Planning (Assessment of Environmental Effects) Regulations 1988

By virtue of the Town and Country Planning (Assessment of Environmental Effects) (Amendment) Regulations 1994, which came into force on 6 April 1994, the provisions of the 1988 Regulations now apply to wind energy development. Wind generators are listed within Schedule 2 to the 1988 Regulations as a form of development for which environmental assessment may be appropriate, depending on such factors as the nature, size and location of proposal.

Planning Policy Guidance Notes

PPG 22 Renewable Energy

PPG 22 sets out Government planning policy advice concerned with developing renewable energy sources, against the background of the Government's policies for the environment, and for developing these renewable energy sources. For ease of reference the Government's policy on new and renewable energy as stated in Energy Paper No 62 is:

"*To stimulate the development of renewable energy sources wherever they have prospects of being economically attractive and environmentally acceptable in order to contribute to:*

- *diverse, secure and sustainable energy supplies*
- *reduction in the emission of pollutants*
- *encouragement of internationally competitive industries.*

In doing this it will take account of those factors which influence business competitiveness and work towards 1500MW DNC of new electricity generating capacity from renewable sources for the UK by 2000."

The main principle running through PPG 22 is the requirement to balance the local environmental impact of renewable energy generation against global environmental benefits.

This is best illustrated by reference to extracts from paragraphs 21 and 26, the first considering land use planning matters and the second advising on development plans.

> *"Sites proposed for the development of renewable energy sources will often be in rural areas or on the coast, and such development will almost always have some local environmental effects. The Government's policies for developing renewable energy sources must be weighed carefully with its continuing commitment to policies for protecting the environment."*

> *"Authorities will need to consider both the immediate impact of renewable energy projects on the local environment and their wider contribution to reducing emissions of greenhouse gases."*

The PPG specifically considers noise issues within paragraphs 39-51 of its wind annex. The document provides an overview of the issues to be addressed but as it admits, there was insufficient information available at the time of writing for more quantitative general guidance to be given.

PPG 24: Planning and Noise

PPG 24 Planning and Noise, issued in September 1994, gives guidance to local authorities in England and replaces Circular 10/73. This document too highlights the potential conflicts of interest which have to be considered as part of the planning process. The aim of the guidance contained within PPG 24, as stated in the opening paragraph. is:

> *"..... to provide advice on how the planning system can be used to minimise the adverse impact of noise without placing unreasonable restrictions on development or adding unduly to the costs and administrative burdens of business."*

Paragraph 10 continues:

> *"Much of the development which is necessary for the creation of jobs and the construction and improvement of essential infrastructure will generate noise. The planning system should not place unjustifiable obstacles in the way of such development. Nevertheless, local planning authorities must ensure that development does not cause an unacceptable degree of disturbance. They should also bear in mind that a subsequent intensification or change of use may result in greater intrusion and they may wish to consider the use of appropriate conditions."*

Within Annex 1 of PPG 24 the concept of noise exposure categories (NECs) is developed. These categories are to help identify whether noise is an important issue in the development of residential dwellings within an existing noise environment. However, it identifies that when a new noise source is brought to sensitive properties this guidance is not to be used:

> *"The NEC procedure is only applicable where consideration is being given to introducing residential development into an area with an existing noise source, rather*

than the reverse situation where new noise sources are to be introduced into an existing residential area."

This is because:

> *"...the planning system can be used to impose conditions to protect incoming residential development from an existing noise source but, in general, developers are under no statutory obligation to offer noise protection measures to existing dwellings which will be affected by a proposed new noise source."*

It is also stated that where industrial noise is the dominant noise source rather than transportation noise sources, the NEC noise levels should not be used because:

> *"...there is insufficient information on people's response to industrial noise to allow detailed guidance to be given."*

However, if industrial noise is present but not dominant in a noise environment, then its contribution should be included when establishing the NEC category. The discussion on the setting of noise limits for the various NECs makes reference to sleep disturbance criteria and attenuation of noise through open and closed windows. The approach of PPG 24 is discussed in Chapter 6 for the purposes ofconsidering the setting of noise limits for wind farms.

However, the derivation of the night-time noise limits contained within the NEC table is based upon the concept of sleep disturbance and the protection of the restorative process of sleep. The setting of these criteria has assumed a reduction of the noise from outside the building through to the inside within bedrooms such that the internal noise level is at or below 35dB L_{Aeq}. (Reference is made to the WHO document Environmental Health Criteria 12 - WHO, 1980 [14]. It should be noted that there is currently a review of the criteria contained within this report. The new draft is discussed later in this chapter.) The reduction through a window that has been assumed for the calculation of acceptable external noise levels is 13dB(A) from internal noise level to facade noise level. (It is stated within PPG 24 that this figure is usually taken to be 10-15dB(A) and that for the purpose of deriving the NEC table it has been assumed to be 13dB(A).)

When advising on the assessment of noise from industrial and commercial developments the PPG comments that the likelihood of complaints about noise from industrial development can be assessed, where the Standard is appropriate, using guidance in BS 4142: 1990. It goes on to say that the "rating level" shall be used when stipulating the level of noise that can be permitted.

Planning and Noise Circular (W.O. 16/73)

Welsh Office Circular 16/73 contains guidance for planning authorities concerning new noise sources. This is equivalent to DOE Circular 10/73 recently cancelled by PPG 24 in England. Although the circular does not directly deal with wind turbine-generated noise it provides some guidance as to what might be considered as acceptable noise levels for the incident noise levels from such development.

Noise from fixed installations and industrial premises is considered within paragraphs 24-36 of the Circular. Within paragraph 24 it is recommended that local planning authorities consult their Environmental Heath Departments at an early stage to minimise the noise effects of developments.

Paragraph 27 proposes a method by which noise from a new noise source introduced into an existing residential environment may be assessed. It states:

> *"Where, by the standards established in BS 4142, the noise from the proposed development "is likely to give rise to complaints" even if reasonable sound insulation is required and provided, it will hardly ever be right to give permission. In predicting noise levels from new developments it will be necessary to take account of those which can be expected when the plant is operating at maximum capacity, even if this presupposes a higher level of activity than that initially proposed by the developer."*

Paragraph 28 considers that, where possible, the authorities should operate their development control powers in such a way as to avoid an increase in the ambient noise affecting residential and other noise-sensitive development. It also recognises within this paragraph that this will not always be possible for certain types of development.

Where industrial noise is incident upon a residence, the Circular proposes that the CNL (Corrected Noise Level) for a stationary source to provide a "good standard" of noise within a dwelling with windows closed is 45dB(A) during the day-time and 35dB(A) during the night-time. These are internal noise levels, with windows closed.

MPG 11 The Control of Noise at Surface Mineral Workings

The aim of Mineral Planning Guidance Note 11 is to provide advice on how the planning system may be used to keep noise emissions from surface mineral workings within environmentally acceptable limits without imposing unreasonable burdens upon minerals operators.

Paragraphs 31-35 consider the setting of absolute noise limits for such developments, which are linked to day-time and night-time working periods. MPG 11 states:

> *"The Government takes the view, except in the circumstances outlined below, the day-time nominal limit at properties used as dwellings should normally be 55dB $L_{Aeq,1h}$ (free field)...."*

MPG 11 goes on to say that this level is generally found to be a tolerable noise level and that above this noise level continuous noise starts to cause annoyance.

The suggested night-time noise limit is 42dB $L_{Aeq,1h}$ at a noise-sensitive dwelling. It also recognises that lower nominal noise limits may be appropriate in quiet rural areas if the mineral working threatens to disturb exceptionally low background noise levels.

Paragraphs 37 and 38 discuss the setting of noise limits relative to the existing background noise level. However, MPG 11 recognises the difficulties of this approach when applied to sites where quiet background noise levels exist:

> *"In exceptionally quiet rural areas where the day-time background noise level is below 35dB(A), a condition limiting mineral operators to a 10 decibel excess over the existing background noise level is likely to be both difficult to achieve and unduly restrictive. It would not normally be appropriate to require a day-time limit below 45dB $L_{Aeq,1h}$, as such a limit should prove tolerable to most people in rural areas. The exercise of care and some flexibility are important in addressing these issues."*

Paragraph 39 states:

> *"In the case of night-time working, MPAs and operators should have particular regard to the needs of local people, and discussion with local Environment Health Officers may well be appropriate as to whether the night-time limit stated at paragraph 34 is reasonable. This may be a particular issue in quieter rural areas."*

These comments indicate that for very quiet background noise environments, the operation of mineral extraction plant should not be allowed to exceed 42dB $L_{Aeq,1h}$ during the course of a night, but that a lower limit may be appropriate after discussions with the local Environmental Health Officer.

British Standards

BS 4142: 1990: Method for rating industrial noise affecting mixed residential and industrial areas

It is stated within the foreword of this British Standard that:

> *"The standard is intended to meet the need for rating various noises of an industrial nature affecting persons living in the vicinity. It gives a method of determining a noise level, together with procedures for assessing whether the noise in question is likely to give rise to complaints. Although, in general, there will be a relationship between incidence of complaints and the level of general community annoyance, quantitative assessment of the latter is beyond the scope of this standard as is the assessment of nuisance."*

This indicates that although the standard may be used for the rating of a noise incident upon a receiver position, it is not appropriate for either the quantitative assessment of general community annoyance or the assessment of nuisance.

The foreword continues:

> *"In general, a noise is liable to provoke complaints whenever its level exceeds the background noise by a certain margin; or when it attains a certain absolute level."*

This indicates that complaints may occur if the incident noise level exceeds the background noise level by a margin or if the incident noise exceeds an absolute level that may not be related to the background noise level.

The foreword to BS 4142 also states:

> *"This standard is intended to be used for assessing the measured noise from existing premises or the calculated (or measured) noise levels from new or modified premises. It may be found helpful in certain aspects of environmental planning and may be used in conjunction with recommendations on noise levels and methods of measurement published elsewhere."*

The scope explains that the standard provides a method for assessing whether noise measured at the outside of a building is likely to give rise to complaints from people residing inside the building.

BS 4142 itself acknowledges that it is not suitable for assessing noise in situations where the background noise level is very low, ie below an A-weighted sound pressure level of 30dB.

The rating method described within BS 4142 compares the incident noise from an industrial source, be it calculated or measured, with the measured background noise at the position where the new noise source is incident. The noise levels of the source are measured in terms of $L_{Aeq,T}$ but for background noise level, $L_{A90,T}$ is used. When performing an assessment using BS 4142, not only is the level of incident noise from the new noise source of concern but also the character of the source. BS 4142 proposes that a penalty be applied if the noise has the following characteristics:

> *"7.2 If the noise contains a distinguishable, discrete, continuous note (whine, hiss, screech, hum, etc), or if there are distinct impulses in the noise (bangs, clicks, clatters, or thumps), or if the noise is irregular enough in character to attract attention, add 5dB to the specific noise level to obtain the rating level. Make only a single 5dB correction if one or more of the above characteristics is present."*

The method of assessment then subtracts the measured background noise level from the rated noise level. A difference of 10dB(A) or greater is considered to indicate that complaints are likely. A difference of around 5dB is of marginal significance. The lower the value the less likelihood there is of complaints.

The issues associated with the application of BS 4142 to noise from wind farms in rural areas are discussed in Chapter 6.

BS 5228: Part 1: 1984 Noise Control on construction and open sites. Part 1: Code of Practice for basic information and procedures for noise control

The scope of BS 5228 Part 1 [15] covers recommendations for basic methods of noise control relating to construction sites and other open sites where noisy work activities and operations are carried out. It describes the legislative background to noise control and provides guidance concerning methods of predicting and measuring noise. It also contains recommendations on how the impact of noise on people living nearby and on-site workers can be minimised.

Section 11 within the British Standard discusses the setting of noise criteria. When setting target noise levels at sensitive dwellings adjacent to a site, it is recognised that the period of falling asleep and just before awakening are the most sensitive. It is suggested that site noise will be required to be limited to $L_{Aeq,1h}$ of 40-45dB at the facade to avoid sleep disturbance; this is equivalent to a free field sound pressure level of 37-42dB. The free field sound pressure level is that which is measured when the measurement position is situated further than 3.5 metres from a reflecting surface.

BS 7445: Parts 1-3: 1991 Description and measurement of environmental noise

- ***Part 1. Guide to quantities and procedures***
- ***Part 2. Guide to the acquisition of data pertinent to land use***
- ***Part 3. Guide to application to noise limits***

BS 7445: Parts 1-3: 1991 [16] is the equivalent British Standard to ISO 1996/1-3: 1982 and is identical to this ISO standard. This International Standard does not specify limits for environmental noise. The stated aim of these standards is to:

> *"...provide authorities with material for the description of noise in community environments. Based on the principles described in this International Standard, acceptable limits of noise can be specified and compliance with these limits can be controlled."*

Part 1 of the standard describes the preferred measurement units which should be used, the type of equipment that should be used for determining the noise level and measurement positions. The standard introduces the concept of measurements performed within a building when assessing the impact upon a nearby receiver. Section 5.2.3 of the standard states that the preferred measurement position within a building is:

> *"at least 1 metre from the walls or other major reflecting surfaces, 1.2 to 1.5 metres above floor level and about 1.5 metres from windows."*

Section 5.3 of the standard discusses the possible meteorological effects upon the measurements that may be undertaken. It does not specify that there are weather conditions during which measurements are unacceptable. However, it recommends that measurements be made when conditions will be those that will allow the most stable propagation of the noise from the source to the receiver, with a significant wind component from the source to the receiver.

The purpose of Part 2 of the British Standard is:

> *"To provide methods for the acquisition of data describing environmental noise. Using these data as a basis, authorities may establish a system for selecting the appropriate*

land use, as far as levels of noise - existing or planned - which are acceptable with respect to land use, existing or planned."

This part of the British Standard gives some guidance as to the method by which a rating may be made of the noise source, taking into account whether it has an impulsive character or whether it contains any tonal components. The control of such acoustic emissions from a wind turbine are normally addressed through the warranty provided by the manufacturer of the wind turbines and the planning permission for the development.

The tonal adjustment as described below is proposed within BS 7445 in order to take into account the effects of tonal noise:

"A prominent tonal component may be detected in 1/3 octave spectra if the level of a 1/3 octave band exceeds the level of adjacent bands by 5dB or more, but a narrow band frequency analysis may be required in order to detect precisely the occurrence of one or more tonal components in a noise signal. If tonal components are clearly audible and their presence can be detected by a 1/3 octave analysis, the adjustment may be 5 or 6dB. If the components are only just detectable by the observer and demonstrated by narrow band analysis, an adjustment of 2 to 3dB may be appropriate."

Part 2 also states that the measurement of the noise source should be undertaken when the propagation conditions are stable and when the meteorological conditions will enhance propagation towards the receiver position. BS 7445 states that wind conditions should be from the source to the receiver and within an angle of ± 45° of a line connecting the centre of the source with the centre of the receiver position. It also states the wind speeds for this assessment should not exceed an average wind speed of 5m/s between the heights of 3 and 11 metres. This typically equates to average wind speeds of 7.8m/s and 5.9m/s respectively, when measured at a height of 30 metres, which are low to moderate wind speeds for turbine operation (see "wind shear" entry in Glossary). It is also stated within BS 7445 Part 2, Paragraph 5.4.3.3, Note 1, that it should always be ascertained that the wind noise at the microphone does not interfere with the measurements.

Part 3 of BS 7445 describes the application of noise limits and the elements which are necessary in any setting of noise limits. These include:

- the noise descriptor to be used
- the relevant time intervals
- the sources and their conditions of operation, where appropriate
- the locations where the noise limits have to be verified
- meteorological conditions, where appropriate
- criteria for assessment of compliance with the set limits.

Guidance is given within this section of the standard as to how to set the conditions for any noise limits and for checking compliance with any of the noise limits that might have been agreed or imposed by the local authority.

BS 7135: Part 1: 1989: Noise emitted by computer and business equipment Part 1. Method of measurement of airborne noise

BS 7135: Part 1 [17] is a measurement method for noise emitted by computer and business equipment. The methods described within the standard are only relevant to the measurement of these noise sources. However, within Annex D (Measurement of impulsive sound pressure levels and discrete tones at the operator position) are methods for the determination of the impulsiveness of the noise and the tonality of the noise.

Measurement of the impulsive sound is performed by aural examination of the noise source at the operator positions. If the noise emitted is perceived to include short-duration high-amplitude sound, then the following test shall be performed:

> *"The A-weighted impulse sound pressure level, L_{pAI}, shall be measured for the same modes of operation and measurement conditions used for the measurement of the A-weighted sound pressure level, L_{pA}, according to 7.7. The difference in decibels between the A-weighted impulse sound pressure level, L_{pAI}, and the A-weighted sound pressure level, L_{pA}, shall be obtained. The difference ($L_{pAI} - L_{pA}$) is the impulse parameter ΔL_I, which may be considered a measure of the impulsive content of the noise; if $\Delta L_I \geq 3dB$, the noise is considered to be impulsive."*

The impulsive response of a sound level meter is defined by the time constant for the input signal. An impulse sound level meter has a time constant of 35ms compared with a fast time weighting network of 125ms. The measurement method described within BS 7135 (Section 7.7 of the Standard) to determine the L_{pA} sound pressure level requires that a measurement be performed for a period of at least 8 seconds. Although it is not clearly identified within the standard as to whether the measurement is an L_{Aeq} level or a mean level, it is assumed that the L_{Aeq} level should be recorded.

Section D.4 of the annex describes a method for the detection of a tone within a broad band noise. Section D.4.1 states the following:

> *"A discrete tone which occurs in a broad-band noise is partially masked by the noise contained in a relatively narrow frequency band, called the critical band, that is centred at the frequency of the tone. Noise at frequencies outside the critical band does not contribute significantly to the masking effect. The width of the critical band is a function of the frequency. In general, a tone is just audible when the sound pressure level of a tone is about 4dB below the sound pressure level of the masking noise contained in the critical band centred around the tone. For the purpose of this annex, a discrete tone is defined as being prominent if the sound pressure level of the tone exceeds the sound pressure level of the masking noise in the critical band by 6dB. This corresponds, in general, to a tone being prominent when it is more than 10dB above the threshold of audibility."*

The standard then proceeds to describe a method of assessment to determine the existence of discrete tones within the emitted noise from a computer. This method employs the concept of Zwicker critical bands. When considering critical band theory for the masking of discrete tones within broad band noise, it is clear that the detection of a tone is related to the frequency and level of the tone compared to the critical band masking level. The defined criteria for the threshold of audibility and prominence is a simplification of these criteria as the detection threshold is frequency-dependent.

The British Standard is designed for the assessment of tones that are emitted from computer equipment. Most tones that are emitted by computers are related to the cooling fans and the scanning frequency of the CRT (cathode ray tube). These frequencies are normally found above 1kHz and for a CRT 15-25kHz. At these frequencies the likelihood of a tone being detected is high when the audibility threshold level is 4dB below the critical masking level. However, at lower frequencies, especially below 500Hz, the audibility threshold for a tone is measured as being 2dB below the critical masking band noise level. Therefore, the criterion that is described within the British Standard is a simplification of the detection thresholds of a normal ear due to the assumptions made with respect to the normal range of discrete frequencies that are emitted by computer equipment.

The critical bandwidths are defined within the British Standard as follows:

The width of the critical band, Δf_c, centred at any frequency, f, is given by the following equation:

$$\Delta f_c = 25 + 75 [1 + 1.4 (f/1000)^2]^{0.69}$$

(e.g. $\Delta f_c = 162.2$Hz at f = 1000Hz)

For the purposes of determining the value of L_n, the critical band is modelled as a rectangular filter with centre frequency, f_0, the lower band edge frequency f_1, and the upper band edge frequency, f_2, where

$$f_1 = f_0 - \Delta f_c/2$$

and

$$f_2 = f_0 + \Delta f_c/2$$

The British Standard also states that the measurements should be performed using the A-weighting network. However, if measurements are performed using linear quantities then the threshold of audibility should be defined as when a tone is 6dB below the masking band level.

The measurement period that should be used for determining the tone levels is defined as a minimum of 8 seconds, following the measurement methodology used for the impulsive noise assessment. However, performing a narrow band analysis on a signal using an FFT (Fast Fourier Transform) Analyser results in blocks of data, between 125 ms and 1 second in length, being analysed, rather than a continuous stream. To derive the sound pressure level for each narrow band over a longer time period, such as 8 seconds, requires that the average level is obtained from a number of shorter measurements.

The determination of the masking band level within the critical band is dependent upon this averaging of the measured noise. However, for a single spectrum using a Hanning window it is expected that the broad band level calculated would have a 68.3 % chance of being within 4.34dB of the true level, a 95.5 % chance of being within 8.68dB and a 99.7 % chance of being within 13.02dB. However, as the number of averages increases, the standard error will become less due to the greater number of samples. Table 1 details the expected error with increase in the number of samples used to determine the average level of each narrow band.

Table 1 Expected error bands using FFT analysis

Number of Samples	Standard Deviation	2 × Standard Deviation	3 × Standard Deviation
1	4.34	8.68	13.02
2	3.07	6.14	9.21
4	2.17	4.34	6.51
8	1.53	3.07	4.60
16	1.09	2.17	3.26
32	0.77	1.53	2.30
64	0.54	1.09	1.63
128	0.38	0.77	1.15
256	0.27	0.54	0.81
512	0.19	0.38	0.58
1024	0.14	0.27	0.41

Therefore, to undertake measurements that have a high degree of accuracy requires that a significant number of measurements are averaged before the level can be confidently predicted to be within 1dB of the level recorded by the analyser. This compares with the advised minimum measurement period of 8 seconds proposed within the standard. As an example, if the highest frequency of interest is 2kHz and the narrow band bandwidth is 2.5Hz, equivalent to 800 lines, then the sampling frequency will require to be 2.56 times the frequency of highest interest, ie 5120Hz. To obtain sufficient data to perform the FFT analysis will require 2048 data points. Therefore, the time that is required to obtain sufficient data for a single spectrum is 2048 × (1/5120Hz) = 0.4 seconds. If it is assumed that the data is collected as a continuous stream, then in the space of 8 seconds it would be expected that 20 spectra are available for averaging. From Table 1 it may be seen that this would lead to an expected accuracy of the measurement of about 1dB for a single standard deviation. For an accuracy of ± 0.2dB, 470 measurements would be required, resulting in an overall measurement period of 188 seconds, approximately 3 minutes.

International Guidance

European Community Directives

Council Directive 85/337 of the European Community requires the assessment of the environmental impact of certain projects in the public and private domain. The terms of this Directive must be implemented by member states. In the UK most of the Directive's terms have been implemented through the Town and Country Planning (Assessment of Environmental Effects) Regulations 1988, reference to which has already been made.

CEC Report EUR 5398 e: 1975

The Commission of the European Communities report EUR 5398 e: Environment and Quality of Life: Damage and Annoyance Caused by Noise [18], contains a number of recommendations for the setting of external and internal noise criteria which will not affect sleep or relaxation in external environments.

The report states within its conclusions that internal L_{Aeq} noise levels within a bedroom of 30-35dB would not affect sleep at all, while a maximum sound level should not exceed the L_{Aeq} level by more than 10dB. The setting of a maximum noise level above the average L_{Aeq} level is due to the human startle response function which results in a sleeper awakening as a result of a short period, high level noise. The report states that a certain safety margin has been taken into account for more susceptible elderly persons when stating this figure. It is proposed within the report that as these levels will result in no sleep disturbance, achieving these noise levels for other rooms within a dwelling will result in no interference in relaxation. Again, the limit for a maximum level 10dB above the continuous L_{Aeq} level applies. However, the report does note that public authorities may be led to decide that such protection should be restricted to specific and particularly sensitive groups, such as invalids, convalescents and residents of old peoples' homes, thereby indicating that this may also be a very safe criterion for most members of the population.

Noise criteria for relaxation in areas external to the dwelling are not so clearly defined. The recommended noise levels contained within Report EUR 5398 e state that L_{Aeq} levels of 50-55dB will result in slight annoyance. However, reference is made within the report that acceptable guide levels for external areas based upon average L_{Aeq} levels are as follows: 45dB during day-time and 35-40dB during the night time. It is stated that:

> *"This would seem to provide an adequate safeguard for night-time and day-time sleep, relaxation and also for the use for relaxation of open-air facilities such as balconies, terraces and gardens."*

OECD Report: Reducing Noise in OECD Countries: 1978

The OECD report Reducing Noise in OECD Countries [19] provides guidance and decision criteria for noise abatement policies. Within this document three criteria are quoted, which are used in some countries not identified within the report, to set internal noise levels. These are as follows:

The extension of time to fall asleep	L_{Aeq} = 35dB
The shortening of light sleep	L_{Aeq} = 45dB
The shortening of deep sleep	L_{Aeq} = 50dB

The three categories of sleep noise criteria reflect the sensitivity which has been found in the average person to noise at various stages of the sleep cycle. It is considered that the most sensitive period for sleep being affected by noise is when a person is falling asleep. Therefore, it is during this period that the lowest noise levels should be achieved within a dwelling and thereby any criteria set. Light sleep or REM (rapid eye movement) sleep is less affected by noise. This sleep period is when most dreaming occurs. Deep sleep is the least sensitive sleep category in the nightly sleep cycle. As such, a level 15dB(A) higher than the falling asleep level may exist without any adverse affect upon a sleeping subject.

It is also stated within this document that maximum peak levels should not exceed the background noise level by 10-15dB(A) to ensure that no sleep disturbance occurs. All the noise levels stated above are internal noise levels.

WHO Environmental Health Criteria 12 - Noise: 1980

The World Health Organisation Environmental Health Criteria [14] recommends an internal noise level of about 35dB(A) L_{eq} during the night in order to prevent sleep disturbance. Some effects of noise level on sleep are described within the main body of the report:

> *"The effects of noise on sleep appear to increase as the ambient noise levels exceed 35dB(A) L_{eq} (Berland et al, 1972). In one study, the probability of subjects being awakened by a peak sound level of 40dB(A) was 5%, increasing to 30% at 70dB(A). When changes in sleep changes were taken as an indication of disturbance, the proportion of subjects affected was 10% at 40dB(A) and 60% at 70dB(A) (Thiessen, 1969)."*

It is to this document that PPG 24 refers when establishing noise exposure categories for the night-time.

WHO Environmental Health Criteria Document on Community Noise, External Review Draft, 1993

There is currently a review of existing research of environmental health noise criteria being undertaken by the World Health Organisation [20]. The final report of the temporary advisors was submitted to the WHO in 1995 but at the time of writing has yet to be published as a replacement of the 1980 document. The external review draft includes a review of current work being performed with respect to sleep disturbance and noise. Section 11.1.1.3 dealing with sleep disturbance effects states:

"Sleep disturbance due to continuous, as well as intermittent noise, has been demonstrated by electrophysical and behavioural methods. The more intense the background noise is, the more disturbing is its effect on sleep. Measurable effects start from about 30dB(A) L_{eq}. Physiological sleep effects include changes in the pattern of sleep stages, especially a reduction in proportion of REM-sleep. Subjective effects have also been identified such as difficulties in falling asleep, subjective sleep quality and adverse after-effects like headaches and tiredness. The sensitive groups will mainly include elderly persons, shift workers, persons who are especially vulnerable due to physical or mental disorders and other individuals who have sleeping difficulties.

Sleep disturbance increases with increased maximum noise level. Even if the total equivalent noise is fairly low, a small number of noise events with a high maximum sound pressure level will affect sleep. Therefore, guidelines for community noise to avoid sleep disturbance should be expressed in terms of equivalent noise level as well as maximum levels and number of noise events. It should be noted that low frequency noise, for example, from ventilation systems, can disturb rest and sleep even at low intensity.

Where noise is continuous, the equivalent noise level should not exceed 30dB(A) indoors, if negative effects on sleep are to be avoided. In the presence of a large proportion of low frequency noise a still lower guideline value is recommended. It should be noted that adverse effect of noise partly depends on the nature of the source."

The comments with respect to low frequency noise reflect the effect of using an A-weighted sound pressure level. If most of the acoustic energy was concentrated at a very low frequency, then high levels of acoustic energy might exist but an A-weighted level may still only be 30dB(A). As an example, the A-weighting network applies a correction of 50dB at a frequency of 20Hz. Therefore, a level of 80dB at 20Hz would meet this 30dB(A) requirement.

Section 11.1.1.6 dealing with annoyance responses states that:

"Community annoyance varies with activity (speech communication, relaxation to radio and TV, etc). The threshold of annoyance for steady continuous noise is around 50dB(A)L_{eq} outdoors. Few people are seriously annoyed during the day time at noise levels below around 55dB(A)L_{eq} outdoors. Noise levels during the evening and night should be 5 to 10dB lower than during the day."

Section 11.1.2.1 deals with internal noise criteria for dwellings. It states:

"For dwellings, the critical effects are sleep disturbance, annoyance and speech interference. Specifically, for bedrooms the critical effect is sleep disturbance. Recommended guideline values inside bedrooms are 30dB(A)L_{eq} for steady-state continuous noise and for a noise event 45dB(A)L_{MAX}. Lower levels may be annoying depending on the nature of the noise source. The maximum level should be measured with the instrument set at 'fast'.

To protect the majority of the people from being seriously annoyed during the day time, the sound pressure level from steady, continuous noise on balconies, terraces and in outdoor living areas should not exceed 55dB(A)L_{eq}. To protect the majority of people from being moderately annoyed during the day time, the noise level should not exceed 50dB(A) L_{eq}. Where it is practical and feasible the lower sound pressure level should be considered the maximum desirable sound pressure level for decisions in relation to new development.

At night-time outdoors, sound pressure levels should not exceed 45dB(A)L_{eq}, so that people may sleep with bedroom windows open. This value has been obtained by assuming that the reduction from outside to inside with the window open is 15dB."

It should be noted that an assumption of 15dB(A) level reduction between external and internal noise levels has been assumed. This is quite a high level of attenuation through a building envelope if large glazed areas exist within the building facade of a neighbouring residence. The actual level difference between external and internal noise levels (free field to internal) is typically 10-5dB(A) for a face with 25 - 40 % glazed facade area, respectively. Large glazed areas are not uncommon when patio doors or large picture windows exist in a dwelling but are less common for bedrooms.

Summary of noise limits and criteria in published guidance

Table 2 Summary of sleep disturbance criteria and internal noise levels

Source of Proposed Criteria	Falling Asleep	Light Sleep	Deep Sleep	Max. Level
CEC Report EUR 5398 e: 1975 Environment and Quality of Life: Damage and Annoyance Caused by Noise		L_{Aeq} = 30 to 35		L_{Aeq} + 10
OECD Report: Reducing Noise in OECD Countries: 1978	L_{Aeq} = 35	L_{Aeq} = 45	L_{Aeq} = 50	L_{Aeq}+10 to 15
WHO Environmental Health Criteria 12 - Noise: 1980	L_{Aeq} = 35	L_{Aeq} = 35	L_{Aeq} = 35	
WHO Criteria Document: Community Noise: Environmental Health Criteria: External Review Draft 1993	L_{Aeq} = 30	L_{Aeq} = 30	L_{Aeq} = 30	L_{AMAX}< 45dB
PPG 24 Planning and Noise	L_{Aeq} = 35 (Based on WHO Environmental Health Criteria 12)			
Planning and Noise Circular W.O. 16/73	Good Standard Internal Noise Level CNL (Corrected Noise Level) Day = 45dB(A) Night = 35dB(A)			

Table 3 Summary of external noise criteria

Source of Criterion	External Noise Limit dB
CEC Report EUR 5398 e: 1975 Environment and Quality of Life: Damage and Annoyance Caused by Noise	L_{Aeq} = 50 - 55
British Standard BS 5228: Part 1: 1984 Noise Control on Construction and Open Sites. Part 1. Code of practice for basic information and procedures for noise control	$L_{Aeq,1\ Hour}$ at facade = 40 - 45
PPG 24 Planning and Noise	BS 4142 where appropriate
MPG 11 Control of Noise at Surface Mineral Workings	Day $L_{Aeq,1h}$= 55, (No less than 45 in quiet area) Night $L_{Aeq,1h}$ = 42 Gardens/open spaces $L_{Aeq,1h}$= 55-65
WHO Criteria Document: Community Noise: Environmental Health Criteria: External Review Draft 1993	Day-time L_{Aeq}= 50 Moderate Annoyance Night-time L_{Aeq}= 45

Experience in other countries

USA

The largest concentration of wind turbines in the world is situated in California, USA. Three main groups of turbines exist at Altamont, Palm Springs and Mojave Desert. Some work has been performed to provide noise criteria for these sites such that a minimum of disturbance is caused to neighbouring properties.

The most recent revisions have been performed under the title "*Tri-County Wind Energy: Mitigation Compliance Monitoring Program*" which has been performed for the Alameda, Contra Costa & Solano Counties and the California Energy Commission. Within this document is a section dealing specifically with noise which contains a brief description of the sources of noise from wind turbines. It also provides a summary of existing policies and regulations for wind turbines and makes a recommendation for adoption by the counties sponsoring the report. Extracts from this and other guidance from the USA are contained in Appendix B.

Denmark

The development of wind turbines and wind farms in Denmark has been under way for at least 15 years. During this time, work has been performed to assess the potential for noise emissions from wind turbines and also the level of ambient noise due to wind in trees and grasses. This work was used, to a degree, to formulate policy for wind turbines with respect to noise. This has been issued by the Ministry of the Environment, Denmark, National Agency of Environmental Protection, and is called *Statutory Order from the Ministry of the Environment No.304 of May 14, 1991 on Noise from Windmills.*

Part 2 of this document states the following:

> *"Establishment and Operation of Windmills*
>
> *Section 2. The noise load from windmills shall not exceed 45dB(A) at outdoor open spaces in the immediate vicinity of neighbouring properties in open country.*
>
> *Subsection 2. For the purposes of this order neighbouring properties means all residential buildings other than the private house of the windmill owner.*
>
> *Subsection 3. The noise load from windmills shall not exceed 40dB(A) in the most noise-inflicted spot at outdoor open spaces in residential areas and other noise-sensitive land uses.*
>
> *Subsection 4. For the purposes of this Order noise-sensitive land uses means areas used or reserved for the purposes of institutions, week-end houses, allotment gardens or recreation.*
>
> *Section 3. The noise load shall be determined according to the guidelines laid down in the Annex to this order as the equivalent corrected A-weighted noise level at a height of 1.5 metres at a wind speed of 8m/s at 10 metres above ground height."*

This statutory order defines the measurement position, the wind conditions and the level which should not be exceeded. The determination of the sound power level (SWL) from the wind turbines has also be defined within the Annex and is the method reported by most Danish manufacturers of wind turbines. The quoted SWL is that which is emitted by the turbine when operating at 8m/s wind speed measured at a height of 10 metres above ground level.

In the UK the level which must be achieved by a wind farm site has sometimes been set at the cut-in wind speeds of the wind turbines, the expectation being that wind-induced noise at the receiver position will increase at a greater rate than the emitted noise from the turbine. Therefore, for a comparison of agreements and conditions which have already been undertaken by some developers in the UK it is better to compare directly these levels at cut-in.

The emitted noise from a wind turbine increases with wind speed. This increase is typically about 1dB(A)/m/s. Different wind turbines have different rates of increase but this figure is fairly average for most commercially available wind turbines. Allowing for the height difference between the hub height (sometimes used for specifying the wind conditions when undertaking a noise test for compliance to any agreed noise level in the UK) and the wind speed and height used for the Danish Statutory Order of 8m/s at 10 metres height, Table 4 details the equivalent L_{Aeq} level which might be expected to meet the Danish Statutory Order at the cut-in wind speed of the wind turbines. A range is indicated to reflect the effects of varying ground roughness (0.01-0.05m) and rate of increase of noise with wind speed (0.75-1.0dB/m/s).

Table 4 Comparison of Danish limits to noise levels at cut-in

L_{Aeq} @ 8m/s @ 10m height dB(A)	Equivalent L_{Aeq} @ 5m/s @ 30m height dB(A)
45	40-42
40	35-37

The determination of the character of the noise emitted by wind turbines is performed by both a subjective and an objective test. This takes the form of listening to the emitted noise at the affected property and/or performing objective measurements of the incident noise at the property. The method by which tones are evaluated is the Joint Nordic Method for the Evaluation of Tone in Broadband Noise [21]. This method applies a 5dB(A) penalty to the incident noise from the wind turbine when the tone is deemed "prominent" using the objective test method.

The determination of when a tone is "prominent" is the result of laboratory tests of different tone and masking levels and different tone frequencies. (There is current work being performed for the DOE by NPL & ISVR to determine a more appropriate correction method for tonal noise. It is expected that this will not be included within a revision to BS 4142 for a number of years.)

The audibility criterion that is defined within the Joint Nordic Method is based upon Zwicker critical bands. The audibility criterion is frequency-dependent unlike the criterion defined within BS 7135 which is not frequency-dependent. The audibility threshold is defined as:

ΔL_t Audibility Criterion $= -2 - \text{Log}\,(1 + (f_t / 502)^{2.5})$

where f_t = tone frequency.

The Joint Nordic Method also defines a method for the analysis of tones in non-stationary conditions, ie if the level or frequency of the tone is varying.

The details of the Joint Nordic Method are discussed further in Chapter 6.

Netherlands

The Netherlands has no specific legislation concerning noise from wind turbines but has noise regulations for industrial noise which state the following:

$L_{Aeq,24hr}$ = 40dB(A) for rural areas without traffic
L_{Aeq} = 45dB(A) for quiet residential neighbourhoods in the city
L_{Aeq} = 50dB(A) for residential neighbourhoods in the city

The 45dB(A) and 50dB(A) limits are day-time values and should be reduced by 5dB(A) for evening periods and by 10dB(A) during the night. It should be noted that this implies that quiet residential neighbourhoods will, at night, have stricter noise limits than rural areas without traffic. It is understood that these are only recommendations and municipalities may use other standards when they issue a Nuisance Act permit.

Where a noise zone has not been proposed, the quality of the environment around the proposed wind farm will be considered. For example, if a wind farm were to be developed and dwellings were located nearby, background noise measurements would be undertaken to assess the prevailing background noise levels at the dwellings, the background noise level being defined as the L_{A95} level. Turbine noise would then not be allowed to exceed this level, ie the wind farm would be designed to not exceed the existing background noise levels.

Germany

German recommendations for acceptable noise levels are given in documents covering "The law for the protection against any emissions" and detailed under Technical Instructions for Noise.

The sound pressure levels, measured as $L_{Aeq,T}$, which must not be exceeded, are as follows:

	Day-Time	Night-Time
Commercial Areas	65dB(A)	50dB(A)
Mixed Areas	60dB(A)	45dB(A)
General Residential	55dB(A)	40dB(A)
Pure Residential	50dB(A)	35dB(A)

There currently exists a method for the determination of the audibility of tones , Draft DIN 45 681 [22]. This method is in draft form and is based upon ISO 7779 which forms the basis of BS 7135 Part 1 Annex D. This Draft DIN standard proposes a penalty rating method that follows the guidance contained within ISO 1996 (BS 7445) which gives a tonal penalty to the noise, that is related to the audibility of the tone. The penalty varies from 0-6dB depending upon the exceedence of the tone above the tone detection threshold. However, the penalty system is based upon the tone detection thresholds that are described in ISO 7779, and like BS 7135, the detection thresholds do not follow classic critical band theory. The audibility threshold described in DIN 45 861 is 6dB below the critical band masking level. Classic theory would indicate that this is 4dB over-sensitive at frequencies below 500Hz. Experience through the application of the tonal assessment method described in DIN 45 681 would indicate that a tonal penalty would be, and is, applied even when a tone is not audible but the assessment method indicates that one exists.

DIN 45 681 usefully defines which lines in the spectrum should be counted as contributing to the tone energy. Section 4.3.2 explains:

> *"It is not always obvious whether sidebands contribute to tone energy. A sideband should be included in the sum if the difference with respect to the maximum narrowband level is less than 10dB, and the difference with respect to the average narrowband of the masking noise in the critical band about the tone is larger than 6dB."*

5. SURVEY OF PUBLIC REACTION TO NOISE FROM WIND FARMS

Introduction

One element of the work of the Working Group was to assess the circumstances which have or have not resulted in complaints by the public over noise from wind farms. A survey of public reaction to noise from wind turbines as reported to Environmental Health Departments was therefore conducted, based upon the operational wind farms in England and Wales as of February 1994. A list and brief description of the wind farms used in the survey is given in Table 5 and Fig 1 shows their location.

Table 5 Operational wind farms in England and Wales (Feb 1994)

Wind Farm	Turbine Manufacturer	No.	Rated Power kW	Total Capacity kW
Cemmaes, Powys	WEG	24	300	7200
Kirkby Moor, Cumbria	Vestas	12	400	4800
Chelker, Yorkshire	WEG	4	300	1200
Ovenden Moor, Yorkshire	Vestas	23	400	9200
Delabole, Cornwall	Vestas	10	400	4000
Penrhyddlan and Llidiartywaun, Powys	Mitsubishi	103	300	30900
Rhyd-y-groes, Anglesey	Bonus	24	300	7200
Blyth Harbour, Northumberland	HMZ	9	300	2700
Orton Airport, Cumbria	Carters	10	300	3000
Goonhilly Downs, Cornwall	Vestas	14	400	5600
Cold Northcott, Cornwall	WEG	22	300*	6700
Blood Hill, Norfolk	Vestas	10	225	2250
Taff-Ely, Mid Glamorgan	Nordtank	20	450	9000
Carland Cross, Cornwall	Vestas	15	400	6000
Coal Clough, W Yorkshire	Vestas	24	400	9600
Llangwyryfon, Dyfed	WEG	20	300	6000
Haverigg, Cumbria	Vestas	5	225	1125
Royd Moor, S Yorkshire	Bonus	13	450	5850

* Includes 1x400 kW Turbine

A questionnaire was sent to local authorities having wind farms in their areas. A summary of the results of this survey appears in Table 6 and a more detailed discussion follows.

Figure 1 Wind farms constructed under NFFO-1 and -2

Table 6 Summary of complaints from wind farms
(figures in italics are from conversations on phone rather than from the questionnaire)

Wind Farm	Distance from residences to wind farm (m)	Number of complaints			Aspects of noise leading to complaints			
		Verbal	Written	Distant	Overall	Tones	Swish	Other
Cemmaes		*0*	*0*	*0*	*n/a*	*n/a*	*n/a*	*n/a*
Kirkby Moor	*700*	*0*	*0*	*0*	*n/a*	*n/a*	*n/a*	*n/a*
Chelker	350-500	0	0	0	n/a	n/a	n/a	n/a
Ovenden Moor	320-630	0	0	0	n/a	n/a	n/a	n/a
Delabole	350-1380	15	7	5	No	Yes	No	Yes
Penrhyddlan and Llidiartywaun	700-1200		5	2	Yes	Yes	Yes	No
Rhyd-y-Groes	400-600	1	1	0	Yes	No	No	Yes
Blyth Harbour		*0*	*0*	*0*	*n/a*	*n/a*	*n/a*	*n/a*
Orton Airport								
Goonhilly Downs								
Cold Northcott	380-500	10+	5	1	Yes	Yes	Yes	No
Blood Hill	400-450	0	0	0	n/a	n/a	n/a	n/a
Taff-Ely		*1*	*1*	*0*				
Carland Cross	370-410	2	2	2	Yes	Yes	Yes	Yes
Coal Clough	420	0	0	0	n/a	n/a	n/a	n/a
Llangwyryfon								
Haverigg	600, 1000	0	0	0	n/a	n/a	n/a	n/a
Royd Moor								

Effects of topography

Following experience from mainland Europe, initial expectations had been that the noise from wind turbines would be most intrusive at wind speeds at and just above cut-in. It had been expected that as the wind speed increased, the background noise generated by the passage of wind through trees and around buildings would increase at a faster rate than the noise generated by the turbines. The margin of the turbine noise above background noise would then have been greatest at relatively low wind speeds with the turbine noise progressively drowned out as the wind speed increased. This has not always been the case, however, particularly at many of the sites at which complaints over wind farm noise have arisen. At Cold Northcott, Penrhyddlan and Llidiartywaun, Rhyd-y-Groes and Delabole the noise was felt to be more intrusive at hub height wind speeds of 8m/s and above. In some cases this is influenced by the switching to a higher turbine rotational speed in higher winds but is primarily because properties are frequently sited in sheltered areas. It is not unusual for turbines to be operating in relatively strong winds on an exposed hill top location while some of the nearest properties in relatively sheltered valleys remain out of the wind and hence background noise levels can remain low in the absence of significant wind-generated background noise.

Change in attitude with time

There was no firm evidence of complainants becoming accustomed to the noise and their level of concern diminishing as a result. Decreasing annoyance was seen at some wind farm sites but this was usually due to remedial action being taken to reduce the noise from the wind turbines. An example of this occurred at Delabole where the turbines on commissioning could under certain conditions produce a noise described as a "squawk". This was also observed at Carland Cross using the same model of turbines and was believed to be caused by an instability in the flow over the turbine rotor blades. The effect was remedied by making adjustments to the pitch control settings and application of tapes, or boundary layer trips, to the trailing edges of the blades. These boundary layer trips disturbed the boundary layer or air flow close to the surface of the blade, causing it to become turbulent rather than laminar. As a laminar boundary layer is a prerequisite for the excitation process to occur this eliminated the noise source.

At sites which have not been able to reduce noise levels to the satisfaction of residents, complainants have become impatient and shown increasing annoyance.

Characteristics of the noise

At all sites at which complaints have been made reference has also been made to particular characteristics of the noise. Mechanical noise of a tonal nature, usually from the gearbox, has been frequently cited as being an aspect of the noise leading to complaints. In cases where mechanical noise is present it is not surprising that this should lead to increased annoyance, as is reflected in the penalties for tonal content added to rating levels of noise in standards such as BS 4142.

Blade swish is a phenomenon more peculiar to wind turbines which has emerged as another characteristic which can under certain circumstances add to the likelihood of complaints. Swish was identified as being one aspect of the noise leading to complaints at Penrhyddlan and Llidiartywaun, Cold Northcott and Carland Cross. Recorded time trace data from a property near to Carland Cross showed peak to trough differences of the A-weighted noise up to 3dB in an open situation and up to 6dB in a location where multiple reflections from nearby buildings affected noise levels. A noticeable level of swish was also observed by the Environmental Health Officer at Coal Clough although no complaint has been made at this site.

Intermittent blade thump was cited as being a contributing factor leading to complaints at Carland Cross.

Noise levels

As illustrated later in Chapter 6 background noise and turbine noise levels can be quite variable and show a fair degree of scatter even when plotted against wind speed. From the often limited data available it has therefore not been possible to reach any firm conclusions on noise levels which are likely to lead to complaints, particularly as in many cases the character of the noise has been as influential as the actual noise level in leading to complaints.

Time of day

Indications of periods during which the noise was found to be most audible or most intrusive were generally the same irrespective of whether weekdays or the weekend were being considered. At Cold Northcott, Rhyd-y-Groes and Delabole night-time (22.00-06.00) was reported to be the period at which nearby residents found the noise most intrusive, along with the evening (18.00-22.00) at Cold Northcott and Delabole and early morning (06.00-09.00) at Rhyd-y-Groes.

Relative impact, indoors compared to outdoors

The level of intrusion was in general a degree less indoors than out of doors. If the level of intrusion was considered high outdoors it was low indoors; if the noise could only be heard faintly outdoors it was inaudible indoors. On some sites (Blood Hill and Chelker) the turbines were considered largely inaudible both indoors and outdoors. The finding that outdoor levels were found to be more intrusive than indoor levels is somewhat at odds with the previous finding that the intrusion was in some cases greater at night when you would expect people to be indoors.

Reasons for absence of complaints

Although this section has concentrated on the factors affecting the likelihood of complaints it should be noted that at eight of the thirteen wind farms for which we have data no complaints have been received. The most frequently given reason is (not surprisingly) the low noise levels or inaudibility of the wind farm. Perceived low noise levels are usually the result of one or more factors including:

- background noise levels being sufficiently high at all wind speeds to substantially mask the turbine noise
- relatively quiet turbines with little or no tonal content in the noise emissions
- relatively large separation distances between turbines and nearest residences
- public acceptability of the wind farm in general.

Conclusions from the survey

- The framework for assessing wind turbines needs to relate noise at residences to turbine noise, taking into account the possibility of nearest residences remaining sheltered from the wind when turbines are operating in moderate-to-high wind speeds.

- Once nearby residents are sensitised to noise they are unlikely to get used to it over a relatively short period of time (approximately 12-18 months at the time of writing).

- The assessment method should impose penalties for distinctive characteristics of the noise.

- The assessment method should take account of the lower background noise levels at night.

- By using best practice it is possible to develop wind farms which are unlikely to lead to complaints over noise levels from the nearby residents.

6. NOISE LIMITS

Introduction

The background against which members of the Noise Working Group have set out to define a procedure for the measurement and rating of noise from wind turbines has been explored in Chapter 2. This chapter describes a framework for measurements with indicative noise levels thought to offer a reasonable degree of protection to wind farm neighbours without placing unreasonable restrictions on wind farm development or adding unduly to the costs and administrative burdens on wind farm developers or local authorities. The suggested noise limits and their reasonableness have been evaluated with regard to regulating the development of wind energy in the public interest. They have been presented in a manner that makes them a suitable basis for noise-related planning conditions or covenants within an agreement between a developer of a wind farm and the local authority.

The noise limits suggested have been derived with reference to:

- existing standards and guidance relating to noise emissions
- the need of society for renewable energy sources to reduce the emission of pollutants in pursuance of Government energy policy
- the ability of manufacturers and developers to meet these noise limits
- the researches of the Noise Working Group in the UK, Denmark, Holland and Germany
- the professional experience of members of the Working Group in regulating noise emissions from wind turbines and other noise sources
- the discussion of the issues at meetings of the Noise Working Group and with others with appropriate experience.

The Noise Working Group has sought to protect both the internal and external amenity of the wind farm neighbour. Wind farms are usually sited in the more rural areas of the UK where enjoyment of the external environment can be as important as the environment within the home.

The noise limits have been devised with regard for the human environment without specific consideration of the effect of noise on farm livestock. Members of the Noise Working Group are however unaware of any problems in this area to date. Indeed, at many windswept locations the turbine towers and transformers appear to offer a welcome degree of protection from the elements.

The guidance contained in this chapter refers to the operation of the wind farm, and is not appropriate to the construction phase which should be considered separately according to existing guidance such as BS 5228: 1984, Noise Control on Construction and Open Sites.

Locations for setting noise limits

At the wind farm, at the site boundary or at noise-sensitive properties?

There are broadly four options to consider when deciding upon the most appropriate location(s) to set noise limits:

1) In the wind farm.

2) At the boundary of the site occupied by the wind farm.

3) At the surrounding noise-sensitive properties.

4) At any position over a given distance from the nearest turbine.

The advantages of options (1) and (2) are that at these positions the noise will be easier to monitor as access to the site is controlled by the operator and the noise levels will be higher and therefore probably more easy to distinguish from the background noise. The disadvantage with this approach is that in its simplest form it does not take account of the proximity of the noise-sensitive properties, and even if noise levels at nearest properties are theoretically derived from limits and measurements close to the wind farm, this type of limit offers little protection to residents if the inferred levels prove inaccurate.

Option (3) has been the preferred method on all planning conditions on wind farms in the UK to date and is described as the normal approach in Annex 5 of PPG 24. This approach has the advantage that the limits can directly reflect the existing environment at the nearest properties and the impact that the wind farm may have on this environment. In some circumstances access to nearest properties may prove problematical but it is the Noise Working Group's experience that in general residents are happy to allow access to monitor noise levels, particularly if monitoring is required in response to complaints.

The fourth option, setting limits at a standard distance from the development in addition to those limits set at nearest properties, was one of the recommendations of the Welsh Affairs Committee's Report on Wind Energy [23]. This approach has some merits in that it avoids large areas of land becoming unsuitable for future development because of noise and conversely provides the wind farm operator with some protection from claims of nuisance from future development. In practice, because of the population distribution in the UK, limits on wind farm noise will be dictated by consideration of nearest properties. This has been the case with wind farm developments built to date in England and Wales. If limits were related to background noise levels then a knowledge of the variation in background noise levels with wind speed at all positions around a wind farm would be required. Determining these levels would be prohibitively expensive unless some crude assumptions were made.

For the reasons given above the Noise Working Group recommends that the current practice on controlling wind farm noise by the application of noise limits at the nearest noise-sensitive properties is the most appropriate approach. This approach has the advantage that the limits can directly reflect the existing environment at the nearest properties and the impact that the wind farm may have on this environment, for the reasons given above.

Internal or external noise limits?

Given that one of the aims of imposing noise limits is to protect the internal environment one might consider it appropriate to set these limits and hence monitoring locations at positions within the building. There are, however, some practicalities to take into consideration which lead us to believe that the current practice of setting external limits on noise is the more sensible approach:

- Monitoring of noise to demonstrate compliance with planning conditions may require data to be logged over a period of days in order to capture enough data at the required conditions. It may not always be feasible or reasonable to expect to leave equipment set up in someone's bedroom or living room for this period of time.

- Noise levels inside a dwelling would be extremely difficult to predict as they would depend upon the noise insulation properties of the windows, doors, roof and walls and the acoustic properties of the rooms. Each room in each property would have to be considered separately. It is simpler and as safe to predict free-field noise levels outside of the property and then make a conservative assumption on the attenuation properties of the building envelope.

- Noise limits, and therefore measurements, are in any event required outside the property to protect the external amenity. If internal noise levels can be inferred from these external limits then a requirement for internal measurements would place an unreasonable burden on the operator.

The noise limits applied to protect the external amenity should only apply to those areas of the property which are frequently used for relaxation or activities for which a quiet environment is highly desirable. For example, if a farm house is one of the noise-sensitive properties it would probably not be appropriate to apply limits to all the land belonging to the farm.

Types of noise limit

Options available

There are three types of constraints that can be placed on noise-producing developments. Ranked in order of complexity these are:

1) A minimum separation distance between the development and the nearest properties.

2) An absolute limit based on the average level of noise which should not be exceeded in a specified time period.

3) A relative limit based upon the permitted increase in noise level with respect to the background noise level. This is the approach used in BS 4142: 1990.

The descriptions of (2) and (3) are taken from PPG 24 which indicates either may be appropriate depending upon circumstances. The merits of each approach are considered in turn below.

Minimum separation distance

Paragraph 47 of the annex to PPG 22 refers to experience from mainland Europe which has shown that there is unlikely to be a significant noise problem for a residential property situated further than distances of 350-400 metres from a wind turbine. The PPG also suggests that:

> *"Lesser separation distances may be acceptable depending on the turbines used and the specific conditions at a site."*

This was true for the flat, open sites typical of Northern Europe and for the size and number of turbines used in wind farms at the time of writing PPG 22. We believe the guidance in PPG 22 was intended to give the reader an appreciation of the magnitude of the separation distances that would be required to protect local amenity. Indeed, wind farms have been constructed with this order of separation distance which have not resulted in complaints over noise. There are however a number of further considerations relevant today.

The emitted sound power level (SWL) from different wind turbines may vary by several dB for the same wind speed condition at hub height depending upon the size and design features of the turbine. Assuming hemi-spherical propagation with atmospheric absorption of 0.005dB/m this means that a quiet wind turbine with a SWL = 95dB(A) positioned at 245m from a dwelling would have the same acoustic impact as a turbine with a SWL = 101dB(A) positioned at 437m from a dwelling. (Note: this would result in an incident noise level at a dwelling of ≈ 38dB(A) from a single wind turbine.)

For small and medium-sized wind farms, say less than 10 to 20 turbines, incident noise levels at a residence are usually only influenced by those turbines closest to the residence. However, the advent of the larger wind farms being proposed and built today means that the cumulative effect of many turbines at some distance from the residence may also increase the noise levels around a property. Greater separation distances will therefore be required to achieve the same noise levels as a smaller wind farm using the same type of turbines.

The difference in noise emissions between different types of machine, the increase in scale of turbines and wind farms seen today and topographical effects described below all dictate that separation distances of 350-400 metres cannot be relied upon to give adequate protection to neighbours of wind farms.

Absolute limits

There are a number of ways in which absolute noise limits for wind farms can and have been set:

- A maximum level not to be exceeded at any wind speed at any property.

- A maximum level not to be exceeded at a specific wind speed or over a range of wind speeds set irrespective of the prevailing background noise level.

- A maximum level not to be exceeded at a specific wind speed or over range of wind speeds based on measurements of the prevailing background noise level taken prior to the construction of the wind farm.

The second option is of the type used in Denmark where noise from wind turbines is commonly limited to 40dB(A) in residential areas when measured at a wind speed of 8m/s at 10m height. This approach has its attractions in that it is relatively simple to use. Manufacturers need only state sound power levels for their machines at one wind speed, developers do not have to concern themselves with background noise surveys and actual levels need only be monitored at one, frequently occurring wind speed. The flat open countryside of Denmark enables one to be reasonably confident that if the noise limits at 8m/s are attained then the noise from the wind farm at other wind speeds is unlikely to be unduly disturbing. As demonstrated in Chapter 4, at cut-in the noise level will be less than 36-37dB(A) whereas at higher wind speeds the background will increase at a faster rate with wind speed than the turbine noise, such that the background noise soon approaches that of the turbine.

PPG 22 also advises at paragraph 42 that wind-generated background noise increases with wind speed and at a rate greater than that of wind turbines. It is also stated that the greatest level difference between turbine noise and background noise is liable to occur when wind speeds are low. PPG 22 does however note that for some sheltered locations the background noise levels may remain low even when wind speeds are well above the cut-in wind speed for the wind turbines.

In general, the assumption that the greatest difference in level might be at low wind speeds is true for flat sites which do not offer any shelter from the wind. These types of sites may be found in the Netherlands and Denmark where the topography of the landscape is such that little shelter exists. However, within the UK landscape, the positioning of a majority of wind farms to the West of the country has resulted in sites being developed within landscapes that are not flat. The effect of deep valleys (like those found in Wales, the Pennines and Scotland) and sheltered positions (like those that are found in Cornwall), is to protect dwellings from the effects of the wind and thereby from an increase in the background noise level due to the wind. Figs 2, 3 and 4 show the differences that can be experienced by dwellings when positioned in exposed or sheltered positions.

Fig 2 details measurements made within a deep valley positioned 150 metres below a mountain top plateau. Fig 3 details measurements made in a location which was partially protected from the prevailing wind by existing buildings and a tree wind break whereas Fig 4 details measurements performed at an exposed position on the top of a mountain. Wind speed measurements were performed on the top of a mountain at positions where wind turbines would be expected to be erected. It should be noted that the anemometer measurement height is different in Fig 3. The actual wind speed at the hub height of a wind turbine might be expected to be higher than that shown in Figs 2 & 4 by as much as a factor of 1.21, ie a wind speed of 10m/s measured at a height of 10 metres may be expected to be a wind speed of 12.1m/s measured at a hub height of 30 metres.

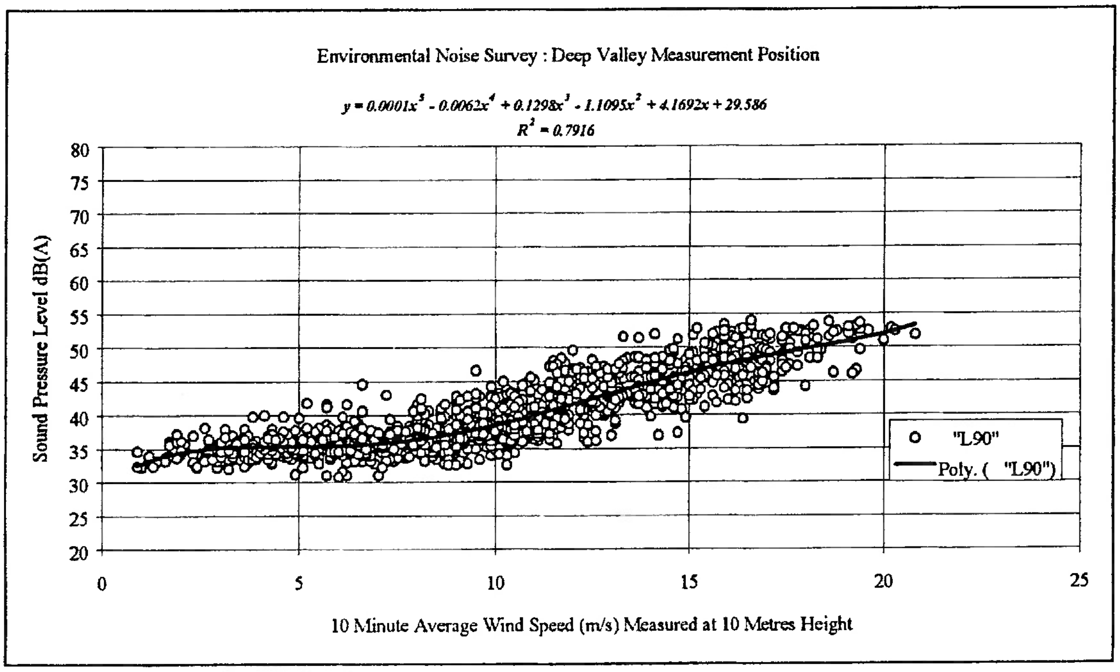


Figure 2 Background noise measurements in a deep valley position

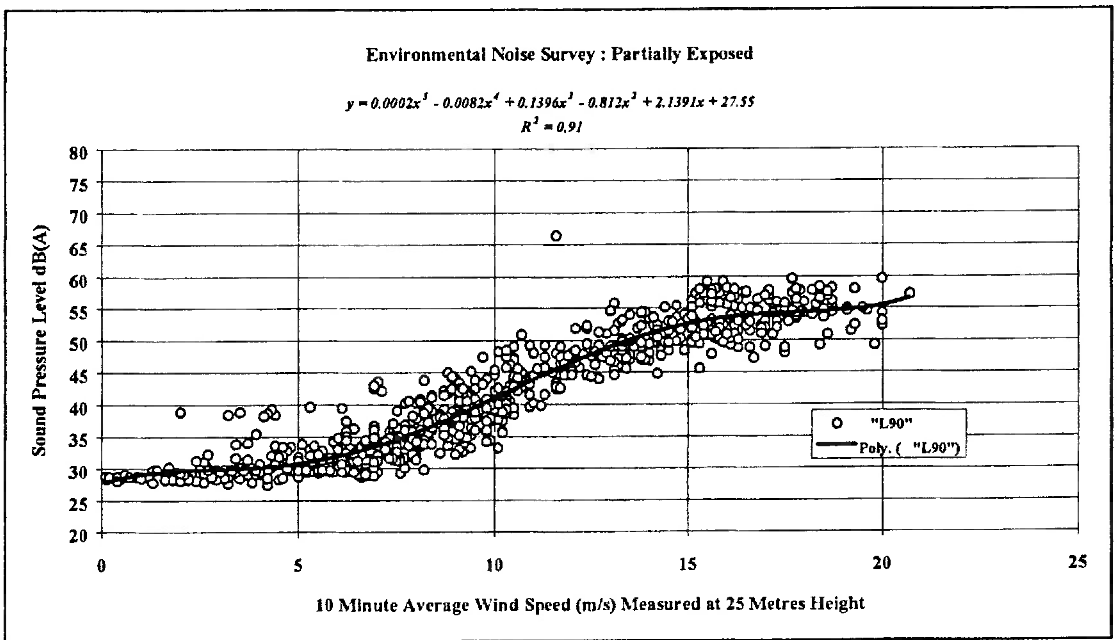


Figure 3 Background noise measurements in a partially exposed position

The variation of the rate of increase of the background noise level with wind speed has resulted in some sites experiencing complaints at high wind speeds but no complaints at low wind speeds. This is because, although turbine noise continues to rise with an increase in wind speed, the background noise levels have remained unchanged. Therefore, the level difference between the incident noise from a wind farm and the prevailing background noise level when the wind farm is not operating has been greatest at these higher wind speeds.

It may be seen that this sheltering effect results in each site having its own background noise environment with respect to wind-generated noise. Therefore, each position adjacent to a site should be considered for sheltering effects from the wind. The assumption that background noise levels will increase at a greater rate than the emitted turbine noise does not always hold true for the hillier sites which are found within the UK.

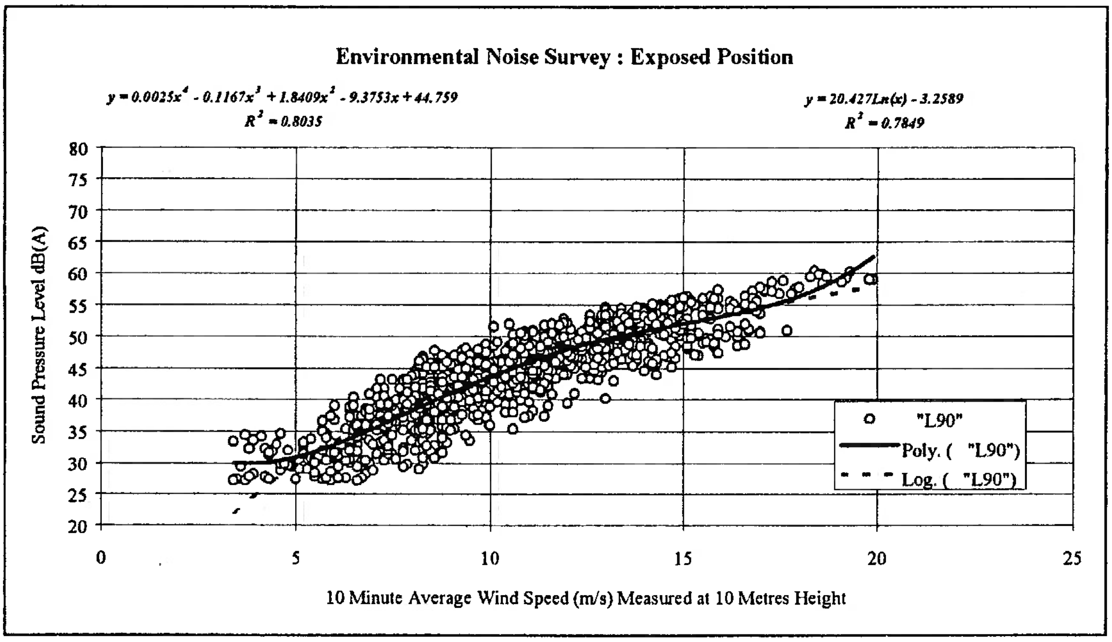


Figure 4 Background noise measurements in an exposed position

Even in Denmark the assumption that background noise increases with wind speed at a faster rate than the turbine noise may not be true for variable speed machines which, although usually quieter than fixed speed machines at low wind speeds, are characterised by a steeper rate of increase in noise emission with wind speed.

For the reasons given above the Noise Working Group considers that absolute noise limits applied at all wind speeds are not suited to wind farms in typical UK locations and that limits set relative to the background noise are more appropriate in the majority of cases. Later in this chapter consideration is given to the use of absolute levels in circumstances when background noise levels are low and in cases where low turbine noise levels can be achieved over a range of wind speeds.

Relative limits

PPG 24 introduces the concept of using BS 4142, a standard designed to predict the likelihood of complaints, as a tool for setting noise limits on industrial development. Paragraph 19 within Annex 3 of PPG 24 considers noise from industrial and commercial developments. It is stated that:

> *"The likelihood of complaints about noise from industrial development can be assessed, where the Standard is appropriate, using guidance in BS 4142: 1990. Tonal*

or impulsive characteristics of the noise are likely to increase the scope for complaints and this is taken into account by the "rating level" defined within BS 4142. This "rating level" should be used when stipulating the level of noise that can be permitted."

It should be noted that the guidance proposes the use of BS 4142 where the standard is appropriate. For the reasons described in the next section a literal interpretation of BS 4142 is difficult to apply to an assessment of wind farm noise and it may therefore not be appropriate. The Noise Working Group does however consider the principle of setting noise limits relative to the existing background noise level is appropriate, subject to the discussion on low noise levels later in this chapter.

Problems with interpretation and the literal application of BS 4142.

Paragraphs 43-44 of PPG 22 consider the use of BS 4142: 1990 and reports that this standard has been advocated as the standard which comes nearest to dealing with the issues encountered in wind farm developments.

Paragraph 44 states three reasons why using BS 4142: 1990 may be inappropriate for assessing wind turbine noise. These are:

"a) Wind farms are likely to be developed in largely rural areas and not in the areas to which the standard is principally addressed, namely mixed residential and industrial areas;

b) the scope of BS 4142 specifically precludes situations where background noise levels are below 30dB(A);

c) BS 4142 recommends that noise measurements should not be taken in extreme weather conditions such as high wind speeds greater than 5 metres per second average".

Paragraph 45 of the annex to PPG 22 states that:

"Where any of these factors gives rise to concern about whether BS 4142 is appropriate as a means of determining potential or actual perceived noise nuisance, the combined effect of the wind turbines should be determined by reference to the particular character and sensitivity of the area."

It is therefore worth exploring the reasons behind these qualifications on the use of BS 4142 and what measures are necessary to overcome these limitations.

Although the standard is intended for use in mixed residential and industrial areas as suggested by its title, there are no obvious reasons which prevent its application in more rural areas and indeed Members of the Noise Working Group have used it in such areas. There is no evidence to suggest that the average rural dweller is more or less sensitive to noise than their suburban or urban counterparts. On the one hand some people may be attracted to the countryside for its peace and quiet whereas for others the countryside is their workplace and noisy activities are a part of working life.

The scope of BS 4142 precludes its use where background noise levels are below 30dB(A). Background noise levels in rural areas, particularly during the quiet periods of the day and night, may frequently fall below this level. Two reasons have been suggested for this limitation in scope [24]:

- Measurements of background noise giving results below 30dB(A) may not be reliable due to the limitations of the instrumentation (although one could be fairly certain that the actual levels were no more than those measured!).

- The standard is designed to assess the likelihood of complaints from people residing inside a building based on measurements outside of the building. It is considered that when noise levels are less than 30dB(A) when measured externally the masking level inside the property will be dominated by internal noise sources.

This exclusion of the rating method contained within BS 4142 for these situations might be considered to leave rural environments, which can be very quiet, open to developments which could result in a significant change in the noise environment.

The current standard might be precluded if a background noise level was measured of 29dB(A) and the rated incident noise level were 40dB(A). Using the assessment method proposed within BS 4142, a level difference of 11dB(A) would otherwise be considered likely to give rise to complaints. However, if the background noise level were 31dB(A) and the rated noise level again 40dB(A), BS 4142 would no longer be precluded from use and a level difference of 9dB(A) would still be considered likely to give rise to complaints. The only difference is an increase in the measured background noise level of 2dB(A).

This apparent inconsistency has been considered by the committee for BS 4142 and has led to a proposed change within the scope of BS 4142, in the form of a revision. It is proposed that it will now read:

"The method is not applicable for assessing the noise inside buildings or when the background and specific noise levels are low.

Note: For the purposes of this Standard, background noise levels below 30dB and rating levels below 35dB are considered to be very low."

The question that arises is: if one intends to apply the principles of BS 4142 to the protection of external amenity, and the instrumentation is available to accurately measure noise levels below 30dB(A), should a margin above background approach be pursued in low noise environments or can an absolute level be justified in such circumstances? This question is addressed in the following section.

BS 4142 also suggests that:

"Noise level measurements should not generally be made under extreme weather conditions such as high winds (greater than 5m/s average)...."

The reason given for this limitation is:

"Weather conditions may affect measurements either by generating extraneous noise or by influencing sound propagation."

PPG 22 warns that:

"Wind farms are likely to be sited in windy conditions where the BS 4142 conditions may not be satisfied."

At the nearest residences to wind farms, even though the wind speed will usually be less than at the wind farm site, the local wind speed may still rise above 5m/s during periods when measurements are required. One should therefore exercise caution to ensure that measurements are not contaminated by wind noise on the microphone and consider the use of secondary windshields.

Propagation effects in high winds could result in unrepresentative results being obtained, particularly for ground-based sources located some distance upwind or downwind of the receiver. The warning contained in BS 4142 about taking measurements in winds greater than 5m/s guards against these effects on sound propagation. In the case of wind farms the turbines will often be in winds greater than 5m/s when at the same time the nearest residences are in relatively calm conditions. As wind speeds at both locations and all points in between will affect propagation and because most, if not all, turbine operation will occur at hub-height wind speeds greater than 5m/s one could argue that measurements taken in such conditions would strictly be outside the scope of BS 4142. It should be noted however that the effect of wind strength and direction on propagation may be less for elevated sources such as wind turbines. It is of course essential to be able to take measurements during windy conditions when assessing wind turbine noise and so it is suggested here that measurements are taken over a variety of wind directions to ensure that typical results are obtained.

Setting noise limits relative to the background noise level is relatively straightforward when the prevailing background noise level and source level are constant. However, wind turbines emit noise that is related to wind speed, and the environment within which they are heard will probably also be dependent upon the strength of the wind and the noise associated with its effects. It is therefore necessary to derive a background noise level that is indicative of the noise environment at the receiving property for different wind speeds so that the turbine noise level at any particular wind speed can be compared with the background noise level in the same wind conditions. This is consistent with the approach of BS 4142: 1990 which offers the following guidance on the measurement of background noise levels:

"Make measurements during periods when the background noise is typical of the background noise when the specific noise source is or will be operating."

"Measure the background noise during periods when weather conditions are similar to

those which prevail when the specific noise level is measured or are likely to be typical during the operation of a new or modified specific noise source."

In the case of wind turbines the specific noise level varies with wind speed, as does the background noise level. Measurements of the turbine noise level at a given wind speed should therefore only be compared to background noise measurements taken when weather conditions are similar ie the same wind speed. Only by measuring the background noise over a range of wind speeds will it be possible to evaluate the impact of the turbine noise, which also varies with wind speed, on the local environment.

Structure of limits

When assessing the overall noise levels emitted by a wind farm it is necessary to consider the full range of operating windspeeds of the wind turbines. This covers the wind speed range from around 3-5m/s (the cut-in wind speed) up to a wind speed range of 25-35m/s measured at the hub height of a wind turbine. The Noise Working Group is, however, of the opinion that one should only seek to place limits on noise over a range of wind speeds up to 12m/s at 10m height on the site of the wind farm. There are four reasons for restricting the noise limits to this range of wind speed:

1) Wind speeds are not often measured at wind speeds greater than 12m/s at 10m height. For example, measurements over a one year period from May 1993 to April 1994 at the Delabole Wind Farm indicated that the wind speed measured over a 10-minute period exceeded 12m/s at 10m height (which was shown by measurement to be equivalent to 15m/s at the hub-height of 32m) for only 5% of the time. The annual mean wind speed for this year was 8.0m/s.

2) Reliable measurements of background noise levels and turbine noise will be difficult to make in high winds due to the effects of wind noise on the microphone and the fact that one could have to wait several months before such winds were experienced.

3) Turbine manufacturers are unlikely to be able to provide information on sound power levels at such high wind speeds for similar reasons. 12m/s wind speeds are even rarer in other parts of Europe.

4) If a wind farm meets noise limits at wind speeds lower than 12m/s it is most unlikely to cause any greater loss of amenity at higher wind speeds. Whilst turbine noise levels will still be reasonably constant, even in sheltered areas the background is likely to contain much banging and rattling due to the force of the wind.

At the low wind speed range of turbine operation it is expected that some quiet rural locations will experience background noise levels that are very low. At medium wind speeds, it would be expected that background noise levels would increase with increasing wind speed and noise levels above 30dB(A) would be experienced, although possibly at levels still less than the predicted or actual levels from the wind farm. At high wind speeds it may be expected that, unless tones are present, the wind noise will mask turbine noise levels unless significant shelter is afforded to a dwelling. These different environmental factors require the development of an assessment procedure that will take into account individual dwellings, the noise environment and shelter from the wind that each dwelling experiences.

The recommendation of the Noise Working Group is that generally the noise limits should be set relative to the existing background noise at nearest noise-sensitive properties and that the limits should reflect the variation in both turbine source noise and background noise with wind speed. The Noise Working Group has also considered whether the low noise limits which this could imply in particularly quiet areas are appropriate and has concluded that it is not necessary to use a margin above background approach in such low noise environments. This would be unduly restrictive on developments which are recognised as having wider national and global benefits. Such low limits are, in any event, not necessary in order to offer a reasonable degree of protection to the wind farm neighbour. It is instead proposed to control noise through absolute limits up until wind speeds where the background noise has increased to a level such that relative limits are again appropriate. The proposed values for an absolute limit and their justification are discussed in the next section.

Separate noise limits should apply for day-time and for night-time. The reason for this is that during the night the protection of external amenity becomes less important and the emphasis should be on preventing sleep disturbance. Day-time noise limits will be derived from background noise data taken during quiet periods of the day and similarly the night-time limits will be derived from background noise data collected during the night. Background noise data collected during the night may be lower than those collected during the quiet periods of the day and would lead to unnecessarily tight restrictions on wind farm noise. The absolute limit for night-time operation can be higher than that in place during the day because of the extra attenuation afforded by the propagation of sound through even an open window.

Quiet daytime periods are defined as:

All evenings from 6pm to 11pm,
plus Saturday afternoon from 1pm to 6pm,
plus all day Sunday, 7am to 6pm.

Night time is defined as 11pm to 7am.

Consideration has also be given to circumstances where a more simplified approach, based on a fixed limit, may be appropriate.

Setting values for noise limits

Selection of units

The 1990 revision of BS 4142 was to bring the British Standard into line with ISO 1996 which has subsequently been adopted as British Standard BS 7445. The change that occurred was the proposal that the rating level of a new noise source be based upon a measured L_{Aeq} rather than a visual averaging of the meter. Also, sound power level data for wind turbines are based upon the measured L_{Aeq} at a predetermined distance from a wind turbine. Therefore, it might be expected to be appropriate to use the L_{Aeq} index to perform an assessment of wind turbine noise at dwellings.

However, experience in the field when performing such measurements indicates that short, transitory noise events can significantly change the L_{Aeq}. These events are not related to the noise emitted by the wind farm. These transitory noise events can be sources such as low flying aircraft, bird song, animal noises, cars, wind effects on the microphone, etc. The rating and assessment method contained within BS 4142 compares the existing L_{A90} background noise level with the L_{Aeq} of the rated noise level from the new source. A level difference of 10dB(A) between these two levels indicates that complaints are likely from neighbouring residents to the new noise source.

Measurements performed in rural areas indicate that the ambient L_{Aeq} noise levels may be 5-25dB(A) above the L_{90} background noise level due to these transitory events. Therefore, when performing noise measurements for the assessment of compliance with planning conditions or obligations, confusion can occur due to the L_{Aeq} being significantly higher than the L_{90} background noise level due to noise sources not associated with the wind farm. This might unfairly indicate that the condition is being failed if the condition is related to an L_{Aeq} exceedence above the background L_{A90}.

Fig 5 details environmental noise measurements that indicate the high background L_{Aeq} leve ls when compared with the background L_{A90} noise levels. These measurements were performed in the absence of any other noise source except those found in a typical rural environment. The figure plots the noise measurements performed over a 24-hour period. It may be seen that there are many occasions when the L_{Aeq} exceeds the L_{A90} by over 10dB(A) and at times by over 20dB(A).

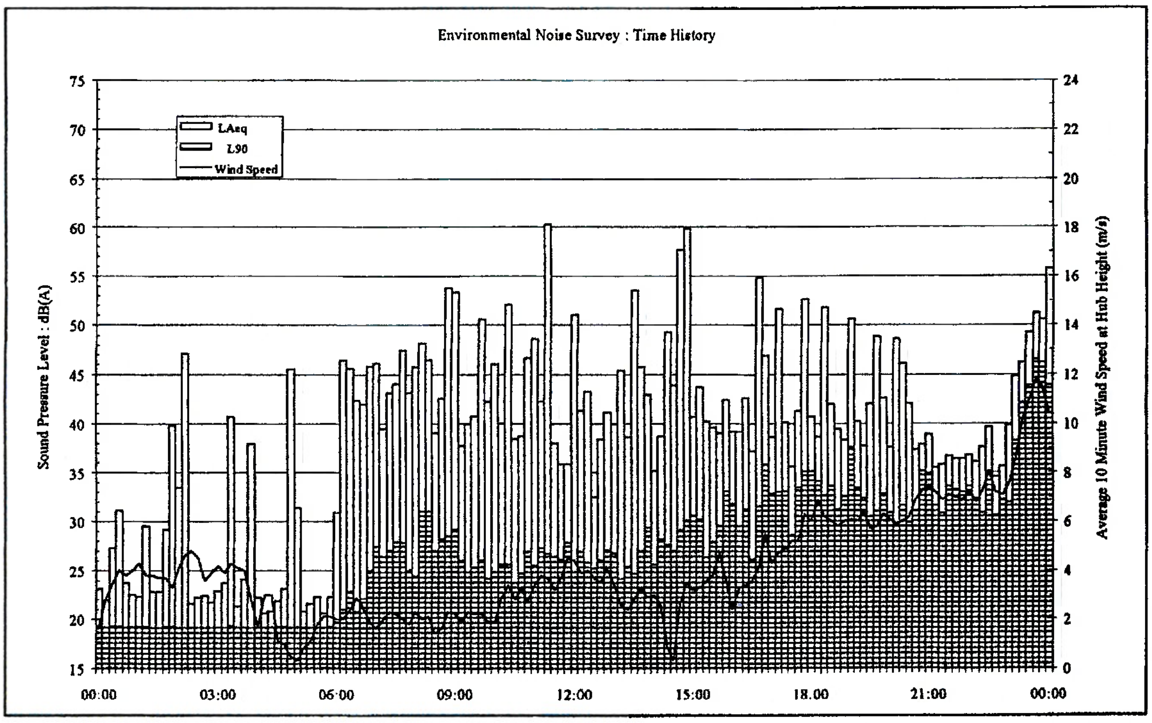


Figure 5 Comparison of L_{Aeq} and L_{A90} background noise levels

Note: The electrical noise floor of the sound level meter used to obtain this data was 18dB(A).

This problem has been encountered when using the L_{Aeq} index and has led to the use of other noise descriptors. Measurements of the L_{A90} and the L_{A50} have been proposed for the testing and application of noise conditions for wind farms. In South West England, conditions have been agreed with local authorities that relate the L_{A90} noise levels of the wind farm to either the existing background noise level during the test or to an agreed level at a specified wind speed, as measured on the wind farm site. The selection of an L_{A90} level does not follow the guidance contained within BS 4142 or BS 7445 but it does attempt to address the problems that may be experienced in the field. Early work performed at the Carmarthen Bay demonstration site used the L_{A50} index to assess turbine noise. Again, this was to minimise the errors that may occur due to transient noise events.

Another related drawback of using two noise indices as suggested by BS 4142 (although outside of its scope in rural locations) becomes apparent when one considers the effect of correcting the noise source measurements for background noise. BS 4142 proposes that a correction should be applied when the new noise source does not exceed the background noise level by more than 10dB (see section 5.4.4 of BS 4142). It advises that to obtain the correct level for the specific noise source, the L_{A90} background noise level when the source is not operating should be subtracted from the measured L_{Aeq} when the source is on. However, as has been identified above, in quiet noise environments the L_{Aeq} level may be 10-20dB(A) above the background noise level even when the source is not operating. Therefore, measurements performed and corrected using the method described within BS 4142 will underestimate the contribution of the existing noise sources to the measured L_{Aeq} noise level when a wind farm is operating. This effect may result in a wind farm being deemed to fail any noise conditions that have been imposed. It is considered very important that, when applying corrections to the measured incident noise source, like indices are used to obtain the necessary corrections, ie L_{A90} levels obtained when the wind farm is not operating are compared with L_{A90} noise levels when the wind farm is operating.

The steady nature of the emitted noise from wind turbines is such that the level difference between the L_{Aeq} and L_{A90} noise levels close to the turbines, and in the absence of other noise sources, is typically less than 2dB(A) as shown in Fig 6. It should be noted that these data are taken using a 1-minute measurement period.

The data in Fig 7 are taken at a residential location a few hundred metres from the nearest turbine. The difference between L_{Aeq} and L_{A90} ranges from 2-4dB(A) although some measurements will be influenced by background noise at these low levels. Data from other operational wind farms indicate that the difference between L_{Aeq} and L_{A90} measurements of wind turbine noise taken at residence-type locations is of the order of 2dB(A).

The use of a 10-minute measurement period has evolved as common practice for wind farm noise assessments. This is because wind speed measurements performed on-site in order to estimate the annual mean wind speed and subsequent energy production are normally performed over 10-minute intervals. As the noise data are usually plotted against wind speed it makes sense to use the same measurement period for the noise measurements.

Experience indicates that a measurement period of 10 minutes is more likely to provide a good correlation of background noise level with site wind speed than a 5-minute period. In simplistic terms, a gust of wind progressing across the ground at 5m/s will cover a distance of

300 metres in a minute. Therefore, separation distances between a wind farm and a dwelling of 1200 metres, a not uncommon distance for large-scale developments, will create a time lag of 4 minutes.

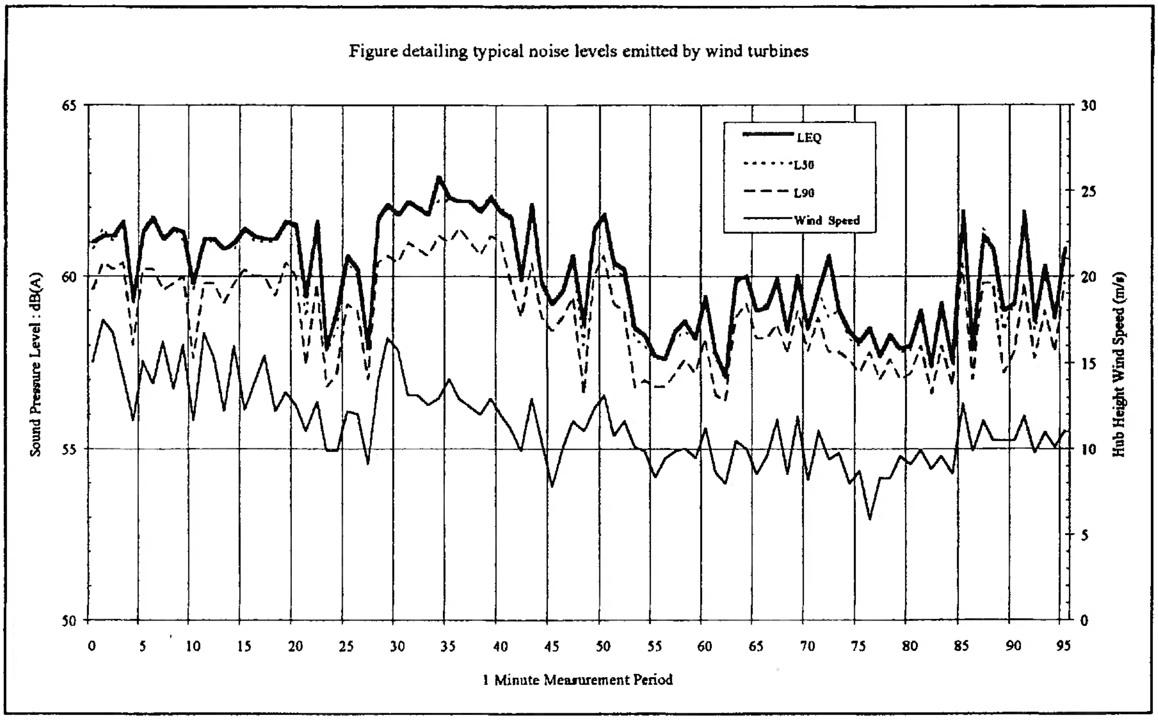


Figure 6 Comparison of measurements with different noise indices

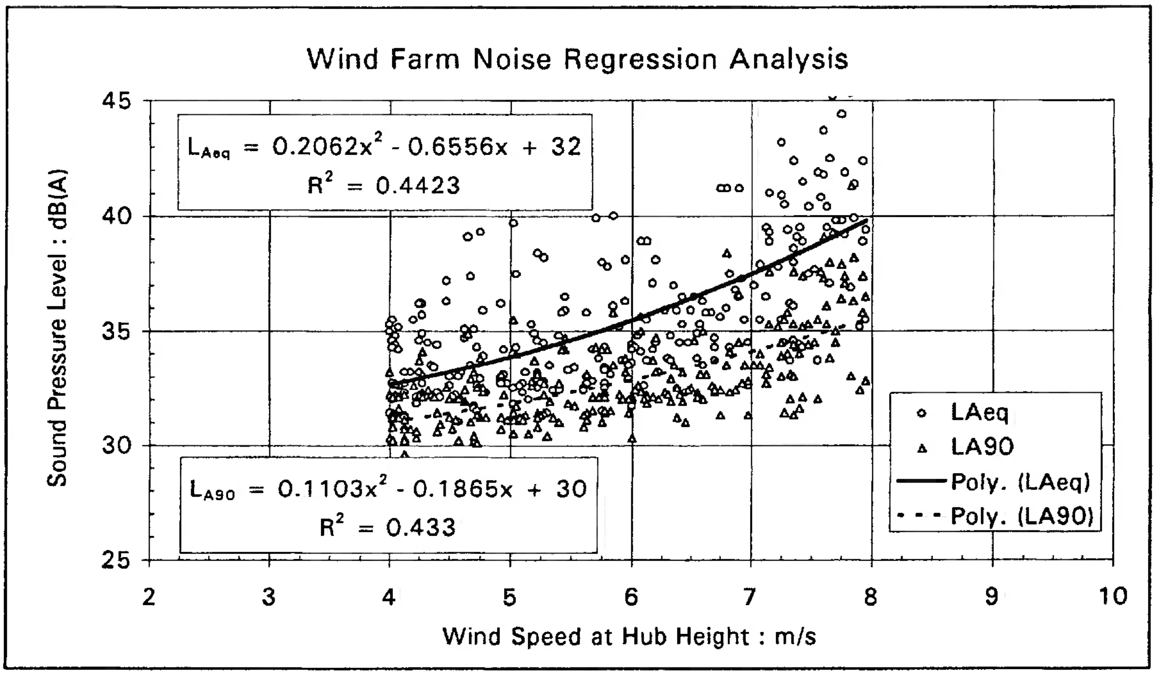


Figure 7 Comparison of L_{Aeq} and L_{A90} turbine measurements at a nearby residence

The effect of extending the measurement period to more than 10 minutes would be to lose some resolution in the variation of noise level with time. As the measurement period is increased the results tend towards those of the most typical conditions and it becomes more difficult to establish the variation of either turbine noise or background noise with wind speed.

In summary, the Noise Working Group is agreed that the $L_{A90,10min}$ descriptor should be used for both the background noise and the wind farm noise and that when setting limits it should be borne in mind that the $L_{A90,10min}$ of the wind farm is likely to be about 1.5-2.5dB(A) less than the L_{Aeq} measured over the same period.

Free-field measurements

The limits to be proposed relate to free field (except for ground reflections) measurements in the vicinity of noise-sensitive properties. Measurements performed near or at a building facade will exhibit higher noise levels due to the reflection of the sound from the facade. As this effect is dependent upon the measurement position, it is difficult to allow for in noise predictions and therefore free-field noise levels which are unaffected by the facade of a building are preferred. The potential for "hot-spots" due to particular building configurations should be discussed with the EHO during the initial site assessment. For example, courtyards with an open side facing the site of the proposed wind farm will require special consideration. Further advice on the positioning of microphones is to be found in Chapter 7.

Cumulative impact

The Noise Working Group is of the opinion that absolute noise limits and margins above background should relate to the cumulative effect of all wind turbines in the area which contribute to the noise received at the properties in question. It is clearly unreasonable to suggest that, because a wind farm was constructed in the vicinity in the past which resulted in increased noise levels at some properties, the residents of those properties are now able to tolerate still higher noise levels. The existing wind farm should not be considered as part of the prevailing background noise.

The assessment of typical background noise levels

Wind turbines operate day and night dependent upon wind speeds. It will be necessary to acquire background noise data for both day- and night-time periods because:

- the absolute lower limit is likely to be different for day- and night-time operation
- the noise limits are to be related to the background noise levels
- background noise levels may be different in the day than during the night

The impact from the wind turbines during waking hours will be greatest during otherwise quiet periods, usually Saturday afternoon, all day Sunday and weekday evenings. It is therefore proposed that the background noise measurements upon which the day-time noise limits are based are taken during these quiet periods. This is consistent with the approach of PPG 24 which advises in Annex 3, paragraph 19, that:

> *"Since background noise levels vary throughout a 24-hour period it will usually be necessary to assess for separate periods (eg day and night) chosen to suit the hours of operation of the proposed development. Similar considerations apply to developments that will emit significant noise at the weekend as well as during the week."*

In principle this implies, and quite rightly, that one could justify the setting of higher limits during the working day when background noise levels will be higher due to increased human activity. The developers represented in the Noise Working Group thought that this approach would however be unworkable since the wind farm would have to be designed to meet the stricter conditions applicable during quiet periods and the economics of wind farms would not allow one to consider switching off certain turbines at given times of day at the most critical wind speeds. We therefore propose that the day-time limits should be set in relation to the background noise measured during the quiet period of the day and that these should apply over all waking hours.

Should developers wish to investigate the cost effectiveness of switching off turbines at certain times of day over a given range of wind speeds in order to allow more turbines to be placed on a site, then an additional set of background noise data should be obtained for periods when all turbines would be operating.

Data acquired during all hours of the night are considered relevant to setting of night-time noise levels.

It is proposed that the background noise levels upon which limits are based, and the noise limits themselves, are based upon typical rather than extreme values at any given wind speed. An approach based upon extreme values would be difficult to implement as the difference in measurements between turbine noise and background would depend upon the length of time one is prepared to take data. A more sensible approach is to base limits upon typical or average levels, but to appreciate that both turbine and background noise levels can vary over several dB for the same nominal conditions.

The variation in background noise level with wind speed will be determined by correlating $L_{A90,10min}$ noise measurements taken over a period of time with the average wind speeds measured over the same 10-minute periods and then fitting a curve to these data. The mechanics of undertaking the background noise survey and the significance of seasonal effects on background noise are discussed in Chapter 7.

The aim of the background noise survey is to provide an indication of the noise environment existing at each noise-sensitive property in the vicinity of the wind farm. If there are several properties within ear-shot of the proposed wind farm then to conduct noise surveys at each and every property would be time consuming, costly, unnecessary and would therefore impose an unreasonable burden on developers. In such situations it is suggested that the developer and the local authority identify groups of properties that through their exposure and proximity to other noise sources would be expected to have similar background noise levels. In this manner it is expected that the number of noise surveys could be limited to a reasonable amount.

Rating method

The wind farm noise limits proposed below refer to rating levels in a similar manner to that proposed in BS 4142. That is, additions are made to the measured noise to reflect the character of the noise. The procedure for applying penalties for the character of the noise is presented later in this chapter.

Margin above background

It is proposed to limit the noise from a wind farm relative to the existing background noise but with special consideration given to the very low noise limits this would imply in particularly quiet areas. Noise from the wind farm will be limited to 5dB(A) above background for both day- and night-time (with the exception of the lower limits and simplified method described below), remembering that the background level of each period may be different. It should be noted that this limit applies to the noise from the wind farm only and not to the total ambient noise with the wind farm operating. Noise limits would apply up to 12m/s (10m height) on the assumption that, even in the most sheltered areas, if the wind farm can meet the conditions at lower wind speeds, it is unlikely to be a problem in higher winds. In high winds bangs and clatters from existing sources and gusts of wind are likely to be more disturbing than the wind farm noise.

When comparing the proposed margin with the complaints criteria suggested by BS 4142 it is important to bear in mind that the L_{A90} descriptor is also being proposed for the turbine noise. The L_{Aeq} levels can be expected to be about 1.5-2.5dB greater. An addition of 1.5-2.5dB places the margin at the upper end of the range which can be considered to be of marginal significance ie <u>around</u> 5dB.

On balance it is considered that a margin of 5dB(A) will offer a reasonable degree of protection to both the internal and external environment without unduly restricting the development of wind energy which itself has other environmental benefits.

Although not a factor to influence the specification of the allowable margin above background, it is worth noting that limits less than 5dB(A) would be difficult to monitor. One would have to resort to approximate methods such as extrapolating noise levels measured nearer to the turbines than the neighbouring properties, back to the locations of the properties, using an agreed propagation model.

Lower limit

Applying the margin above background approach to some of the very quiet areas in the UK would imply setting noise limits down to say 25-30dB(A) based upon background levels perhaps as low as 20-25dB(A). Limits of this level would prove very restrictive on the development of wind energy. As demonstrated below, it is not necessary to restrict wind turbine noise below certain lower fixed limits in order to provide a reasonable degree of protection to the amenity.

Recommendation of night-time lower limit

During the night one can reasonably expect most people to be indoors and it will not be necessary to control noise to levels below those required to ensure that the restorative process of sleep is not disturbed. A night-time absolute lower limit is therefore appropriate based upon sleep disturbance criteria.

The existing guidance relating to sleep disturbance criteria was reviewed in Chapter 4. The results were summarised, as in Table 7.

Table 7 Summary of sleep disturbance criteria and internal noise levels

Source of Proposed Criteria	Falling Asleep	Light Sleep	Deep Sleep	Max. Level
CEC Report EUR 5398 e: 1975 Environment and Quality of Life: Damage and Annoyance Caused by Noise		L_{Aeq} = 30-35		L_{Aeq} + 10
OECD Report: Reducing Noise in OECD Countries: 1978	L_{Aeq} = 35	L_{Aeq} = 45	L_{Aeq} = 50	L_{Aeq}+10 to 15
WHO Environmental Health Criteria 12 - Noise: 1980	L_{Aeq} = 35	L_{Aeq} = 35	L_{Aeq} = 35	
WHO Criteria Document: Community Noise: Environmental Health Criteria: External Review Draft 1993	L_{Aeq} = 30	L_{Aeq} = 30	L_{Aeq} = 30	L_{AMAX}< 45dB
PPG 24 Planning and Noise, 1994	L_{Aeq} = 35 (Based on WHO Environmental Health Criteria 12)			
Planning and Noise Circular W.O. 16/73	Good Standard Internal Noise Level CNL (Corrected Noise Level) Day = 45dB(A) Night = 35dB(A)			

The Noise Working Group recommends that an appropriate fixed limit for the night-time is 43dB(A). This limit is derived from the 35dB(A) sleep disturbance criteria referred to in PPG 24. An allowance of 10dB(A) has been made for attenuation through an open window (free-field to internal) and 2dB subtracted to account for the use of L_{A90}s rather than L_{Aeq}s (assuming the L_{A90} of turbine noise is 1.5-2.5dB below the L_{Aeq}).

Recommendation of day-time lower limit

Guidance relating to the control of external noise levels was also summarised in table form in Chapter 4 and this too is reproduced below.

Table 8 Summary of external noise criteria

Source of Criterion	External Noise Limit dB
CEC Report EUR 5398 e: 1975 Environment and Quality of Life: Damage and Annoyance Caused by Noise.	L_{Aeq} = 50-55
British Standard BS 5228: Part 1: 1984 Noise Control on Construction and Open Sites. Part 1. Code of practice for basic information and procedures for noise control	$L_{Aeq,1\ Hour}$ at facade = 40-45
PPG 24 Planning and Noise	BS 4142 where appropriate
MPG 11 Control of Noise at Surface Mineral Workings	Day $L_{Aeq,1h}$= 55 (No less than 45 in quiet area) Night $L_{Aeq,1h}$ = 42 Gardens/open spaces $L_{Aeq,1h}$= 55-65
WHO Criteria Document: Community Noise: Environmental Health Criteria: External Review Draft 1993	Daytime L_{Aeq}= 50 Moderate Annoyance Night-time L_{Aeq}= 45

The Noise Working Group believes that the external levels around 50dB(A) suggested by some of these documents for the protection of external amenity would be entirely inappropriate in the quiet rural locations of the UK. Furthermore, even the 43dB(A) limit ($L_{A90,10min}$) derived above to protect sleep disturbance inside the property does not offer sufficient protection to the external amenity in quiet areas of the UK during the day.

It is also the opinion of the Noise Working Group that there is no need to restrict noise levels below a lower absolute limit of $L_{A90,10min}$ = 33dB(A); if an environment is quiet enough so as not to disturb the process of falling asleep or sleep itself then it ought to be quiet enough for the peaceful enjoyment of one's patio or garden. This level would however be a damaging constraint on the development of wind power in the UK as the large separation distances required to achieve such low noise levels would rule out most potential wind farm sites. There are however the following justifications for relaxing this limit:

- Wind farms have global environmental benefits which have to be weighed carefully against the local environmental impact.

- Wind farms do not operate on still days when the more inactive pastimes (eg sunbathing) are likely to take place. For example, wind speed measurements at Delabole Wind Farm over the period May 1993 to April 1994 show that over the Summer months (June, July, August) the wind speed was below the 5m/s cut-in wind speed of the turbines for 34% of the time [25]. If the cut-in wind speed had been reduced to 4m/s the proportion of time would have been reduced to 20%. The figures for the whole year are 22% and 13% of the time for wind speeds below 5m/s and 4m/s respectively. So that residents benefit from periods of low wind speeds it is important to ensure that the turbine controllers do not allow for excessive idling. When a turbine is idling it is rotating, probably at a speed less than its normal operating speed, but without producing any power. The turbines can however generate a degree of noise in this condition, although usually at lower levels than when the turbines synchronise with the grid and start producing power.

- The absolute lower limits will only come into force when the turbine noise is more than 5dB above the background noise level and when this level of 5dB above background is below a figure in the range discussed below. The period of greater exposure to noise will therefore be limited and on some sites will not occur at all.

- There is no evidence for or against the assertion that wind farm noise with no audible tones is acceptable up to and including $L_{A90,10min}$ levels of 40dB(A) even when background noise levels are 30dB or less.

- Noise levels inside the property will be approximately 10dB less than those outside assuming an open window. Noise levels could therefore be increased before sleep and relaxation inside the property begin to be affected.

For periods during the day the Noise Working Group has adopted the approach that external noise limits should lie somewhere between that required to avoid sleep disturbance even if the occupant is outside of the property and the higher level that would still prevent sleep disturbance inside the property.

The Noise Working Group has therefore concluded that in low noise environments the day-time level of the $L_{A90,10min}$ of the wind farm noise should be limited to an absolute level within the range of 35-40dB(A). We believe that limits within this range offer a reasonable degree of protection to wind farm neighbours without placing unreasonable restriction on wind farm development. The levels are low compared to some of the advisory documents reviewed and this is because of our concern to properly protect the external environment.

As the night-time lower fixed limit is greater than the day-time limit, the night-time limit could become superfluous unless background noise levels are less during the night than during the quiet day-time periods. Where the local authority and the developer are in agreement that the background noise levels do not vary significantly between the quiet day-time periods and the night-time, then a single lower fixed limit of 35-40dB(A) can be imposed based upon background noise levels taken during quiet day-time periods and the night analysed together.

There are two aspects to consider when assessing the impact of the absolute lower limit:

- Although the range of limit proposed is 5dB, the actual difference in wind farm noise levels between the two cases, at any given wind speed, is usually less than 5dB.

- Imposing an absolute lower limit of 40dB(A) on a property with background noise levels at turbine cut-in of, say, 30dB(A) will not result in the turbine noise being 10dB greater than the background.

These two initially somewhat surprising results arise because of the variation in turbine noise with wind speed and can be illustrated by reference to Fig 8. Noise limits with an absolute lower limit of 35dB(A) and 40dB(A), both giving way to a 5dB margin above background criterion at higher wind speeds, have been constructed for a typical background noise curve in a quiet and reasonably sheltered rural location. Two lines were then drawn to represent the maximum level of turbine noise which could be experienced for each of the two cases. The slope of the increase in turbine noise with wind speed has been chosen to be 1.0dB(A) per m/s, a typical rate of increase for modern turbines.

It can be seen that the gap between the two lines representing the turbine noise is somewhat less than 5dB (3.5dB for the example given) and that the turbine noise limited to an absolute lower limit of 40dB(A) is only 37dB(A) at a typical cut-in wind speed of 4m/s. The extent to which these two effects are seen increases with the rate of increase in turbine noise with wind speed and the degree of shelter of the property from the wind.

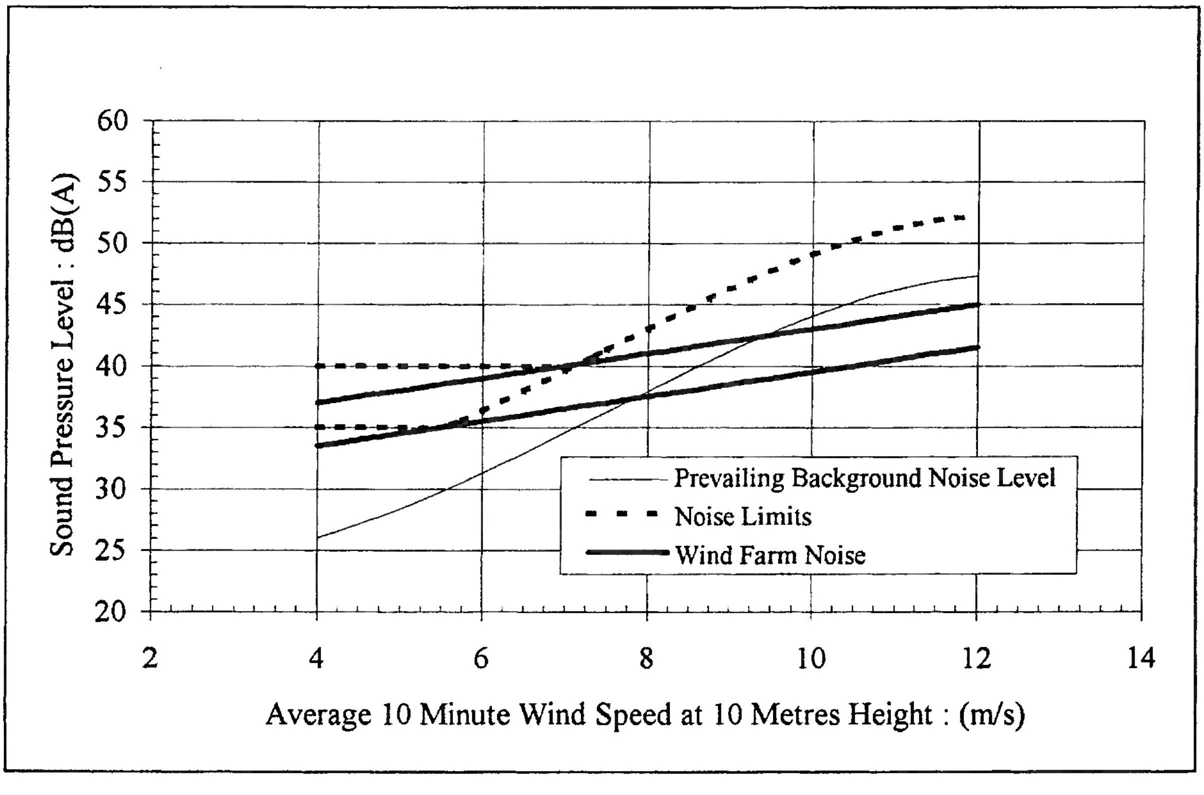


Figure 8 Comparison of day-time noise criteria

It is of interest to note that the Danish Statutory Order for Noise from Wind Mills [12] proposes noise limits of 45 and 40dB L_{Aeq} at dwellings and noise-sensitive locations when measured at external positions. These noise levels must be shown by calculation to be achievable before construction of the wind farm. However, the source sound power level used to perform this calculation is set at a wind speed of 8m/s at a height of 10 metres above ground level. This is equivalent to a wind speed of about 9.5m/s at the hub height of the wind turbine (see "wind shear" in Glossary). Table 4 in Chapter 4 indicates the predicted noise levels that may be experienced at the cut-in wind speed for wind turbines of 30m hub height, based upon the Danish Statutory Order criteria levels. It may be seen that at the cut-in wind speed, it would be expected that these levels would be 35-42dB L_{Aeq}. Thus, the levels proposed here for absolute lower limits are similar to those in use in Denmark at cut-in. The difference is that the lower absolute limits proposed for use in the UK will extend to higher wind speeds until the background noise increases sufficiently to be within 5dB of the turbine noise.

The actual value chosen for the day-time lower limit, within the range of 35-40dB(A), should depend upon a number of factors:

- Number of dwellings in the neighbourhood of the wind farm.

  The planning process is trying to balance the benefits arising out of the development of renewable energy sources against the local environmental impact. The more dwellings that are in the vicinity of a wind farm the tighter the limits should be as the total environmental impact will be greater. Conversely if only a few dwellings are affected, then the environmental impact is less and noise limits towards the upper end of the range may be appropriate. Developers still have to consider the interests of individuals as protected under the Environmental Protection Act 1990. It is our belief however, in accordance with the report of the Welsh Affairs Committee [23], that there have been no cases of complaints of noise at levels similar to those caused by wind farms leading to a successful prosecution as a statutory nuisance. It should be noted however that the Welsh Affairs Committee also reports that although the noise may not be a statutory nuisance it can clearly be a cause for distress and disturbance, particularly if residents have been promised inaudibility and the noise has a particular quality leading to complaints.

- The effect of noise limits on the number of kWh generated.

  Similar arguments can be made when considering the effect of noise limits on uptake of wind energy. A single wind turbine causing noise levels of 40dB(A) at several nearby residences would have less planning merit (noise considerations only) than 30 wind turbines also causing the same amount of noise at several nearby residences.

- Duration and level of exposure.

  The proportion of the time at which background noise levels are low and how low the background noise level gets are both recognised as factors which could affect the setting of an appropriate lower limit. For example, a property which experienced background noise levels below 30dB(A) for a substantial proportion of the time in which the turbines would be operating could be expected to receive tighter noise limits than a property at which the background noise levels soon increased to levels above 35dB(A). This approach is difficult to formulate precisely and a degree of judgement should be exercised.

Increased lower fixed limit with financial involvement

It is widely accepted that the level of disturbance or annoyance caused by a noise source is not only dependent upon the level and character of the noise but also on the receiver's attitude towards the noise source in general. If the residents at the noise-sensitive properties were financially involved in the project then higher noise limits will be appropriate, particularly if a tie could be made between the wind farm and the property, such as giving the developer first option to buy the property if it came up for sale. We recommend that both day- and night-time lower fixed limits can be increased to 45dB(A) and that consideration should be given to increasing the permissible margin above background where the occupier of the property has some financial involvement in the wind farm.

Simplified assessment method

Much of the complexity of the proposed method is necessary because of the variety of background noise environments present in the UK. However, if the developer can demonstrate that noise conditions would be met even if there was no increase in background noise with wind speed until quite high wind speeds, then a simplified approach can be adopted. We are of the opinion that if the noise is limited to an $L_{A90,10min}$ of 35dB(A) up to wind speeds of 10m/s at 10m height then this condition alone would offer sufficient protection of amenity, and background noise surveys would be unnecessary. We feel that, even in sheltered areas when the wind speed exceeds 10m/s on the wind farm site, some additional background noise will be generated which will increase background levels at the property. This type of condition may be suitable for single turbines or wind farms with very large separation distances between the turbines and the nearest properties.

Summary of noise limits

A graphical representation of the recommended limits appears in Figs 9 and 10 based upon a fairly typical background noise curve for a quiet rural area. Both background levels and turbine noise are determined by best fit curves through representative data. Further guidance appears in Chapter 7.

At low wind speeds noise is controlled through the application of the lower absolute limit in the range of $L_{A90,10min}$ = 35-40dB (day-time) and 43dB (night-time). In the example shown, during the day, between wind speeds of 5.5m/s and 7.0m/s depending on the lower limit agreed, a limit of 5dB above the existing background noise limit then comes into force.

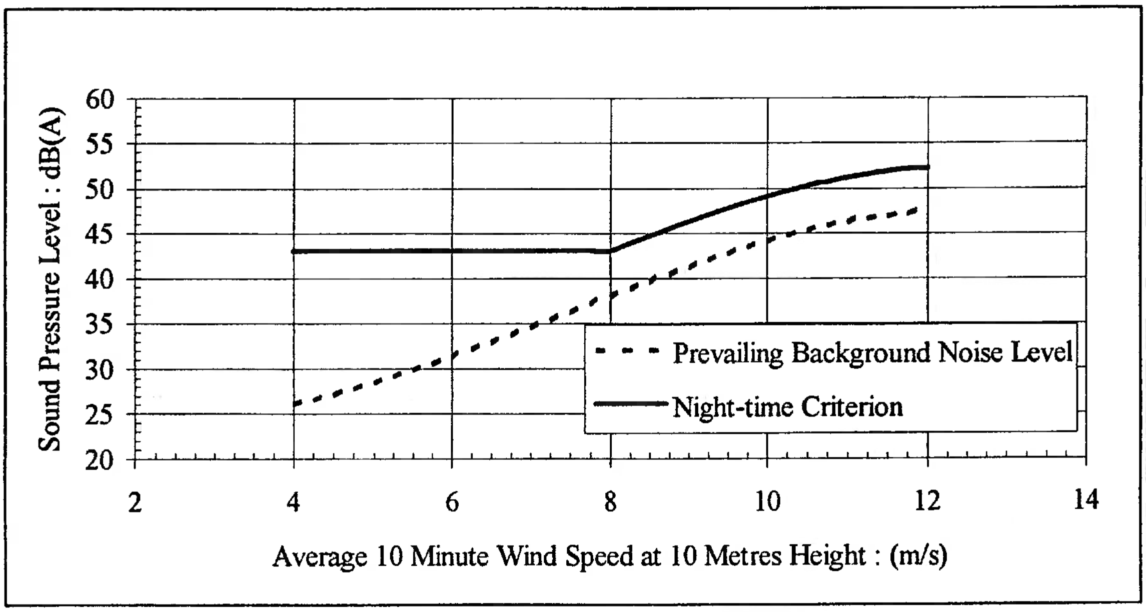


Figure 9 Example of night-time noise criterion

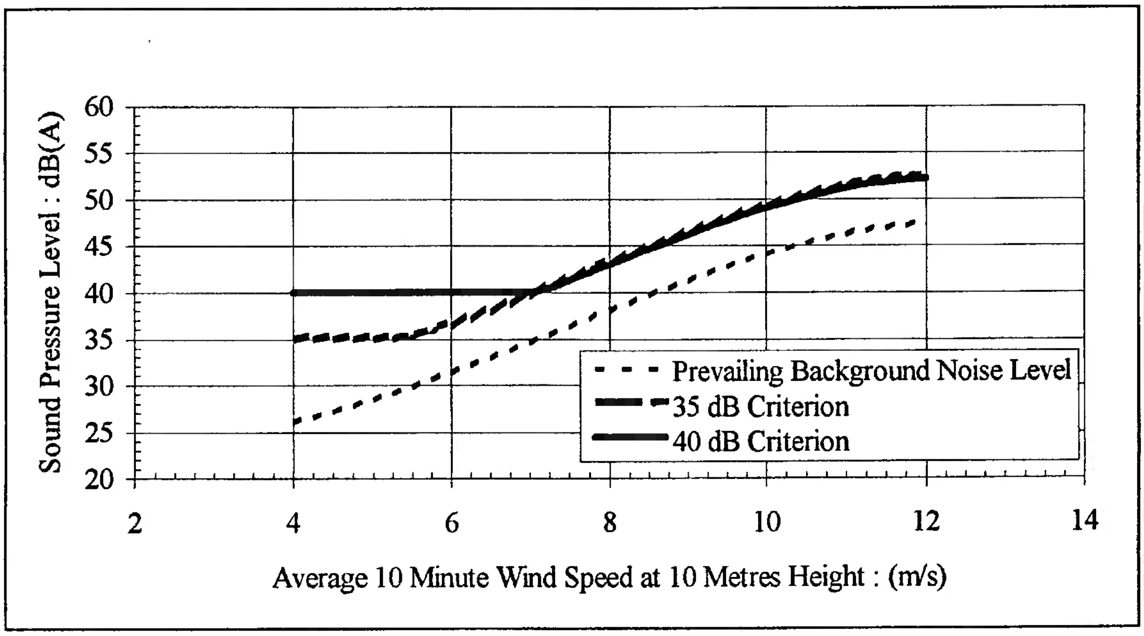


Figure 10 Examples of day-time noise criteria

Penalties for the character of the noise

We have decided that, as far as possible, the limits suggested here for wind turbine noise should account for the particular character of the noise received. This is the approach adopted by BS 4142 in which the rating level of the noise source includes the addition of any adjustment necessary for the character of the noise [2]. We have considered the two main elements that can add to the character of wind turbine noise: blade swish and tones.

Blade swish

Blade swish, the amplitude modulation at blade passing frequency of the aerodynamic noise caused by the passage of the blades through the air, has been fully described in Chapter 3.

The modulation or rhythmic swish emitted by wind turbines has been considered by some to have a characteristic that is irregular enough to attract attention. The level and depth of modulation of the blade noise is, to a degree, turbine-dependent and is dependent upon the position of the observer. Some wind turbines emit a greater level of modulation of the blade noise than others. Therefore, although some wind turbines might be considered to have a character that may attract one's attention, others have noise characteristics which are considerably less intrusive and unlikely to attract one's attention and be subject to any penalty.

This modulation of blade noise may result in a variation of the overall A-weighted noise level by as much as 3dB(A) (peak to trough) when measured close to a wind turbine. As distance from the wind turbine/wind farm increases, this depth of modulation would be expected to decrease as atmospheric absorption attenuates the high frequency energy radiated by the blade. However, it has been found that positions close to reflective surfaces may result in an increase in the modulation depth perceived at a receiver position remote from a site. If there are more than two hard, reflective surfaces, then the increase in modulation depth may be as much as ± 6dB(A) (peak to trough).

The selection of the measurement position can also result in particular frequencies exhibiting a greater depth of modulation due to standing wave effects from reflected waves off the surrounding structures. These effects are very specific to the positions at which measurements are undertaken and are more the result of building layouts at the receiver position than a change in the character of the emitted wind turbine noise.

It is the opinion of the Noise Working Group that there is insufficient data available at this time to formulate an accurate measurement methodology for blade swish where it occurs. It is envisaged that further research will be required to enable proper measurement and assessment to be devised, if in the future this is felt to be necessary. Work is already under way aimed at establishing the causes of blade swish, the frequency and magnitude of its occurrence and developing an appropriate metric for its measurement.

The noise levels recommended in this report take into account the character of noise described in Chapter 3 as blade swish. Given that all wind turbines exhibit blade swish to a certain extent we feel this is a more common-sense approach given the current level of knowledge. Debates at public inquiries on whether a literal interpretation of clause 7.2 of BS 4142:1990 would include blade swish have in general been unhelpful.

Method of tonal assessment

Introduction

It has been our experience, confirmed by the survey reported in Chapter 5, that where complaints have been made over noise from existing wind farms the tonal character of the noise has been the feature that has caused greatest annoyance. This finding corresponds with the results of a survey of EHOs and noise consultants undertaken by NPL on complaints about industrial noise sources [26] which indicated that a significant number of noise complaints are caused by the tonal character of the noise. In order to reflect the increased potential for annoyance caused by noise containing a tonal component we therefore feel it appropriate that tonal noise should be penalised. This penalty should be imposed in a similar manner to that described in BS 4142 ie the noise level of the source is described as a rated level, that is the sum of the overall level and any penalty due to a tonal content.

Review of options

Broadly speaking, there are three methods by which a noise can be assessed as to whether a tonal penalty is appropriate: subjective methods, 1/3 octave methods and narrow band methods. The relative merits of each are reviewed below.

Subjective methods

The method for rating a noise source that is contained within BS 4142 requires that the noise is assessed by the subjective judgement of a listener. The perceived level of the tonal noise will however be dependent upon the attitude of the listener towards the noise source and the sensitivity of the individual to tonal noise. What may therefore be acceptable to one person may not be acceptable to another. Another drawback with this method is that in order to obtain a warranty for a wind turbine from a manufacturer that includes a criterion for tonal emission, an objective measurement procedure must be agreed. This warranty will provide little comfort unless tonal emissions from the wind farm are assessed in a similar manner. The absence of any standard method within the UK has caused problems when agreeing noise conditions. To reduce these potential areas of conflict it is proposed that an objective test be undertaken of the incident noise that assesses the audibility of any tonal noise emissions and provides a rating for the noise.

Methods based on 1/3 octave bands

BS 7445 [16] (ISO 1996, DIN 45 465) indicates that a prominent tone may be identified when the level difference between contiguous third octaves is greater than 5dB. This definition of prominent tone is satisfactory when the frequency of interest is above 500Hz. However, at frequencies below 500Hz the criterion is too severe. It is possible that at low frequencies, this assessment method may result in a tone being measured objectively when none is audible. This effect has been allowed for within the third octave criteria that have been developed by Kern County in the USA, see Appendix B. Furthermore the method is unsuited to the detection of tones that are only just detectable by the observer and would prove difficult to implement for the sometimes complex spectrum shapes associated with wind turbine noise.

Narrow band analysis

The principles of three, narrow band, tonal assessment methods, BS 7135 [17], the Joint Nordic Method [21]and the draft DIN 45 681 [22], have been described in Chapter 4. This Section reviews the strengths and weaknesses of the methods available so that recommendations leading to a reliable method of assessment can be made.

All three methods are based upon the concept of Zwicker critical bands. The methods compare the sound pressure level of the tone to the sound pressure level of the broadband masking noise with a range of frequency either side of the tone, the critical band width. The audibility of a tone is determined according to the difference between the tone level and the masking level, often referred to as the tone level difference. The main differences between the methods are in the precise specification of the critical band width, audibility criteria and the measures taken, if any, for non-stationary tones (tones whose amplitude varies with time).

The Joint Nordic Method simplifies the derivation of the critical band bandwidths, ie the critical bandwidth for a tone below 500Hz is 100Hz and above 500Hz is 0.2 × the tone frequency. BS 7135 and DIN 45 681 use the mathematical formula obtained by Zwicker. The width of the critical band, Δf_c, centred at any frequency, f, is given by the following equation:

$$\Delta f_c = 25 + 75 \times [\ 1 + 1.4 \times (\ f / 1000\ )^2\ ]^{0.69}$$

(eg Δf_c = 162.2Hz at f = 1000Hz)

This results in a small, frequency-dependent difference between the Joint Nordic Method and the other two methods in the calculated critical band masking level. Fig 11 details the level difference between each critical band assuming a flat spectrum. It may be seen that predicted difference will be less than 1dB until a frequency of over 1.0kHz is reached, although a peak of 0.69dB occurs at a frequency of 500Hz. The graph shows that the Joint Nordic Method would underestimate the masking level around a tone of 500Hz by 0.69dB.

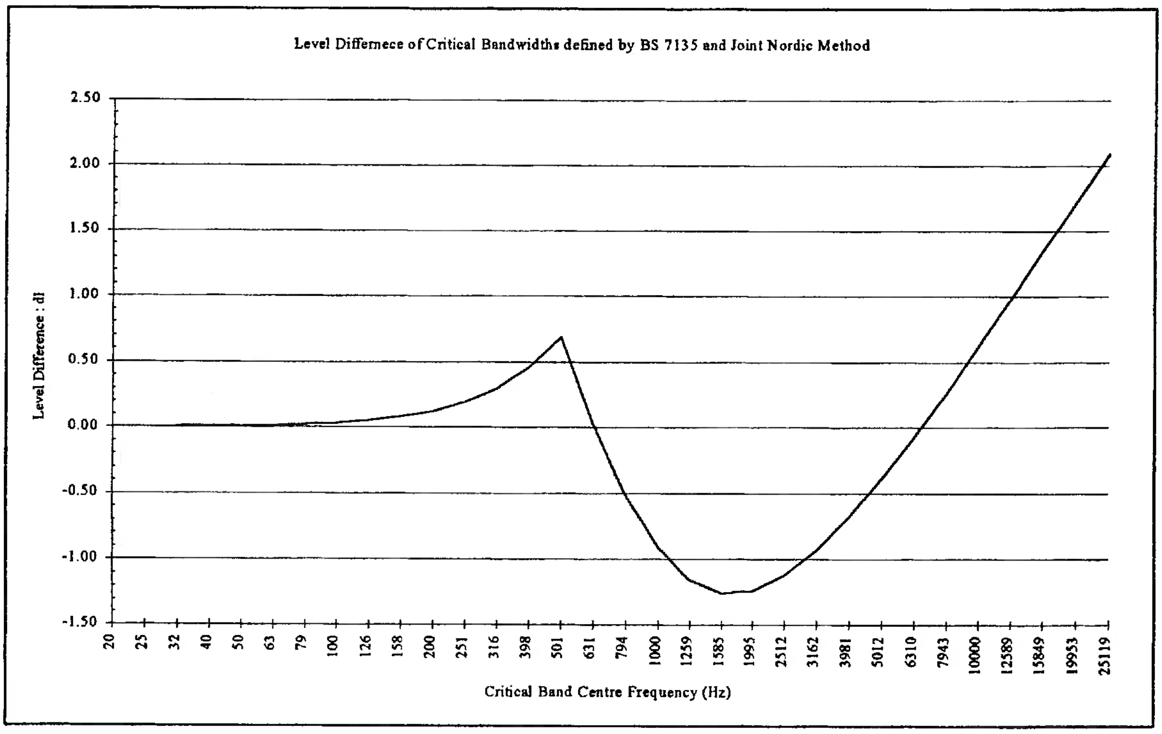


Figure 11 Level difference of critical bandwidths defined by BS 7135 and the Joint Nordic Method

Differences also exist in audibility criteria. Fig 12 details the difference between the audibility criteria defined within the Joint Nordic Method, BS 7135 and DIN 45 681. It can be seen that at relatively low frequencies, commonly of interest when assessing tonal noise from wind turbines, the audibility threshold for DIN 45 681 is up to 4dB lower than the Joint Nordic Method. The Joint Nordic Method uses the frequency-dependent audibility curve suggested by Zwicker whereas the other two methods adopt a simplified approach, assuming the tone level difference necessary for audibility is constant across the frequency range. The following extract from the draft DIN 45 681 illustrates the thinking behind this approach.

"At low frequencies the level difference L_G - L_T (L_G = masking level, L_T = tone level) *at the audibility threshold is 2dB. This rises continuously to 6dB at high frequencies. On average then, a sinusoidal tone in a masking noise is just perceptible (midrange audibility threshold) when L_G - L_T = 4dB. This is the value set by the tone content criterion ISO 7779: 1988, section D.4.1* (and BS 7135).

The mid-range hearing threshold is defined such that in repeated hearing tests a group of people with normal hearing will perceive the tone in 50% of cases. The tone content criterion introduced by this standard (a noise has tone content when L_G - L_T = 6dB, see section 2.) is more stringent at midrange and low frequencies in that about 20 to 30% of people will hear the tone."

At low frequencies the differences between the two approaches to audibility is reduced because the Joint Nordic Method applies a "Hanning correction" to the measured level of the masking noise. This is designed to correct for the effective analysis bandwidth of the frequency analyser being wider than the frequency resolution. With the commonly applied

Hanning window, the analysis bandwidth is 1.5 times the resolution resulting in a correction or reduction in the measured level of 10log1.5dB or 1.8dB. This means that a tone of given magnitude would appear to have a level difference 1.8dB greater when analysed using the Joint Nordic Method than it would have if assessed using BS 7135 or DIN 45 681.

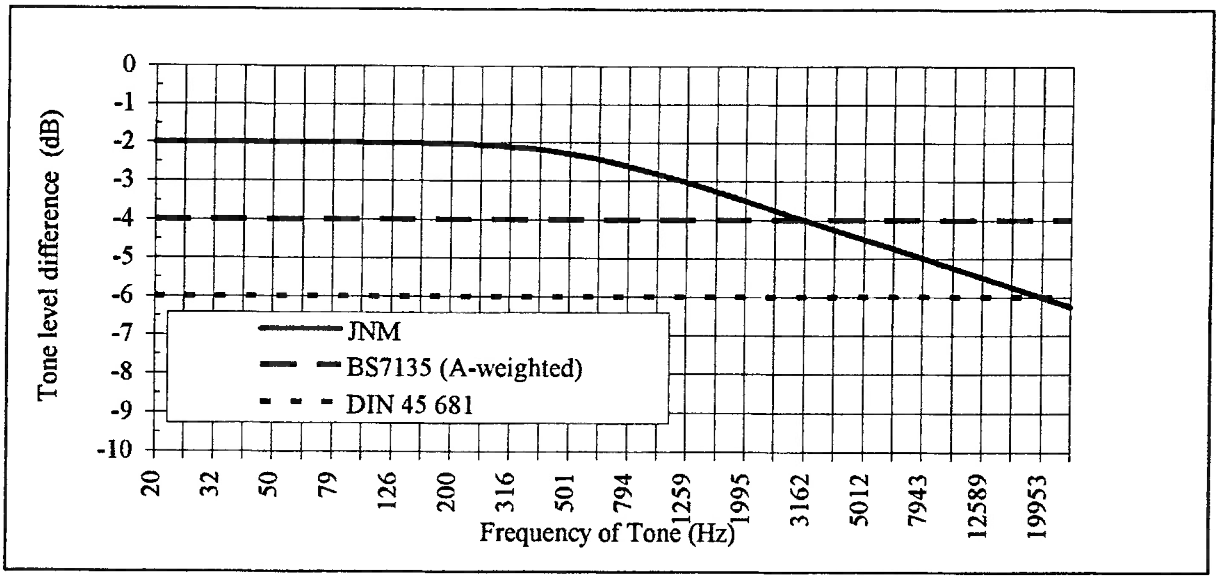


Figure 12 Difference in audibility criteria as defined by the Joint Nordic Method, BS 7135 and DIN 45 681.

The situation is further complicated by the recommendation within BS 7135 that if the measurements are performed using a linear weighting instead of an A-weighting the threshold of audibility should be reduced so that a tone is deemed audible when it is 6dB below the masking level in the critical band, the same level as in the DIN standard. This suggestion for change in audibility criteria with frequency weighting is difficult to understand as the tone is compared to masking noise of similar frequency to itself and differences will be second order, resulting from the slope in the A-weighting curve. It has been demonstrated [27] that, for wind turbine noise, choice of frequency weighting has no systematic effect on the magnitude of the tone level difference.

Tones from wind turbines can be classed as non-stationary; that is, the level of a tone, and hence its audibility, can fluctuate by several dB over the course of a few seconds [28]. These fluctuations arise from variations in source level and short-term propagation effects over distances of a few hundred metres. The Joint Nordic Method is the only one of the three which attempts to deal with non-stationary tones by suggesting that the highest level of the tone is found by averaging the five highest tone levels from a number of individual spectra. It has been shown [28] that, for wind turbine noise measured at near-residence type locations, averaging the 10% highest tone levels will result in the measured tone level being typically 3-4dB higher than if it had been derived from the rms level of the tone in accordance with DIN 45 681 or BS 7135.

It can be seen from the above discussion that even the use of objective, narrow band methods of tonal analysis can lead to widely differing assessments of audibility because of differences in the specification of critical band widths and audibility curves and in the treatment of Hanning correction, frequency weighting and non-stationary tones. The Noise Working Group has decided that the method proposed here will be based upon the Joint Nordic Method because of the more accurate, frequency-dependent audibility curve and in the interests of maintaining consistency, where possible, with other recommended practices.

The Joint Nordic Method is the tonal assessment method that is proposed for the assessment of the character of the noise within Nordic countries and has been adopted by the IEA as the basis for tonal assessment in their series of Recommended Practices [11]. It has also been adopted by Danish wind turbine manufacturers as a standard against which they will test and warrant their wind turbines. The tonal assessment method within the current draft of IEC/TC 88 Part 10 [29], dealing with acoustic measurement techniques of wind turbines, is also based upon the Joint Nordic Method. This method, therefore, currently seems to be the method by which most wind turbine manufacturers within the world market will be assessing the tonality of their wind turbines.

Description of Recommended Method

The recommended method is based upon the Joint Nordic Method for non-stationary tones with some embellishments in areas where it is not entirely prescriptive such as tone identification and averaging periods. The method aims to assess the audibility of a tone as perceived by the average listener. There are three main steps in the procedure:

A) Frequency analysis of the noise at receiver locations.

B) Determination of the sound pressure level of the tone(s) and the sound pressure level of the masking noise within the critical band.

C) Evaluation of the difference between the tone and the masking noise sound pressure levels (ΔL_{tm}) by comparison with a criterion curve to determine the audibility of a tone.

A. Frequency analysis

The analysis of non-stationary tones is quite intensive; it will therefore be convenient to record the signal to be analysed on to tape. For each tonal assessment 2-minutes of uninterrupted clean A-weighted recording is required.

A 2-minute, rms-averaged FFT is performed on the sampled data using a Hanning window, a frequency resolution of 3.0 ± 0.5Hz and an analysis bandwidth of 2kHz. It may be necessary to inspect a similar spectrum with greater bandwidth to ensure that there are no tones present at higher frequencies.

The short term, individual rms-averaged FFTs within the sampled data are also calculated using the same parameters as described above. This results in an averaging time of 0.29 to 0.4 seconds.

B. Determination of sound pressure levels

The bandwidth of a critical bands is:

Centre Frequency f_c, Hz	20-500	Above 500
Bandwidth	100Hz	20% of f_c

If a single tone is present the critical band is centred upon the tone. If two or more, closely spaced tones are present, the critical band is placed so that it contains the maximum possible amount of tonal energy. In order to do this it is first necessary to identify the tones within the spectrum. To do this each line in the 2-minute spectrum must be classified according to the following criteria based upon the draft DIN 45 681. A peak is classed as a tone if its level is more than 6dB above the logarithmic average of the sound pressure levels of the rest of the lines in the critical band centred on the peak, but excluding the one line each side of the peak. If the peak qualifies as tone the adjacent lines are also classified as a tone if their level is within 10dB of the peak and greater than 6dB above the average level previously calculated. If a spectral line is more than 6dB above the average masking level and more than 10dB below the peak level it is classified as neither tone nor masking. Having identified the tones the critical band can be placed to maximise the sound pressure level of the tones within the critical band.

Because classifying a line as a tone means it can no longer be counted as masking, an iterative procedure is required for the proper identification of tones and masking. This is described by reference to the worked example below.

Fig 13 shows the stages in the tone identification and classification process. These are:

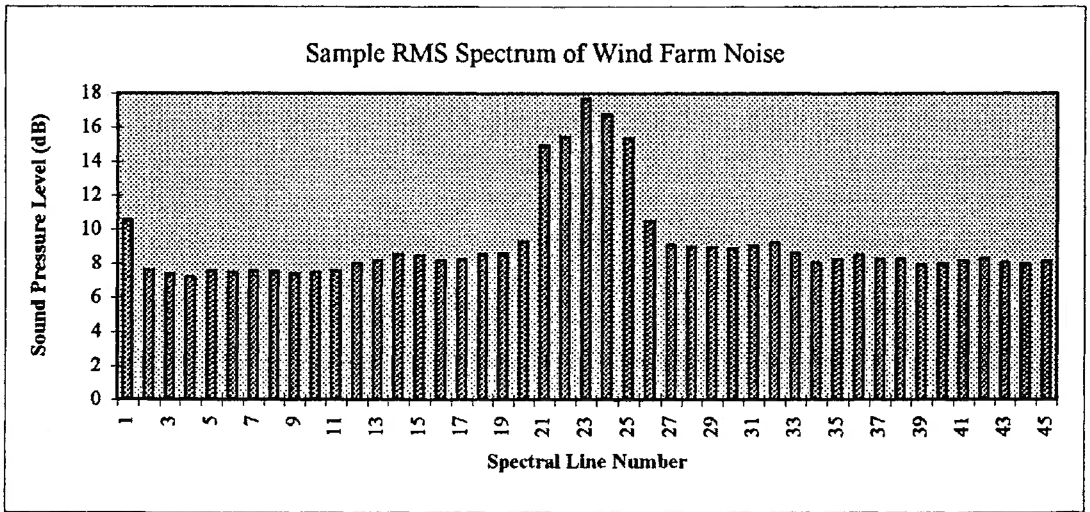
- Find peaks in the spectrum, in this case line 23.
- Calculate the average energy in the critical band centred on each peak, not including the two lines adjacent to the peak (9.10dB).
- If the peak is more than 6dB above the average masking level then it is a tone, therefore line 23 is a tone.
- Classify adjacent spectral lines:

  Pass 1
  - Compare spectral lines above and below the peak to the average level.
  - If a line is more than 6dB above the average and less than 10dB below the peak then it is a tone, therefore lines 22, 24 and 25 are tones.

  Pass 2
  - Calculate new average masking level centred around the peak, discounting adjacent spectral lines and all other lines classed as tones (8.75dB).
  - Compare spectral lines above and below the peak to the average level.

- If a line is more than 6dB above the average and less than 10dB below the peak then it is a tone, therefore lines 21, 22, 24 and 25 are tones.

Pass 3
- Calculate new average masking level centred around the peak, discounting adjacent spectral lines and all other lines classed as tones (8.39dB).
- Compare spectral lines above and below the peak to the average level.
- If a line is more than 6dB above the average and less than 10dB below the peak then it is a tone. Therefore lines 21, 22, 24 and 25 are tones, but no spectral lines have been reclassified in this pass so the iterative process is complete.



Tone Identification and Classification						
Peak line = 23	**Peak Level = 17.71dB**					
	Pass 1		**Pass 2**		**Pass 3**	
Average about peak	9.10		8.75		8.39	
Adjacent line assessment	**Level above average**	**Classif-ication**	**Level above average**	**Classif-ication**	**Level above average**	**Classif-ication**
Line number						
19	-0.49	masking	-0.14	masking	0.22	masking
20	0.20	masking	0.55	masking	0.91	masking
21	5.83	masking	6.18	tone	6.54	tone
22	6.34	tone	6.69	tone	7.05	tone
24	7.64	tone	7.99	tone	8.35	tone
25	6.26	tone	6.61	tone	6.97	tone
26	1.40	masking	1.75	masking	2.11	masking
27	-0.01	masking	0.34	masking	0.70	masking

Figure 13 Tone identification and classification process

If a spectral line is more than 6dB above the average masking level and more than 10dB below the peak level then it is classified as neither tone nor masking, and not included in the calculation for either level.

The process described above is repeated for every critical band centred around tonal peaks in the spectrum. The result is that within each critical band every spectral line is classified as tone energy, masking energy or neither.

Having identified the lines in each spectrum contributing to tonal levels, masking levels or neither, the tonal analysis can continue as follows:

- The masking energy within the critical band is calculated from the 2-minute rms spectrum. Calculate the masking level in the critical band, L_{pm}, correcting for a reduction in the number of lines due to the exclusion of tones and for the Hanning window.

  $$L_{pm} = 10\log\sum 10^{L_m/10} + 10\log\frac{\text{critical band width}}{(N_m \times \Delta f)} + 10\log(1/1.5)$$

  where L_m = sound pressure level of each line containing masking noise
  N_m = number of lines within the critical band containing masking noise.
  $\sum$ = sum of

- For each of the short term spectra of 0.29 to 0.4 seconds duration, calculate the tone energy within each critical band, L_{pt}', using the lines identified as tones from the 2-minute spectrum.

  $$L_{pt}' = 10\log\sum 10^{L_t/10}$$

  where L_t is the sound pressure level of each line containing tonal noise.

  The Joint Nordic Method for non-stationary tones calculates tone level as the mean of the top 5 levels from a "number of analysis" (at least 50 short term spectra as interpreted by the IEA Recommended Practice). As the result obtained using 5 out of 50 would obviously be different to that using 5 out of 500, the method proposed here is more specific. The tone level used in the assessment, L_{pt}, is the arithmetic mean of the top 10% of tone levels, L_{pt}', from all the short-term spectra constituting the 2 minutes of data.

C. Evaluation of the audibility of the tone(s)

The audibility of a tone is dependent upon the tone level difference, ΔL_{tm}, and the frequency of the tone:

$$\Delta L_{tm} = L_{pt} - L_{pm}$$

The audibility criterion is defined as follows:

$$\Delta L_{tm,crit} = -2 - \text{Log}\left(1 + (f/502)^{2.5}\right)$$

where f = frequency at the centre of the critical band.

This is the level at which the average listener will be just able to hear the tone. Fig 14 details the audibility criterion based upon the above equation. It can be seen from the figure that the audibility criterion is related to the frequency of the tone.

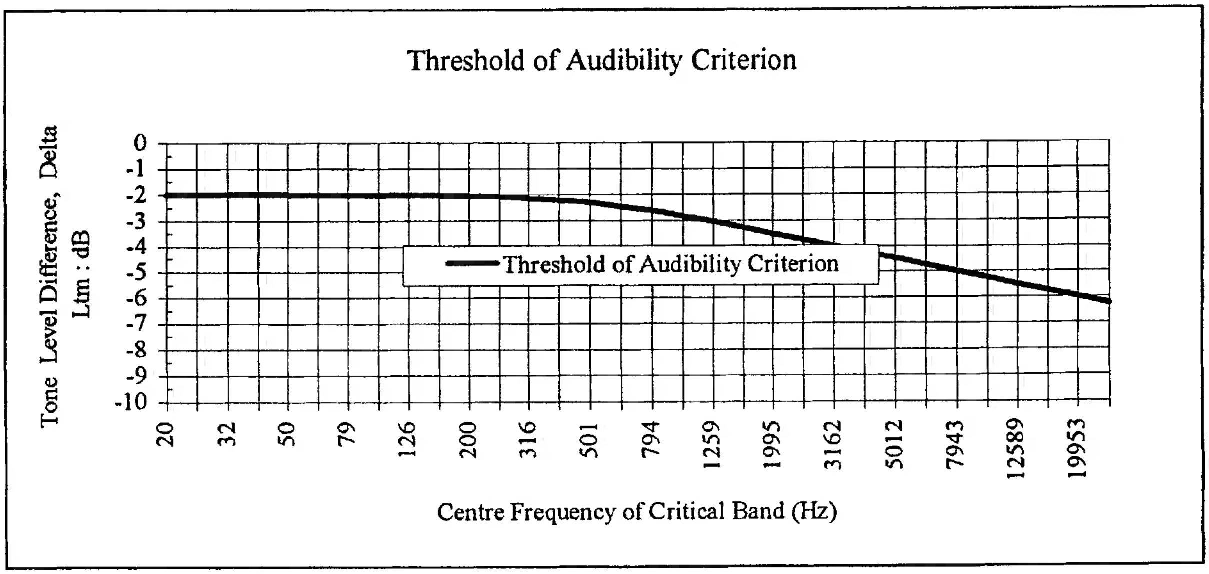


Figure 14 The audibility criterion for tonal noise assessment

It is recognised that this method for assessing the audibility of a tone is somewhat complex and may prove difficult for some to perform. It is nevertheless a rigorous implementation of the widely accepted Joint Nordic Method. It would be helpful to be able to simplify the method without undue loss of reliability so it can be more easily applied. One possibility is to replace the assessment of the tonal pressure from the top 10% of the short term spectra with a level derived from the 2-minute rms spectra. This would however require the adjustment of the audibility criterion to account for the reduced tonal levels which would result from such a change. Further work would be required to calibrate a new audibility criterion with the average listener's response.

Penalties for tonal noise

No standard, objective method is currently available within the UK for the assignment of penalties to noise containing tonal components. BS 4142 allows for a subjective assessment to determine whether a 5dB penalty should be added (see Chapter 4). The DOE has initiated studies on tonal penalties and rating systems but this work is not expected to be included within any revised version of BS 4142 for a number of years. Therefore, the penalty system proposed derives from existing standards and guidance, recent research on the subjective response to tones from wind farms and the experiences of members of the Noise Working Group.

Comparison of existing standards

The tonal penalties imposed by the Joint Nordic Method (JNM), draft Din 45 681 and BS 7445 are considered below.

The Joint Nordic Method proposes that a 5dB penalty be applied when the tone is considered prominent; prominence is defined as being 6.5dB above audibility. The method proposed by the Noise Working Group is based upon the Joint Nordic Method for variable tones.

Draft DIN 45 681 proposes that a sliding scale of penalties ranging from 0-6dB be used which is related to the level of a tone above the audibility criterion. When applying these penalties to the method proposed by the Noise Working Group three differences between the Noise Working Group method and the DIN standard have to be borne in mind:

1. The audibility criterion is different for the two methods (see Fig 12). For tones of less than 800Hz, ie those most commonly identified in wind turbine spectra, the tone level difference required for audibility is 3-4dB lower for the DIN standard than for the JNM. This implies that tones will be identified as audible at lower levels using the DIN standard.

2. Conversely, the method proposed here is based upon an average of the highest 10% of short-term spectra rather than on rms spectra which results in higher tone levels being identified using this method. Studies have shown this difference to be on average 3.6dB, with a range of 2.2-4.4dB [28].

3. The method proposed here, being based upon the JNM, applies a Hanning correction (reduction) of 1.8dB to the broadband masking noise thus increasing the tone level difference by 1.8dB when compared to the DIN standard.

The net result of these differences is that a tone measured using this method and equal in level difference to the audibility criterion of the JNM would be ranked between zero and 3.2dB below audibility using the draft DIN standard, typically -2dB below audibility. Or put the other way round, a tone identified as being on the threshold of audibility using the DIN standard would be ranked as 2dB above audibility using this method. The penalties specified in the draft DIN 45 681 and how they transpose to the audibility criterion of the Noise Working Group's implementation of the JNM are shown in Table 9.

BS 7445 also describes a progressive approach to tonal penalties differentiating between tones that are "just detectable" and "clearly audible".

> *"In some practical cases, a prominent tonal component may be detected in 1/3 octave spectra if the level of a 1/3 octave band exceeds the level of adjacent bands by 5dB or more, but a narrow band frequency analysis may be required in order to detect precisely the occurrence of one or more tonal components in a noise signal. If tonal components are clearly audible and their presence can be detected by a 1/3 octave analysis, the adjustment may be 5 or 6dB. If the components are only just detectable by the observer and demonstrated by narrow band analysis, an adjustment of 2 to 3dB may be appropriate."*

Table 9 Comparison of DIN 45 681 with the Joint Nordic Method

Tone Level above Audibility, ΔL (dB), using DIN 45681	Equivalent Tone Level above Audibility, ΔL (dB), using this Implementation of the JNM for Variable Tones	Tone Penalty, dB, from DIN 45681
$0 \geq \Delta L$	$2 \geq \Delta L$	0
$0 < \Delta L \leq 2$	$2 < \Delta L \leq 4$	1
$2 < \Delta L \leq 4$	$4 < \Delta L \leq 6$	2
$4 < \Delta L \leq 6$	$6 < \Delta L \leq 8$	3
$6 < \Delta L \leq 8$	$8 < \Delta L \leq 10$	4
$8 < \Delta L \leq 10$	$10 < \Delta L \leq 12$	5
$L > 10$	$L > 12$	6

Pedersen [30] has computed the equivalent narrow band tone level difference for a tone responsible for a 5dB increase in a 1/3 octave band level. The tone level differences are calculated using the critical band widths of the JNM but do not include any correction for use of the Hanning window. In order to enable a comparison with the JNM for variable tones to bemade, a further adjustment of 3.6dB is required because of the difference in peak and rms levels as for the DIN standard above. The results are frequency-dependent and summarised in Table 10.

Table 10 Comparison of a 1/3 octave based criterion to the JNM audibility criterion

Tone Frequency Hz	Equivalent Tone Level Difference of 5dB 1/3 Octave Tone	Tone Level Difference after Correction (+1.8+3.6)	JNM Audibility Criterion	Equivalent Margin above Audibility for 5dB Penalty.
50	-6	-0.6	-2.0	1.4
100	-3	2.4	-2.0	4.4
200	0	5.4	-2.0	7.4
400	3	8.4	-2.2	10.6
500	4	9.4	-2.3	11.7
800	4	9.4	-2.6	12.0
1000	4	9.4	-2.8	12.2
2000	4	9.4	-3.5	12.9

It can be seen that the results are strongly frequency-dependent, but for the frequency range of interest (100-800Hz) the application of the 5-6dB penalty for a clearly audible tone would be incurred at levels above audibility of 4.4-12dB when using the JNM for variable tones. Given the above it is unclear at what levels the 2-3dB penalty would be incurred but one could interpret "just detectable by the observer" as any audible tone.

A graphical comparison of the three penalty systems is shown in Fig 15. The BS7445 penalties for "just detectable" and "clearly audible" have been set in the middle of the range suggested, ie 2.5dB and 5.5dB respectively, and have been plotted for 100Hz and 800Hz tones to represent the frequency range most commonly encountered.

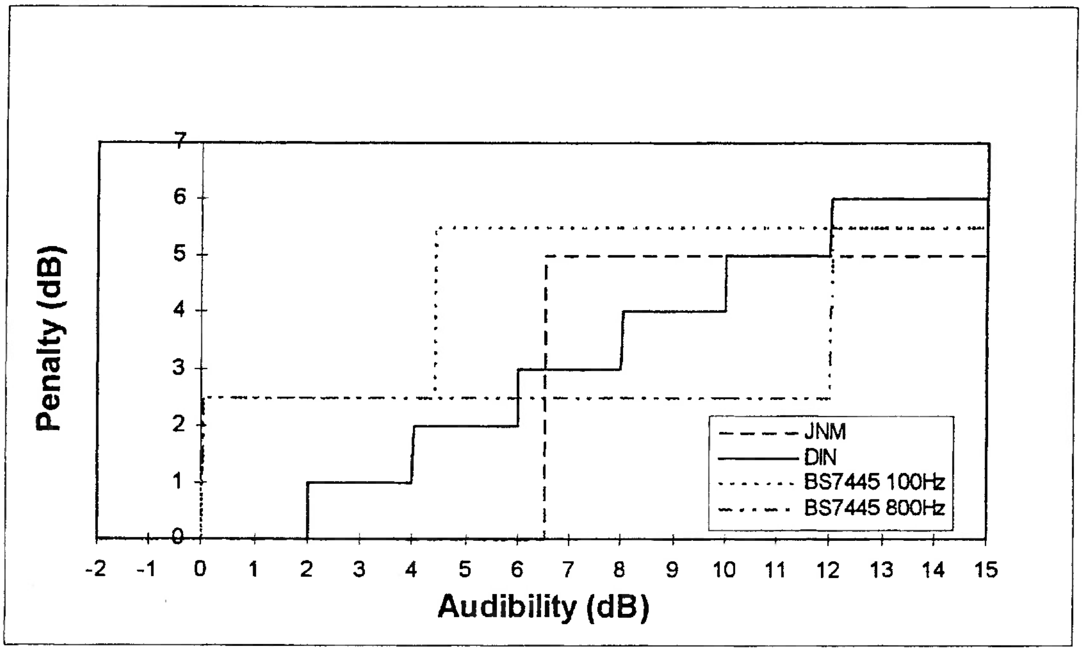


Figure 15 Comparison of tonal penalties from various standards

Recommended levels of tonal penalties

The members of the Noise Working Group agreed on the penalty system depicted in Fig 16 based upon their review of existing standards and guidance, recent research on the subjective response to tones from wind farms from listening tests [27] and their experiences in the field.

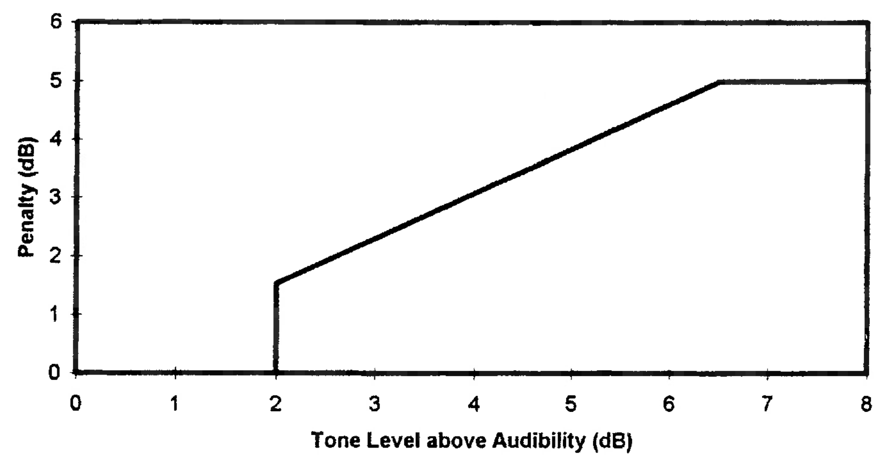


Figure 16 Penalties for tonal noise

At levels of audibility above 6.5dB a 5dB penalty is incurred. Between audibility levels of 2dB and 6.5dB a sliding scale of penalties is introduced varying linearly from 1.54dB to 5dB. Extrapolation of this linear relationship passes through the origin. No penalties are incurred at audibility levels below 2dB.

A penalty of 5dB at 6.5dB above audibility is suggested because:

- it is consistent with the Joint Nordic Method upon which the Noise Working Group method is based and is broadly in line with the advice for prominent tones in BS 7445

- the results from the listening tests demonstrated that at audibility levels at and above 6dB more than 95% of listeners describe the tone as audible and around 50% find the tone to be prominent

A sliding scale of penalties is preferred for audibilities between 2dB and 6.5dB because:

- intuition suggests that annoyance gradually increases with margin above audibility

- it prevents large differences in tonal penalty being affected by small differences in the measured level of audibility

- it enables local authorities to exert downward pressure on tonal levels from turbines which do not represent best practice

- it penalises tones which the subjective tests indicate a large proportion of the population will be able to hear

- below levels of audibility of 2-4dB the results from the listening tests indicate that the measured level of audibility does not correlate well with the subjective response, be it percentage of subjects describing the tone as audible or equal annoyance level; the Noise Working Group was agreed that a significant penalty should be introduced at 2dB above audibility; a convenient method for constructing such a penalty system which increases progressively up to 5dB at 6.5dB above audibility was a straight line passing through the origin but with no penalties incurred below 2dB of audibility.

- it is the view of the Noise Working Group, based upon a comparison of their experiences of tonal levels from a variety of wind farms against measured levels for those wind farms, that tonal penalties are not appropriate at levels measured below 2dB.

It is important to note that although this assessment procedure and associated penalties have been derived and tested [27, 28] using the best information currently available they have not yet been proven in the field. For example, little is known about the medium to long term variation in tonal levels from wind turbines and, if such variations do occur, which levels are most appropriate for assessment purposes. It is the belief of the Noise Working Group that the best of the turbines currently available are without tonal noise problems and would not warrant any penalty; it is intended that this assessment procedure reflects that evaluation.

Complex tones containing harmonic components

A wind turbine may emit a complex tone comprising a series of harmonics (partials) at integral multiples of some fundamental frequency. Although several peaks may occur in a narrow band spectrum of such noise, the tone complex is usually perceived as having a single pitch. For the purposes of this specification, when an audible discrete tone comprises two or more harmonic components, only that component with the greatest audibility need be evaluated unless two or more harmonics lie within the same critical band.

Variable speed machines

If a variable speed wind turbine were to be assessed using this technique and the wind turbine were to emit tonal noise, the variation in rotation speed would result in a variation of the tone frequency. Over a two-minute period it would be expected that the tone would affect the masking band level centred around the tone such that the masking band level would be considered higher than the actual level when measured instantaneously.

Additional problems will also occur with variable frequency tones, as the tone frequency during the analysis will not be the same throughout the assessment period. Therefore, the average maximum level for an individual tone will not necessarily be easily determined.

It is possible these difficulties could be overcome if tonal measurements were performed close to one machine and the measurements were of short duration. Further experience in this area is needed before more precise advice can be given.

7. NOISE MONITORING

Introduction

During the planning stage of a wind farm, discussions are likely to have been held with the local Environmental Health Officer with respect to agreeing acceptable levels of noise from the proposed site. The performance of a background noise survey around the site will help identify the dwellings that are the most sensitive with respect to noise and the wind speeds at which the greatest noise impact from the development will occur.

The prevailing background noise level at sensitive dwellings will need to be agreed with the local EHO so that noise limits at different turbine operating wind speeds can be set. Predictions are then undertaken and changes made to the proposed wind turbine layout, where necessary, to ensure that the noise limits that have been set can be achieved.

These noise limits may then form the basis of any conditions that are imposed by the local district council and agreed by the developer. Testing of these conditions is required to ensure compliance in the event of any complaints arising over noise from the wind turbines. Therefore, a method for undertaking this compliance test is required that eliminates errors due to noise not associated with the wind farm and which relates the operating condition of the wind farm to the noise levels incident at a dwelling.

Monitoring will be complaint-driven as developer access to properties cannot be guaranteed. A condition requiring periodic monitoring at residences in the absence of complaints would be unenforceable and therefore fail the test of a planning condition.

Monitoring locations

Nearest properties

Monitoring should be undertaken at the locations to which the noise limits apply, ie the noise-sensitive properties around the wind farm from which complaints have been received.

Microphone height and position

The microphone should be tripod mounted at a height of 1.2-1.5m above ground level in accordance with the requirements of BS 4142. A height of 1.2m is most commonly used as the microphone is then that little more out of the wind, less likely to be shaken or blown over and 1.2m is generally a more convenient working height.

The measurement position should be selected to minimise the effects of reflections from buildings because the noise limits recommended refer to free-field measurements for the reasons given in Chapter 6. Measurements performed in the field around existing wind farms indicate that reflection effects from buildings are minimised when measurement positions are at least 10 metres from a building facade. This compares with the guidance given in the USA where measurements are performed at a distance of 50' (15.24m) from the sensitive property. However, it should be borne in mind that areas within gardens such as patios may be used by an occupier more often that other areas of their garden. Such seating areas may be positioned close to buildings for protection from the wind. Dwellings may also have small gardens. In this event, it may not be possible to undertake measurements that are free of reflections from buildings. This should be considered during any initial assessment of the wind farm site by the developer.

In order to ensure that measurements of wind turbine noise are not influenced by reflections off buildings the microphone should be positioned at least 10m away from the facade. It may be appropriate to undertake background noise measurements closer than this if sheltered locations close to the property are most often used for rest and relaxation. Background noise measurements should not be taken closer than 3.5m from the facade. In circumstances where these conditions cannot be fulfilled an alternative location should be identified at which the measurements of free-field turbine noise can be expected to be the same as at the property in question, or can be readily corrected by an agreed method, and with some confidence, to levels at the property.

Equipment

Wind shields

Even using the $L_{A90,10min}$ noise descriptor there is a risk that measured noise levels can become contaminated by the effect of wind noise on the microphone when using the wind shields available commercially. Studies are currently being undertaken to evaluate the constraints on existing measurement systems with a view to offering suggestions for improved windshield design [31].

Certification and calibration

As specified in Sections 3 and 4 of BS 4142: 1990.

Background noise survey

The limits proposed are set in relation to the existing background noise level at wind speeds up to 12m/s measured on the wind farm site at 10m elevation. It is therefore necessary that background noise measurements should be correlated with wind speed measurements performed at the proposed site, such that the actual operating noise levels from the turbines may be compared with the noise levels that would otherwise be experienced at a dwelling.

Survey Period

Background noise measurements should be undertaken over a sufficient period of time to allow a reliable assessment of the prevailing background noise levels to be performed. Variations in the background noise levels due to wind effects may result in changes of ± 5dB(A) during a period of 1 minute, a medium term variation in level. Long-term variation of the background level may be caused by a change in wind direction. Background noise levels will also change according to the amount of rain that may have fallen during the preceding days; levels in deep valleys in Mid-Wales have been found to vary by as much as 25dB L_{A90}. The time of year that measurements are performed may also have an effect. Summer months may be expected to give higher ambient noise levels due to leaves on trees but lower levels due to reduced rainfall. Winter months may result in lower ambient noise levels due to no leaves on trees but higher level due to more rain. Conversely, the increased wind resistance of trees and shrubs in Summer can increase the level of shelter at the property such that lower wind speeds and hence noise levels are experienced for a given wind speed at the wind farm. Periods of external amenity vary in time of year from site to site and this should be considered when planning background noise surveys.

It is expected that to avoid the results being weighted by unrepresentative conditions at least 1 week's worth of measurements will be required. The actual duration will depend upon the weather conditions, in particular the strength and direction of the wind that has blown during the survey period and the amount of rain.

Measurements should not be used from periods of heavy rainfall when noise levels will be high due to the noise of the rain itself, and more important, due to the increased water flow in nearby streams and rivers.

When sheltered dwellings are positioned close to a site within a deep valley, it is recommended that special consideration is given to noise data that are collected for the wind condition that affords maximum shelter to the property.

Measurement of wind speed

Wind speed measurements are likely to be performed on-site as part of the wind resource study prior to development and if they are to be used for the noise assessment, measurements of the 10-minute average should be recorded. Measurements are performed using anemometers placed at known heights above ground level. Wind speed varies with height above ground level, increasing with increased height (see "wind shear" in Glossary). Therefore, the height at which wind speed measurements are performed and the height of the proposed wind turbines will affect the derived prevailing background noise level. We propose that measurements should be corrected to a standard height of 10m using the procedure described under "wind shear" in the Glossary. The recommendations for noise limits have been made assuming wind speed measurements corrected to 10m. Measurements at 10m will be easier to perform due to the availability of portable masts of this height.

Wind speed measurements performed at two different heights on the same mast will allow an assessment of the wind shear that exists at the wind measurement position. Derivation of the wind shear allows an assessment of the wind speed at 10m height to be performed if the anemometers are not positioned at 10m.

Analysis and derivation of background noise levels

The derivation of the prevailing background noise level at a dwelling is performed using the noise data that have been collected at the dwelling and the measured on-site wind speed at the anemometer height.

When deriving the prevailing background noise level, the height at which the wind speed is measured should be clearly stated and converted to 10m height.

It should be expected that measurements performed over an extended survey period will be affected by weather conditions that are not associated with wind speed. Rainfall will lead to increased noise levels at a measurement position due to a number of factors. These may include the increased flow of water within streams and brooks, the sound of rain drops falling on the wind shield and any associated equipment that may contain the sound level meter. Other noise sources may also increase measured noise levels. Work in fields, milking equipment and milk chillers, traffic and aircraft noise all increase the measured noise levels especially during the day-time periods.

The increased levels due to sources not associated with the wind will reduce the correlation between the wind speed and the measured background noise level. However, measurements undertaken during evening and night-time periods are less affected by these extraneous sources as human and animal activity is reduced, thereby minimising any effects. Rainfall, however, is harder to detect. Rain gauges provide an indication when rain fell during survey periods. Increased noise levels during night-time periods that are not associated with respective increases in wind speed are also an indication that rain may have fallen.

It is considered appropriate to remove the noise data that may be affected by rainfall during a survey. Measurements that are affected by human or animal activity during the night, ie traffic passing along nearby roads or owls in nearby trees, should be considered as the noise environment at the dwelling.

Background noise curves are required for both the day-time quiet periods and for the night-time. The periods are defined in Chapter 6.

Appendix C provides a fuller discussion on the measurement of background noise levels.

Measurement of wind farm noise

Wind speed measurement

To assess wind farm noise levels, measurements are correlated with the operating condition of the wind turbines. This is because the emitted noise from a wind turbine is related to the wind speed that a turbine experiences.

A possible method for determining the wind speed during a compliance test is to use an anemometer mast that has a height that is below the lowest point described by the wind turbine rotor, the suggested height being 10 metres. At this height it has been suggested that the true wind speed will be measured, ie which has not been affected by the rotor wakes of wind turbines upwind of the anemometer mast. This mast could then be placed at the original mast position used to determine the prevailing background noise level.

It should be noted that data collection of the wind speed resource at a proposed wind farm site may also have measured the wind shear at the mast position. If measurements have been gathered of the wind speed at 10 metres height, the background noise level measurements may be correlated with this measurement height data and any noise conditions set based upon this wind speed measurement height. A potential additional benefit of using a wind speed measurement height of 10 metres is that the IEA Recommended Practice for the measurement of noise emissions from wind turbines [11] proposes that the standardised sound pressure level and sound power level of a wind turbine be quoted for a wind speed reference condition of 8m/s at a height of 10 metres above ground level. Therefore, the use of a 10m-high anemometer mast may provide additional consistency through the measurement and assessment procedure.

Identification of critical periods for monitoring

It will not normally be necessary to demonstrate compliance with planning conditions at all wind speeds. If monitoring is required in response to complaints then a log of times at which the turbine noise is most intrusive, taken by the complainant, will enable the developer to establish the conditions which require further investigation.

Having established the critical wind speed conditions over which measurements are to be carried out one needs to consider the amount of data that will be required to give a reliable estimate of the typical turbine noise levels in these conditions. It is the opinion of the Noise Working Group that at least 20 to 30 measurements of the $L_{A90,10min}$ should be taken within $\pm$ 2m/s of the critical wind speed. At least ten measurements should lie either side of the critical wind speed. Measurements should be taken in representative conditions and not for example when the wind is in a direction rarely encountered.

To minimise the effects of extraneous noise sources it may be necessary to perform these measurements during night-time periods when other human and animal activity noise sources are likely to be at a minimum.

Analyses

Filtering of data

As with the background noise data it will again be necessary to filter data for effects such as periods of rainfall to ensure reliable results are obtained. Also, if the measurement of wind speed is from an anemometer which may be in the wake of a turbine in certain wind directions these data should also be removed.

Calculation of wind farm noise level

A best fit curve can be fitted to the data obtained for a particular critical wind speed. A straight line will usually be sufficient given the small range in wind speed. The noise level at the critical wind speed can be read from this curve. If this level is below that set in the noise limits and the EHO considers that there are no audible tones then no further action is necessary. If, however, either the noise is above the limit or the application of a tonal penalty may take the noise over the limit then a correction for the influence of the existing background noise should be performed or the measurements repeated at times of lower background noise.

The background noise at the critical wind speed should be assessed using the procedure described for turbine noise above. A correction shall then be made as follows:

$$L_{pw} = 10 \log (10^{L_{pc}/10} - 10^{L_{pb}/10})$$

where L_{pw} = wind farm noise, dB(A)
L_{pc} = combined wind farm and background noise as measured, dB(A)
L_{pb} = background noise only, dB(A).

It is recognised that the correction method above only strictly applies to the correction of one L_{eq} by another. Readers are referred to the paper by Nelson [32] for more discussion on correcting percentile measurements.

Measuring tonal levels

A review of options and a description of a recommended method for tonal assessment were given in Chapter 6. This Section describes the application of that method in the field so that reliable results can be obtained.

Instruments

The information contained in this assessment method is sufficiently complete to allow the identification of audible discrete tones to be made using a variety of measuring instruments; therefore no specific type of instrument is specified. The procedure requires, however, the measurements of the sound pressure level of the tone, L_{pt}, and the sound pressure level of the noise in the critical band centred at the frequency of the tone, L_{pm}. The instruments used should be capable of determining the difference between these levels to within ± 1dB.

Commercially available or specially designed analogue or digital instruments may be used to measure the levels directly or, more conveniently, raw data may be acquired and then processed by a digital computer. An A-weighted network shall be used when performing this assessment as this may be more convenient given a requirement to simultaneously measure the overall A-weighted sound pressure level.

Measurements

Tonal assessment should be carried out at times of typical background noise levels so that the effect of the existing background noise on the masking of tones is not over- or under-emphasised. It has been shown [27] that the audibility of a tone from wind turbines evaluated by the method described in Chapter 6 fluctuates by several dB without any appreciable change in wind speed. It is therefore necessary to introduce some averaging into the assessment procedure to increase the repeatability and reliability of the derived results. As for overall levels, 20 to 30 measurements should be taken within $\pm$ 2m/s of the critical wind speed. These measurements should be taken during the same periods as the measurements of overall noise level. At least ten measurements should lie either side of the critical wind speed. The measurements should be taken over a period of 2 minutes and regularly spaced at 10-minute intervals so that each measurement corresponds to a measurement of the $L_{A90,10min}$ used in the assessment of the overall noise level. As with overall levels, measurements should be taken in representative conditions and not for example when the wind is in a direction rarely encountered.

Analysis

Tonal analysis of each 2-minute sample is performed according to the recommended procedure described in Chapter 6:

- For each of the 2-minute samples calculate the margin above or below the audibility criterion of the tone level difference, ΔL_{tm}, by comparison with the audibility criterion given in Chapter 6.

- Plot the margin above audibility against wind speed for each of the 2-minute samples. For samples for which the tones are inaudible or no tone is identified substitute a value of zero audibility.

- Perform a linear regression to establish the margin above audibility at the critical wind speed. If there is no apparent trend with wind speed then a simple arithmetic average will suffice.

- The tonal penalty, K_T, is derived from the margin above audibility of the tone according to Fig 16 in Chapter 6.

The rating level

The rating level is the arithmetic sum of the wind farm noise level, L_{pw}, and the tonal penalty, K_T. It is this level which determines whether the wind farm has complied with the limits set in the planning condition.

8. THE PLANNING OBLIGATION

The Noise Working Group thought that it would be beneficial to present its recommendations in a form which might be useful to developers and planners. We therefore considered drafting planning conditions, but came to the conclusion that the necessary definitions of terms which would be required would make planning conditions too complicated. Therefore it was decided to produce covenants for inclusion within an Agreement between a developer and a local authority. Alternatively, the developer may be required, through a planning condition, to agree a noise rating and monitoring scheme with the local planning authority prior to operation of the development. The scheme may then incorporate the definitions and provisions which we have included within the Planning Obligation. This may be particularly helpful where a developer does not own the proposed wind farm site.

It is appreciated that on first reading the Planning Obligation can appear somewhat complicated. It is anticipated that when there has been more experience of drafting such obligations it may be possible for some simplifications to be made.

The Planning Obligation is supplemented by some Guidance Notes to which it refers. These Guidance Notes also serve as a useful summary of the proposed measurement procedure.

DATED 1996

THE WIND FARM LIMITED (1)

and

THE COUNCIL (2)

PLANNING OBLIGATION BY AGREEMENT

Relating to Land at

Assumptions within this document:

1. The Developer owns the freehold of the Site
2. There are no other interests in the Site and in particular there is no charge over the Site

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Bond Pearce
Plymouth

THIS PLANNING OBLIGATION BY AGREEMENT is made the day of 199 BETWEEN:

(1) **THE WIND FARM LIMITED** a company registered in with number and whose registered office is at

(2) **THE COUNCIL** of the Council Offices at

WHEREAS:

(1) The Council is the local planning authority for the purposes of the 1990 Act for the area which includes the Site

(2) The Developer owns the legal estate in the Site

(3) The Developer intends to construct and operate the Development

(4) The Developer has by the Application applied to the Council for planning permission for the Development

(5) The Council in exercise of its powers under the 1990 Act has decided to grant planning permission for the Development

(6) The Developer has agreed to enter into this Obligation

NOW THIS OBLIGATION WITNESSES as follows:

1. In this Obligation unless the context otherwise requires:-

1.1 **"the Developer"** means The Wind Farm Limited and its successors in title

1.2 **"the Council"** means The [ ] Council and any successor authority

1.3 **"the Site"** means the land edged red on the plan numbered x attached to this Obligation being land at .....

1.4 **"the Application"** means an application for the Permission for the Development submitted to the Council under the 1990 Act on registered under number ....

1.5 **"the Development"** means the erection on the Site of x wind turbine generators, a grid connection building and ancillary development as specified in the Application

1.6 **"the Permission"** means any planning permission issued pursuant to the Application (together with any modifications thereto made with the consent of the Developer) by the Council on the determination of the Application

1.7 **"the 1990 Act"** means the Town and Country Planning Act 1990 (as amended by the Planning and Compensation Act 1991 and any subsequent legislation)

1.8 **"the Wind Turbines"** means the wind turbine generators proposed to be erected as part of the Development.

2. It is the intention of the parties that:

2.1 This Obligation is made pursuant to the provisions of Section 106 of the 1990 Act

2.2 This Obligation shall be enforceable by the Council

2.3 This Obligation shall not take effect until the Permission has been granted and implemented by the carrying out of a specified operation as defined in Section 56 (4) of the 1990 Act

2.4 No person or company shall be liable for any breach of this Obligation unless he or it holds an interest in the part of the Site in respect of which such breach occurs or held such an interest at the date of the breach

2.5 Nothing in this Obligation shall be construed as prohibiting or limiting the development of the whole or any part of the Site in accordance with any planning permission granted by the Council after the date of this Obligation (save and except the Permission)

2.6 Where the context so requires the singular includes the plural and terms using the masculine gender include the feminine

2.7 References to Schedules and Appendices mean Schedules and Appendices to this Obligation

3. The Developer hereby covenants with the Council to observe and perform the obligations contained in the Schedule all of which relate to the Development

4. Any dispute arising from the terms of this Obligation will be referred to the decision of a single arbitrator (acting as an expert and not an arbitrator) under the terms of the Arbitration Act 1979, such arbitrator to be appointed by agreement between the parties or in default of agreement by the President for the time being of the Institute of Acoustics (or provision for determination of disputes by the County Court)

IN WITNESS whereof the parties hereto have executed these presents the day and year first before written

THE SCHEDULE

1. In this Schedule unless the context otherwise requires:

1.1 **"Audibility"** means the audibility of Tonal Noise as defined in (and to be measured in accordance with) the recommended method in Section 2.1 of the Guidance Note

1.2 **"Background Noise Level"** means the ambient noise level already present within the environment (in the absence of noise generated by the Development) as measured prior to the date of this Obligation and correlated with Wind Speeds

1.3 **"Best Fit Curve"** means a best fit linear regression curve expressing noise levels as a function of wind speed derived from measured noise levels for data points extracted in accordance with the recommendations in Section 1.2 of the Guidance Note

1.4 **"Critical Band Width"** means a band with a prescribed frequency range determined in accordance with the recommendations in Section 2.1 of the Guidance Note Appendix 3

1.5 "$\mathbf{dB(A)_{L90,10min}}$" means the dB(A) level exceeded 90% of the time and measured over a period of 10 minutes

1.6 **"Free-field Conditions"** means an environment in which there are no reflective surfaces (except the ground) affecting measurements within the frequency range being measured

1.7 "**Guidance Note**" means the 'Supplementary Guidance Notes to the Planning Obligation" presented in Chapter 8 of the report "The Assessment and Rating of Noise from Wind Farms", September 1996, report number ETSU-R-97.

1.8 **"Night Hours"** means 2300-0700 hours on all days

1.9 **"Quiet Waking Hours"** means 1800-2300 hours on all days plus 0700-1800 hours on Sundays and 1300-1800 hours on Saturdays

1.10 **"Tonal Noise"** means noise containing a discrete frequency component

1.11 **"Wind Speeds"** means (unless the context otherwise demands) wind speeds measured at a height of 10 metres above ground level on the Site at Ordnance Survey grid reference aaaaaa.

1.12 **"Wind Turbine Noise Level"** means the rated noise level due to the combined effect of all the Wind Turbines including any penalty incurred under clause 7 or 8 of this Schedule but excluding the existing background noise level

2. At the reasonable request of the Council following a complaint to the Council relating to noise emissions from Wind Turbines the Developer shall measure at its expense the level of noise emissions from the Wind Turbines (inclusive of existing background noise) using an L_{A90} index over a minimum of 20 periods each of 10 minutes duration. At least 10 of the periods of measurement shall be made at Wind Speeds between a wind speed specified by the Council and a wind speed of not more than 2 metres per second above that specified by the Council. At least 10 measurements shall be made at Wind Speeds between the wind speed specified by the Council and a wind speed not less than 2 metres per second below that specified by the Council. Measurements of noise emissions shall be made in consecutive 10-minute periods provided that they fall within the wind speed range defined in this clause

3. The measurements under clause 2 shall be made using a sound level meter of at least type 1 quality (as defined in International Electrotechnical Commission standard 651 (1979)) incorporating a windshield with a ½ inch diameter microphone in free-field conditions between 1.2 and 1.5 metres above ground level and at least 10 metres from any wall, hedge or reflective surface (using a fast time weighted response)

4.

<u>Alternative 1</u>

(a) In this clause the values of X Y and Z are specified in the Tables within Appendix A of this Agreement in relation to the dwellings referred to or named as described in Section 1.3 of the Guidance Note.

(b) The Wind Turbine Noise Level as measured in accordance with clauses 2, 3 and 5 shall not exceed:

(i) During Night Hours the greater of the Night Hours L_{A90} Background Noise Level plus XdB or YdB$(A)_{L90,10min}$ at Wind Speeds not exceeding 12 metres per second;

and at all other times

(ii) The greater of the Quiet Waking Hours L_{A90} Background Noise Level plus XdB or ZdB$(A)_{L90,10min}$ at Wind Speeds not exceeding 12 metres per second

Provided that this covenant shall only apply to dwellings existing at the date of this Obligation.

<u>Alternative 2</u>

The Wind Turbine Noise Levels as measured in accordance with clause 2, 3 and 5 shall not exceed 35dB$(A)_{L90,10min}$ at Wind Speeds not exceeding 10 metres per second provided that this can only apply to dwellings existing at the date of this Obligation.

5. (a) Measurements made in accordance with the provisions of this Schedule in order to demonstrate compliance with the requirements of clause 4 shall be correlated with Wind Speeds

(b) The $L_{A90,10min}$ noise level from the combined effect of the Wind Turbines (inclusive of existing background noise) shall be derived using a Best Fit Curve.

6. Tonal Noise shall be measured for Audibility in accordance with the recommended method described in Section 2.1 of the Guidance Note.

7. If Tonal Noise from the combined effect of the Wind Turbines (when measured in accordance with clause 6) exceeds the threshold of Audibility by more than 6.5dB a penalty of 5dB shall be added to the noise level derived in accordance with clause 5(b)

8. If Tonal Noise from the combined effect of the Wind Turbines (when measured in accordance with clause 6) exceeds the threshold of Audibility by more than 2.0dB but less than 6.5dB a penalty of ((5/6.5)xAudibility)dB shall be added to the noise level derived in accordance with clause 5(b)

9. If measurements made in accordance with clauses 2, 3 and 5 exceed the levels of noise emissions provided in clause 4 then in order to investigate compliance with such levels by an assessment of the contribution of background noise to the measured levels the measurements shall be repeated by the Developer at a time when the contribution of the Background Noise Level to measured noise levels can be expected to be less than at the time of the first set of measurements.

10. If measurements made in accordance with clause 9 exceed the levels of noise emissions provided in clause 4, or noise levels measured in accordance with clauses 2, 3, 5, 6, 7 and 8 exceed the levels provided in clause 4, then in order to investigate compliance with such levels by an assessment of the contribution of background noise to the measured levels, measurement shall be made in accordance with the requirements of clause 2, 3 and 5(b) (with the Wind Turbines stationary). A correction shall be applied in accordance with the recommended method in Section 2.0 of the Guidance Note to the measured noise levels in order to determine the contribution of background noise to the overall levels of noise measured when the Wind Turbines are in operation.

11. The Developer shall supply Wind Speeds and wind direction data to the Council at its request to enable the Council to check compliance by the Developer with the provisions of this Schedule.

EXECUTED AS A DEED AND DELIVERED	)
BY authorised to	)
sign for and on behalf of	)
	)
in the presence of:	)

THE COMMON SEAL OF THE	)
COUNCIL	)
was hereunto affixed	)
in the presence of:	)

Authorised Person

Authorised Person

Bond Pearce
1996 (ref GMT)

SUPPLEMENTARY GUIDANCE NOTES TO THE PLANNING OBLIGATION

1.0 Prior to construction of the wind farm

1.1 Identification of properties where background noise surveys are required

Before the wind farm is constructed, the developer/operator should identify the nearest noise-sensitive properties to the wind turbines.

If there is a small number of such properties, a background noise survey will be required at each one.

If there are rather more properties, it may be appropriate to identify a smaller number of properties, in agreement with the local authority/EHO, that have similar background noise levels to a group of properties in their immediate vicinity. A background noise survey will be required at each one of these indicative properties as the noise limits relate to the existing background noise levels.

The precise locations at which the background noise surveys should be made at each property should be agreed in consultation with the local authority/EHO.

In addition, the developer/operator of the wind farm should agree, in consultation with the local authority/EHO, the lower limit on wind farm noise that will apply at each property, or group of properties under consideration. This limit should normally lie in the range 35-40dB(A), except where the occupants of a property receive a financial benefit from the wind farm, where a higher limit of 45dB(A) may be appropriate. It may be desirable to agree these lower limits after the background noise surveys have been completed, rather than beforehand.

Note that where it can be demonstrated that the expected levels of wind farm noise would not exceed 35dB(A) at a property for wind speeds of up to 10m/s at 10m height, then no background noise survey is required for that property.

Note also that where a new wind farm is planned for an area where another wind farm is already operating, the contribution to noise levels from the existing wind farm should not be included in any assessment of prevailing background noise levels.

1.2 The background noise survey

The background noise survey should be taken over a sufficient period of time to enable a reliable assessment of the prevailing background noise levels at each property to be made. As a guideline, an appropriate survey period might be 1 week, although the actual duration will depend upon the weather conditions, in particular the wind speed and direction during the survey period. It must be ensured that, during the survey period, wind speeds over the range zero to at least 12m/s (10min average at 10m height), and a range of wind directions that are typical of the site, are experienced.

The aim of the survey, at each location, is to characterise the variation in prevailing background noise level with wind speed. This is achieved by correlating background noise measurements with wind speed measurements made over identical time periods. The following sections identify the measurements required to enable this.

1.2.1 *Acoustic measurements*

Background noise levels should be measured using the A-weighted L_{90} statistic over consecutive 10-minute intervals, ie $L_{A90,10min}$. A sound level meter of at least IEC 651 type 1 quality should be used, and this should be fitted with a ½" diameter microphone and calibrated in accordance with the procedure specified in BS 4142: 1990.

The microphone should be mounted on a tripod at 1.2-1.5 m above ground level, fitted with a wind shield, and placed in the vicinity of, and external to, the property, at least 3.5m away from any reflecting surfaces. The intention is that the acoustic measurements should be made in "free-field" conditions.

1.2.2 *Wind speed and direction measurements*

Wind speed and direction data should be recorded as average values over 10-minute intervals, v_{10min} & Θ_{10min}, these intervals to be synchronised with the measurement period for the $L_{A90,10min}$ acoustic data.

The measurements should preferably be made using instruments mounted at 10m height. Where this is not possible, wind speeds measured at one height can be "corrected" to the value that would have been measured at another height using the expression:-

$$V_1/V_2 = \ln(h_1/z_0) / \ln(h_2/z_0)$$

where V_1 = wind speed (m/s) at a height of h_1 metres above ground level.
V_2 = wind speed (m/s) at a height of h_2 metres above ground level.
z_0 = ground roughness length (m).

The ground roughness length can be calculated from wind speed measurements at two or more heights. Alternatively it can be estimated from Table 11.

The instruments should be mounted on a mast positioned on the site so that they give a reasonable description of meteorological conditions at the noise-sensitive properties. Where there are several masts on a site, data from the instruments mounted on the mast closest to each property should be used.

Table 11 Roughness lengths for various types of terrain

Type of Terrain	Roughness Length z_0
Water areas, snow or sand surfaces	0.001m
Open, flat land, mown grass, bare soil	0.01m
Farmland with some vegetation	0.05m
Suburbs, towns, forests, many trees and bushes	0.30m

1.2.3 Data reduction

At the end of the survey period, data recorded during periods of rainfall, or afterwards, where rainfall may have affected flow in nearby rivers or streams, should be discarded.

Two sub-sets of the data should be created, for the following periods:

- quiet waking hours (18:00-23:00 every day, 13:00-18:00 on Saturday, 07:00-18:00 on Sunday)

- night hours (23:00-07:00, every day).

These two sub-sets are identified as the "day-time" data, and the "night-time" data.

For each sub-set, a "best fit" curve should be fitted to the data using a least squares approach, usually a polynomial model (of no more than 4th order).

Where there is considerable scatter in the data, it may be appropriate to bin the acoustic data into 1m/s bins, before identifying a best fit model.

These two curves, referred to as the "day-time curve" and the "night-time curve", provide a characterisation of the prevailing background noise levels, for the day-and night-time respectively, as functions of wind speed from zero to 12m/s at 10m height.

Note that whatever model is used to describe the measured data, this should not be extrapolated outside of the range of measured wind speed data.

1.3 Identification of noise criteria

1.3.1 Day-time noise criterion

The criterion curve for acceptable levels of wind farm noise during day-time, ie 07:00-23:00 each day, is usually equal to the day-time curve plus 5dB(A) at every wind speed.

Where this criterion curve falls below the lower limit (35-40dB(A), or 45dB(A) - see Section 1.1), the criterion curve should be amended so that it equals the lower limit. This results in a piece-wise, continuous curve, equal to the lower limit from zero to the wind speed at which the day-time curve plus 5dB(A) equals the lower limit, and the day-time curve plus 5dB(A) thereafter, to an upper wind speed of 12m/s at 10m height.

1.3.2 Night-time noise criterion

The criterion curve for acceptable levels of wind farm noise during night-time, ie 23:00-07:00 each day, is equal to the night-time curve plus 5dB(A) at every wind speed.

Where this criterion curve falls below 43dB(A), the criterion curve is amended so that it equals 43dB(A). As before, this results in a piece-wise, continuous curve, equal to 43dB(A) from 0m/s up to the wind speed at which the night-time curve plus 5dB(A) equals 43dB(A), and the night-time curve plus 5dB(A) thereafter, to an upper wind speed of 12m/s at 10m height.

Note that where the occupants of a noise-sensitive property are financial beneficiaries of the wind farm, the 43dB(A) figure may be replaced with 45dB(A) - see section 1.1.

1.3.3 Table of noise limits

The limits agreed for each property or group of properties can be summarised in tabular form in an Appendix to the Planning Obligation, see Section 4 of the Schedule. Properties not mentioned specifically by name or address should be included by applying limits to "any other property". In Section 4 X refers to the margin above background (usually 5dB), Y refers to the night-time lower fixed limit (usually 43dB) and Z refers to the day-time lower fixed limit (usually in the range 35-40dB).

2.0 Procedure to be followed in the event of a complaint

Where the local authority/EHO receive a complaint about noise levels following the construction of the wind farm, the following steps should be taken:

1 The complainant should log the times when the noise is most intrusive. This will enable the meteorological conditions in which the complaint occurs to be determined and, in particular, the critical wind speed.

2 At least 20 values of the $L_{A90,10min}$ noise statistic should be measured at the affected property using a sound level meter of at least IEC 651 Type 1 quality. This should be fitted with a ½" diameter microphone and calibrated in accordance with the procedure specified in BS 4142: 1990. The microphone should be mounted on a tripod at 1.2-1.5 m above ground level, fitted with a wind shield, and placed in the vicinity of, and external to, the property. The

intention is that, as far as possible, the measurements should be made in "free-field" conditions. To achieve this, the microphone should be placed at least 10m away from the building facade or any reflecting surface, where possible, and no less than 3.5m away where this is not possible with appropriate adjustment made to measured levels to account for facade effects.

The 20 $L_{A90,10min}$ measurements should be synchronised with measurements of the 10-minute average wind speed, and be made in wind speeds within ± 2m/s of the critical wind speed. Further, at least 10 of these should lie either side of it. The measurements should be made during conditions that are generally typical for the site and not, for example, during periods with a rarely encountered wind direction.

To minimise the effects of extraneous noise sources, it may be necessary to perform these measurements during night-time periods.

Any data recorded during periods of rainfall, or immediately afterwards, where rainfall may have affected flow in nearby rivers or streams, should be discarded. Where this is necessary it shall be ensured that the conditions relating to the number of data points, and their distribution, are still adhered to.

3 A least squares, "best fit" curve should be fitted to the data points - generally a straight line fit will be sufficient.

4 The noise level at the critical wind speed, L_c, shall be determined from this best fit curve. If this level lies below the value indicated from the two noise criteria curves at the critical wind speed, and the local authority/EHO consider there to be no audible tones, then no further action is necessary.

5 If the noise level is above the limit, or if the application of a tonal penalty - see later - takes it above the limit, a correction for the influence of background noise should be made. This may be achieved by repeating steps 2-4, with the wind farm switched off, and determining the background noise at the critical wind speed, L_b. The wind farm noise at this speed, L_w, is then calculated as follows:

$$L_w = 10\log\left(10^{\frac{L_c}{10}} - 10^{\frac{L_b}{10}}\right)$$

Ifthe wind farm noise level lies below the value indicated from the two noise criteria curves at the critical wind speed, and the local authority/EHO consider there to be no audible tones, then no further action is necessary.

6 Where, in the opinion of the local authority/EHO, the noise immission contains a tonal component, the following rating procedure should be used. This is based on the repeated application of a tonal assessment methodology - see below.

For each 10-minute interval for which $L_{A90,10min}$ data have been obtained, a tonal assessment - see Section 2.1 - is performed on noise immission during 2-minutes of the 10-minute period. The 2-minute periods should be regularly spaced at 10-minute intervals provided that uninterrupted clean data are obtained.

For each of the 2-minute samples the margin above or below the audibility criterion of the tone level difference, ΔL_{tm}, is calculated by comparison with the audibility criterion given in Section 2.1 below.

The margin above audibility is plotted against wind speed for each of the 2-minute samples. For samples for which the tones were inaudible or no tone was identified, substitute a value of zero audibility.

A linear regression is then performed to establish the margin above audibility at the critical wind speed. If there is no apparent trend with wind speed then a simple arithmetic average will suffice.

The tonal penalty, K_T, is derived from the margin above audibility of the tone according to Fig 17.

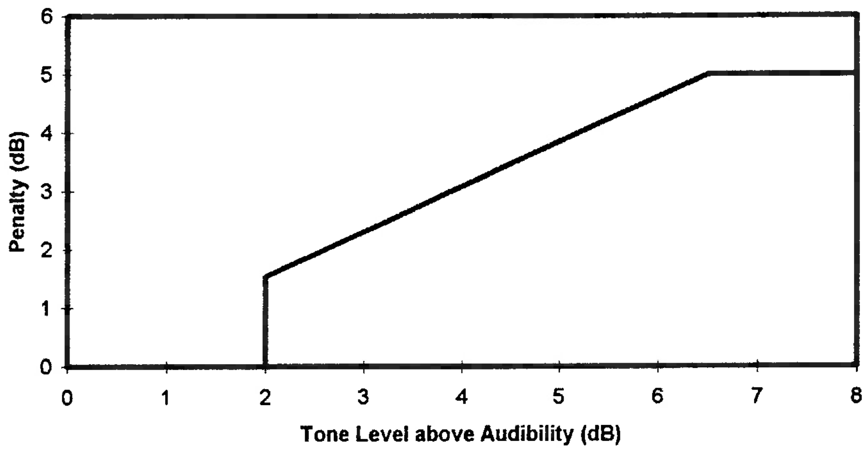


Figure 17 Penalties for tonal noise

The rating level is the arithmetic sum of the wind farm noise level, L_{pw} and the tonal penalty, K_T. It is this level which determines whether the wind farm has complied with the limits set in the planning condition.

2.1 Tonal assessment methodology

The recommended method is based upon the Joint Nordic Method for non-stationary tones with some embellishments in areas where it is not entirely prescriptive such as tone identification and averaging periods. The method aims to assess the audibility of a tone as perceived by the average listener. There are three main steps in the procedure:

A) Frequency analysis of the noise at receiver locations.

B) Determination of the sound pressure level of the tone(s) and the sound pressure level of the masking noise within the critical band.

C) Evaluation of the difference between the tone and the masking noise sound pressure levels (ΔL_{tm}) by comparison with a criterion curve to determine the audibility of a tone.

A. Frequency analysis

The analysis of non-stationary tones is quite intensive; it will therefore be convenient to record the signal to be analysed onto tape. For each tonal assessment 2-minutes of uninterrupted clean A-weighted recording is required.

A 2-minute, rms-averaged FFT is performed on the sampled data using a Hanning window, a frequency resolution of 3.0 ± 0.5Hz and an analysis bandwidth of 2kHz. It may be necessary to inspect a similar spectrum with greater bandwidth to ensure that there are no tones present at higher frequencies.

The short term, individual rms-averaged FFTs within the sampled data are also calculated using the same parameters as described above. This results in an averaging time of 0.29 to 0.4 seconds.

B. Determination of sound pressure levels

The bandwidth of a critical band is:

Centre Frequency f_C, Hz	20-500	Above 500
Bandwidth	100Hz	20% of f_C

If a single tone is present the critical band is centred upon the tone. If two or more, closely spaced tones are present, the critical band is placed so that it contains the maximum possible amount of tonal energy. In order to do this it is first necessary to identify the tones within the spectrum. To do this each line in the 2-minute spectrum must be classified according to the following criteria based upon the draft DIN 45 681. A peak is classed as a tone if its level is more than 6dB above the logarithmic average of the sound pressure levels of the rest of the lines in the critical band centred on the peak, but excluding the one line each side of the peak. If the peak qualifies as tone the adjacent lines are also classified as a tone if their level is within 10dB of the peak and greater than 6dB above the average level previously calculated. If a spectral line is more than 6dB above the average masking level and more than 10dB below the peak level it is classified as nether tone nor masking. Having identified the tones the critical band can be placed to maximise the sound pressure level of the tones within the critical band.

Because classifying a line as a tone means it can no longer be counted as masking, an iterative procedure is required for the proper identification of tones and masking. This is described by reference to the worked example below.

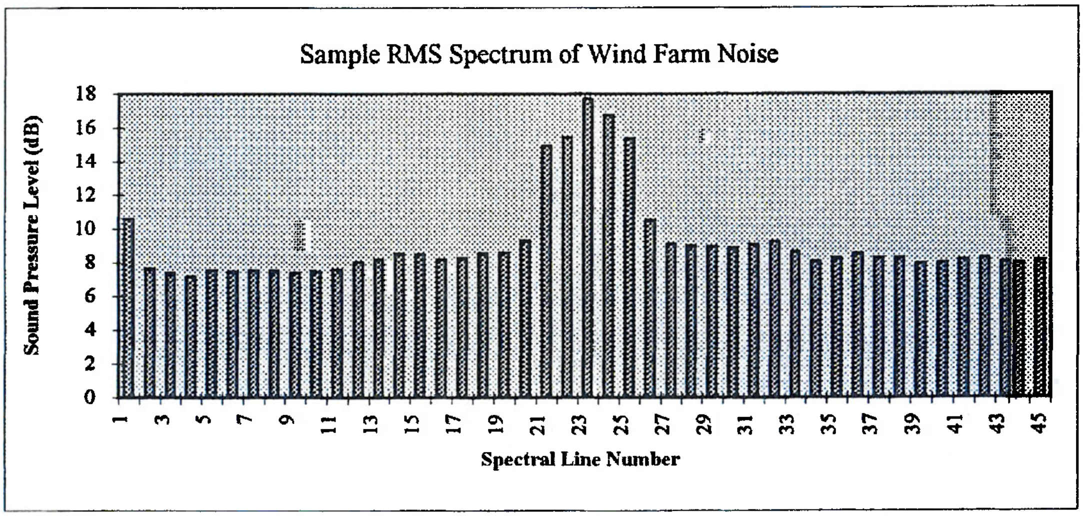
Fig 18 shows the stages in the tone identification and classification process. These are:

- Find peaks in the spectrum, in this case line 23.
- Calculate the average energy in the critical band centred on each peak, not including the two lines adjacent to the peak (9.10dB).
- If the peak is more than 6dB above the average masking level then it is a tone, therefore line 23 is a tone.
- Classify adjacent spectral lines :

Pass 1
- Compare spectral lines above and below the peak to the average level.
- If a line is more than 6dB above the average and less than 10dB below the peak then it is a tone, therefore lines 22, 24 and 25 are tones.

Pass 2
- Calculate new average masking level centred around the peak, discounting adjacent spectral lines and all other lines classed as tones (8.75dB).
- Compare spectral lines above and below the peak to the average level.
- If a line is more than 6dB above the average and less than 10dB below the peak then it is a tone, therefore lines 21, 22, 24 and 25 are tones.

Pass 3
- Calculate new average masking level centred around the peak, discounting adjacent spectral lines and all other lines classed as tones (8.39dB).
- Compare spectral lines above and below the peak to the average level.
- If a line is more than 6dB above the average and less than 10dB below the peak then it is a tone. Therefore lines 21, 22, 24 and 25 are tones, but no spectral lines have been reclassified in this pass so the iterative process is complete.



Tone Ide ntifca tionand Cbssification Peak line = 23	Peak Level = 17.71dB					
	Pas 1		Pass 2		Pass3	
Average about peak	9.10		8.75		8.39	
Adjacent line assessment	Levd above a verage	Cbssif-ication	Level above aver age	Class if-ication	Level ab ove average	Classif-ic ation
Linenumber						
1 9	-0.49	masking	-0.1 4	masking	0.22	masking
20	0.20	masking	0.55	masking	0.91	masking
21	5.83	masking	6. 18	tone	6.54	tone
22	6.34	tone	6. 69	tone	7.05	tone
24	7.64	tone	7. 99	tone	8.35	tone
25	6.26	tone	6.61	tone	6.97	tone
26	1.40	masking	1.75	masking	2.11	masking
27	-0.01	maskin g	0. 34	masking	0.70	masking

Figure 18 Tone i dentification and classification process

If a spectral line is more than 6dB above the average masking level and more than 10dB below the peak level then it is classified as neither tone nor masking, and not included in the calculation for either level.

The process described above is repeated for every critical band centred arou ndtonal peaks in the spectrum. The result is that within each critical band every spectral line is classified as tone energy, masking energy or neither.

Having identified the lines in each spectrum contributing to tonal levels, masking levels or neither, the tonal analysis can continue as follows:

- The masking energy within the critical band is calculated from the 2-minute rms spectrum. Calculate the masking level in the critical band, L_{pm}, correcting for a reduction in the number of lines due to the exclusion of tones and for the Hanning window:

$$L_{pm} = 10\log\sum 10^{L_m/10} + 10\log\frac{(\text{critical band width})}{(N_m \times \Delta f)} + 10\log(1/1.5)$$

where L_m = sound pressure level of each line containing masking noise
N_m = number of lines within the critical band containing masking noise.

- For each of the short term spectra of 0.29 to 0.4 seconds duration, calculate the tone energy within each critical band, L_{pt}', using the lines identified as tones from the 2-minute spectrum.

$$L_{pt}' = 10\log\sum 10^{L_t/10}$$

where L_t is the sound pressure level of each line containing tonal noise.

The tone level used in the assessment, L_{pt}, is the arithmetic mean of the top 10% of tone levels, L_{pt}', from all the short-term spectra constituting the 2-minutes of data.

C. Evaluation of the audibility of the tone(s).

The audibility of a tone is dependent upon the tone level difference, ΔL_{tm}, and the frequency of the tone:

$$\Delta L_{tm} = L_{pt} - L_{pm}.$$

The audibility criterion is defined as follows:

$$\Delta L_{tm,crit} = -2 - \text{Log}\,(1 + (f / 502)^{2.5})$$

where f = frequency at the centre of the critical band.

This is the level at which the average listener will be just able to hear the tone. Fig 19 details the audibility criterion based upon the above equation. It can be seen from the figure that the audibility criterion is related to the frequency of the tone.

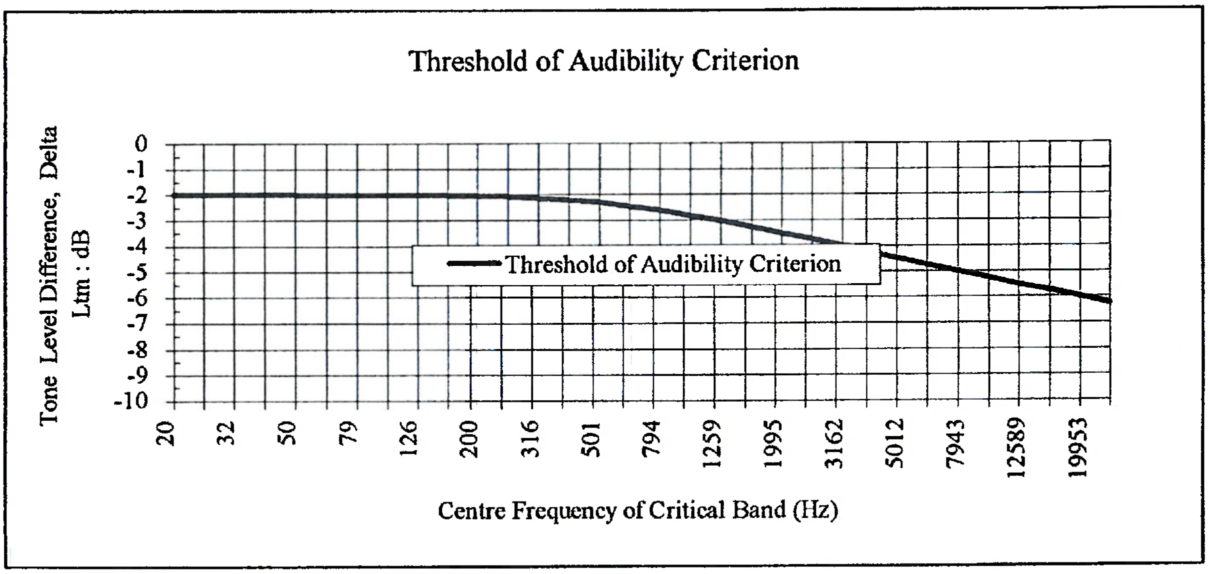


Figure 19 The audibility criterion for tonal noise assessment

Tonal assessment should be carried out at times of typical background noise levels so that the effect of the existing background noise on the masking of tones is not over- or under-emphasised.

It has been shown [27] that the audibility of a tone from wind turbines evaluated by the method described in these guidance notes fluctuates by several dB without any appreciable change in wind speed. It is therefore necessary to introduce some averaging into the assessment procedure to increase the repeatability and reliability of the derived results. As for overall levels, 20 to 30 measurements should be taken within ± 2m/s of the critical wind speed. These measurements should be taken during the same periods as the measurements of overall noise level. At least 10 measurements should lie either side of the critical wind speed. The measurements should be taken over a period of 2 minutes and regularly spaced at 10-minute intervals so that each measurement corresponds to a measurement of the $L_{A90,10min}$ used in the assessment of the overall noise level. As with overall levels, measurements should be taken in representative conditions and not for example when the wind is in a direction rarely encountered.

9. FURTHER WORK

This chapter makes some observations that may form the basis of a review of the contents of this report. It also outlines current research within the DTI New and Renewable Energy Programme of relevance to those working in the environmental assessment of noise from wind turbines.

Review of the report and its recommenda tons

This report was drafted in the light of the best information available at the time and in the circumstances prevailing at the time. However itis acknowledged that as more experience and information become available and as circumstances develop it may become necessary to revise and improve the contents of this report

The Noise Working Group therefore suggests this report and its recommendations are reviewed in 2 years time. We anticipate that the wind industry will itself take the initiative for such a review and that this review will be undertaken by a cross-section of users of the report. This review should establish:

- To what extent have the recommendations been followed?
- Have the recommendations been interpreted as originally intended?
- Do the suggested noise limits provide the right balance between protecting the local amenity and providing for the development of renewable energy sources?
- Do the measurement procedures strike the right balance between repeatability and reliability on the one hand and ease of use on the other?
- Are there any circumstances which the recommendations do not properly address but which could be covered by general advice?

More specific issues which could warrant further attention are:

- The simplification of the tonal assessment metho d.
  An IEA Recommended Practice on "The Measurement of Noise Immission Levels from Wind Turbines at Noise Receptor Locations" is currently under preparation. This may contain a simpler method for the measurement of the d ifference between the tone level and the masking noise based upon rms-averaged spectra. It is unlikely however that this tone level difference will be able to be transformed into a measure of the audibility of a tone without validation by further work.
- Tonal assessment of variable speed machines.
  In 2 years time there is likely to be more information and experience available on the tonal emissions from variable speed machines which could then be incorporated in to the tonal

assessment method.

- The correction of turbine noise for the influence of background noise.
  The report acknowledges that the expression used for correction of turbine noise for background noise is only strictly applicable to L_{eq} measurements and may slightly underestimate the correction required. If user experience shows that greater accuracy is required then further investigation of how to correct one average L_{90} measurement by another will be necessary.

Current research projects

This section briefly reviews current research projects being undertaken as part of the DTI's New and Renewable Energy Programme which may be of interest to readers. The reports from these projects will be available on loan from the Enquiries Bureau at ETSU following publication.

Low Frequency Wind Turbine Noise and Vibration

Contractor:	Powergen.
Objectives:	1. To measure the low frequency noise and vibration levels in the frequency range 0.1Hz to 60Hz in the immediate vicinity of a modern wind farm and at distances up to 1km. 2. To assess the measured noise and vibration levels in relation to existing noise and vibration criteria and in relation to existing published data on low frequency noise and vibration.
Publication:	November 1996.
Report No:	ETSU W/13/00392/REP.

Wind Turbine Measurements for Noise Source Identification

Contractor:	Hoare Lea and Partners.
Objectives:	1. To acquire high quality data on noise and vibration from two types of wind turbine. 2. To relate the noise to vibration and turbulence measurement. 3. To provide full information on the trends of principal noise features with wind speed, wind turbine power, direction of observation, and other relevant parameters. 4. To compare the data with recently developed theory for aerodynamic noise. 5. To establish the mechanisms that result in blade "swish", to determine its temporal and spectral character, to devise an objective metric for blade swish prominence and to identify conditions under which blade swish is likely to occur.
Publication:	December 1996.
Report No:	ETSU W/13/00391/REP.

Wind Farm Noise Control Strategy

Contractor: Wind Prospect Ltd.

Objectives: 1. To develop and implement a tuned dynamic wind farm noise control strategy based upon varying cut-in windspeeds with wind direction to achieve specified noise constraints at specified locations close to a wind farm.

2. To evaluate the effectiveness and financial implications of such a method.

Publication: June 1997.

Report No: ETSU W/13/00499/REP.

Propagation of Noise from Wind Turbines over Variable Terrain

Contractor: The Hayes McKenzie Partnership.

Objectives: 1. To use an impulsive noise source to establish the influence of secondary propagation paths and other terrain effects on received noise levels in complex terrain.

2. To establish improved (empirical) modelling techniques for noise propagation over various types of terrain under different wind conditions.

Publication: March 1997 .

Report No: ETSU W/13/00354/045/REP.

A Critical Appraisal of Wind Farm Noise Propagation

Contractor: Renewable Energy Systems Ltd

Objectives: 1. To obtain high quality noise immission ("far" field) data at locations surrounding a controlled loudspeaker noise source.

2. To obtain high quality noise emission ("near" field) and noise immission ("far" field) data from a number of UK wind farms.

3. To review existing long-term noise immission data previously collected by the participants from UK wind farms.

4. To use these data to critically appraise the performance of a wide range of popular sound propagation models and, based on this, to estimate the prediction uncertainties associated with the different propagation models.

5. To recommend either the "best" sound propagation model to use, or the "best" given certain circumstances, eg flat, open terrain.

6. To develop a new, empirical noise propagation model for predicting wind farm noise immission levels under practically encountered conditions, and to place confidence limits on these predictions by defining an envelope in which sound pressure levels are likely to lie.

Publication: May 1998.

Report No: ETSU W/13/00385/REP.

Noise Immission from Wind Turbines

Contractor: National Engineering Laboratory.

Objectives:

1. To reduce the effects of wind-induced self noise on noise measurements made with outdoor microphones.
2. To measure noise levels around a number of wind farms for comparison with noise propagation models.
3. To develop, validate and generate a PC version of a noise propagation model developed under a previous JOULE II contract.
4. To quantify the uncertainty of reported sound power measurements due to different measurement practices and differing interpretation of existing standards.
5. To quantify the uncertainty of reported tone levels from wind turbines.
6. To quantify the "nuisance value" of noise from wind turbines in comparison with a common reference.

Publication: May 1998.

Report No: ETSU W/13/00503/REP.

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11. GLOSSARY

Aerodynamic Noise
Noise emitted by a wind turbine due to the passage of air over the blades.

Background Noise
The ambient noise level already present within the environment in the absence of wind farm operation.

Blade Passing Frequency
The frequency at which the blades pass the tower ie three times rotational speed for three-bladed machine.

Blade Swish
The modulation of broadband noise at blade passing frequency.

CNEL (Community Noise Equivalent Level)
An Leq noise level with the 5dB penalty added to noise emitted between 1900 and 2200 hours and 10dB added to noise emitted at night between 2200 and 0700 hours.

Critical Bandwidth
A band with a prescribed frequency range centred around a tone.

Cut-in Wind Speed
The wind speed at which a turbine produces a net power output. This is usually at hub height wind speeds of 4-5 metres per second.

Downwind Rotor
Rotor which is positioned downwind of the turbine tower.

Free Field
An environment in which there are no reflective surfaces affecting measurements within the frequency region of interest.

Hertz (Hz)
The unit of frequency measurement representing cycles per second.

Hub
The centre of the rotor.

Hub Height Wind Speed
The wind speed at the hub height of the turbine or the centre of the rotor. Measurements made during turbine operation are corrected for the slowing down effect that an operational wind turbine has on the air.

Infrasound
Sound frequencies below the audible range ie below about 20 Hertz.

L_{AN}
The dB(A) level exceeded N% of the time, eg L_{A90}, the dB(A) level exceeded 90% of the time, is commonly used to estimate background noise level.

Masking
The process by which threshold of audibility of one sound is raised by the presence of another (masking) sound.

Masking Level
A measure of the sound energy contained within a critical band.

Mechanical Noise
Noise emitted by a wind turbine from machinery usually within the nacelle.

Modulation
Periodic variation in phase, frequency or amplitude but most commonly in amplitude when associated with wind turbine noise.

Nacelle
Enclosure at the top of the tower usually housing gearbox and generator.

Pitch Regulation
The control of turbine output power by altering the angle of the turbine blades to the oncoming wind.

Rated Output
The maximum steady output power of the wind turbine.

Rating Level
The noise level, as measured by a defined method, after corrections have been made for any tonal content.

Rotor
Wind turbine blade assembly.

Sound
Energy that is transmitted by pressure waves in air or other materials and is the objective cause of the sensation of hearing. Commonly called noise if it is unwanted.

Sound Intensity
The rate of sound energy transmission per unit area in a specified direction.

Sound Level Meter
An electronic instrument for measuring the rms level of sound in accordance with an accepted national or international standard.

So undPower
The total sound energy radiated by a source per unit time.

So undPower Level
The fundamental measure of sound power. Defined as:

$$L_W = 10 \log \frac{P}{P_o} dB$$

where P is the rms value of sound power in watts, and P_0 is 1pW. (1 x 10^{-12}W).

Sound Pressure
A dynamic variation in atmospheric pressure. The pressure at a point in space minus the static pressure at that point.

Sound Pressure Level
The fundamental measure of sound pressure. Defined as:

$$L_p = 20 \log \frac{P}{P_o} dB$$

where p is the rms value (unless otherwise stated) of sound pressure in pascals and P_0 is $2x10^{-5}N/m^2$ (20μPa) for measurements in air. When A-weighting is used, the sound level is given in dB(A).

Stall Regulation
The control of turbine output power by stalling the air flow over the turbine blade.

S tandardDeviation
A quantitative measure of the spread of readings.

T ones/Tonal Noise
Noise containing a discrete frequency component most often of mechanical origin.

Audible Tone
A tone whose level is sufficiently above the broad band masking level such that it can just be heard by 50% of the population.

Upwind Rotor
Rotor which is positioned upwind of the turbine tower.

Wavelength
The distance measured perpendicular to the wave front in the direction of propagation between two successive points in the wave, which are separated by one period. Equals the ratio of the speed of sound in the medium to the fundamental frequency.

Wind Shear
A description of the increase in wind speed with height above ground level. Wind speeds measured at one height can be "corrected" to the value that would have been measured at another height using the expression:

$$V_1/V_2 = \ln(h_1/z_0) / \ln(h_2/z_0)$$

where V_1 = wind speed (m/s) at a height of h_1 metres above ground level.
V_2 = wind speed (m/s) at a height of h_2 metres above ground level.
z_0 = ground roughness length (m).

The ground roughness length can be calculated from wind speed measurements at two or more heights. Alternatively it can be estimated from Table 12.

Table 12 Roughness length for various types of terrain

Type of Terrain	Roughness length z_0
Water areas, snow or sand surfaces	0.001m
Open, flat land, mown grass, bare soil	0.01m
Farmland with some vegetation	0.05m
Suburbs, towns, forests, many trees and bushes	0.30m

Table 13 Examples of wind shear calculations

z_0 (m)	V_{30}/V_{10}	V_{40}/V_{10}	V_{10} (m/s)	V_{30} (m/s)	V_{40} (m/s)
0.01	1.16	1.20	4.17	4.83	5
0.01	1.16	1.20	8	9.28	9.6
0.05	1.21	1.26	3.96	4.80	5
0.05	1.21	1.26	8	9.68	10.08
0.30	1.31	1.40	3.57	4.68	5
0.30	1.31	1.40	8	10.48	11.2

10-Minute Average Wind Speed (m/s)
The wind speed measured by a calibrated cup anemometer at a specified height above ground level, averaged over a 10-minute period.

APPENDIX A

PRACTICE TO DATE IN CONTROLLING NOISE EMISSIONS FROM WIND GENERATORS BY REFERENCE TO PLANNING CONDITIONS AND COVENANTS IN PLANNING AGREEMENTS

Deli Farm, Delabole
(North Cornwall District Council)

A1 **(a)** The following conditions to regulate noise emissions were attached to a planning permission for the erection of ten wind turbine generators, issued by the Council on 1 August 1991:

1. Wind generators shall not commence productive operation at a wind speed of less than 5 metres per second at a hub height of 25 metres above ground level unless otherwise agreed by the Local Planning Authority.

2. Subject to the provisions of Condition 6 hereof the noise level expressed on a 10-minute L50 basis from the combined effect of the wind turbine generators as measured at any dwelling beyond a distance of 350 metres from any of the turbines shall not exceed 39dBA during low speed operation or 45dBA during high speed operation when measured over a ten minute period with a precision grade sound level meter of at least a type 1 quality using a half inch diameter microphone in free field conditions 1.2 metres above ground level and at least 3.6 metres from any wall, hedge or reflective surface using a slow time weighted response, or if after the turbines commence operation variations to these limits are agreed in writing by the Planning and Development Officer (on the grounds that it would appear that no noise nuisance would be created at the varied levels) then such agreed variations shall be complied with.

3. The change over speed from low (32rpm) to high (48rpm) or from high to low speed operation shall not occur at a wind speed of less than 8 metres per second at hub height (25 metres above ground).

4. The noise emitted from the wind turbine generators as heard at any dwelling shall not be irregular enough to attract attention, contain distinguishable discrete continuous notes or distinct impulses, such as to cause a nuisance to the occupiers of any dwelling beyond a distance of 350 metres from any of the wind turbine generators.

5. All practicable means shall be employed to the satisfaction of the Local Planning Authority in order to prevent and minimise the creation of any nuisance by noise emission during the erection, operation and use of the wind turbine generators. "Practicable" shall have the meaning given to it by the Environmental Protection Act 1990.

6. Noise emitted from the turbines as measured on any point of the boundary of the permitted camp site Lower Pendavey which is shown hatched black on the approved location plan (and when measured over a ten minute period with a precision grade sound level meter of at least a Type 1 quality using a half inch diameter microphone in free field conditions 1.2 metres above ground level and at least 3.6 metres from any wall, hedge or reflective surface using a slow time weighted response) shall not exceed the ambient L50 plus 5dBA.

All the above conditions were imposed for the following reason:

To ensure that noise emitted by the operation of the turbines does not have a detrimental effect on the amenities of a locality and, in particular, on the local residents living in the vicinity of the site.

(b) In addition to the planning conditions the following covenants and agreements were made in a Planning Obligation (the clause numbering has been altered for this Report):

Covenants

1. Upon receiving notification from the Planning and Development Officer for the time being of the Council ("the Planning and Development Officer") that a nuisance or annoyance is in his reasonable opinion being caused to occupiers of dwellings beyond a distance of 300 metres from any of the turbines the Owners will as soon as reasonably practicable take all necessary steps to abate such nuisance or annoyance to the reasonable satisfaction of the Planning and Development Officer.

2. No turbines shall be erected on the site unless they are of the MS-3 (Refined) type at present manufactured and supplied by the Wind Energy Group Limited and strictly in accordance with the specification of the same annexed hereto or such other type as may be approved in writing by the Planning and Development Officer (such approval not to be unreasonably withheld).

3. No wind turbine generator shall be erected in a position which is closer than 350 metres from any dwelling existing at the date of this Agreement.

4. Before any of the turbines are brought into use the First Owner shall submit and obtain the written approval of the Planning and Development Officer (such approval not to be unreasonably withheld) for a scheme for the monitoring of noise emissions and background noise levels and for the keeping of records of such noise emissions and

background noise levels and thereafter the said records shall be kept in accordance with the said scheme and shall be made available at all reasonable times for inspection by the Planning and Development Officer and it is hereby agreed that in the event that a scheme is not approved in writing by the Planning and Development Officer within 28 days of such submission the question of whether the scheme is reasonable can be referred to arbitration in accordance with clause X hereof.

5. They will comply with the following requirements relating to noise:

(i) except as provided by Clause 5 (iv) and subject to the provisions of Clause 7 (iv) hereof the L50 noise level resulting from the combined effect of the wind turbine generators as measured at any dwelling beyond the distance of 350 metres from any of the turbines shall not exceed 39dBA during low speed operation or 45dBA during high speed operation when measured in accordance with the method described in Clause 7 (i).

(ii) the noise emitted from the turbines as heard at any dwelling shall not be irregular enough to attract attention, contain distinguishable discrete continuous notes or distinct impulses such as to cause (in the reasonable opinion of the Planning and Development Officer) a nuisance to the occupiers of any such dwelling beyond a distance of 350 metres from any of the turbines within the area defined in Clause 5 (i).

(iii) all practicable means shall be employed to the reasonable satisfaction of the Planning and Development Officer in order to minimise the creation of any nuisance by noise emission during the erection, operation and use of the turbines. "Practicable" shall have the meaning given to it by section 79 of the Environmental Protection Act 1990.

(iv) noise emitted from the turbines and measured at any point on the boundary of the site with the property known as Lower Pendavey (for the purposes of identification only hatched black on the plan marked "B" annexed hereto) and when measured in accordance with the method described in Clause 7 (i) (during such time as the camping site on the said property may be operated under any planning permission or site licence which may at any time be implemented) shall not exceed the ambient L50 level plus 5dBA.

6. The owners will allow the Planning and Development Officer and his authorised representatives (being only employees or suitably qualified agents of the Council) to have such access as he or they require to the

Site at all reasonable times for the purposes of monitoring compliance by the Owners with their obligations herein.

Agreements

7.

(i) The level of noise emissions referred to in this Agreement shall be measured over a ten minute period with a precision grade sound level meter (of a least a Type 1 quality) using a half inch diameter microphone in free field conditions 1.2 metres above ground level and at least 3.6 metres away from any wall hedge or reflective surface (using a slow time weighted response).

(ii) If the turbines in operation on the Site shall be of the type referred to in Clause 2 measurements under this Agreement of noise levels at the slower speed of operation and the higher speed of operation of the turbines shall be made with average hub height wind speeds of 6 metres and 9 metres per second respectively.

(iii) If the turbines in operation on the Site shall be of a type other than that referred to in Clause 2 the scheme to be submitted under Clause 4 shall include proposals for an alternative basis of measurement to that described in Clause 7 (ii).

(iv) Following a reasonable period of operation of the turbines if upon representations by the First Owner the Planning and Development Officer is of the opinion that other levels of noise emission ("the Alternative Levels") than specified in Clause 5(i) and Clause 5(iv) would give rise to no nuisance to dwellings beyond a distance of 350 metres from any of the turbines the parties hereto shall conclude a Supplemental Agreement whereby the First Owner the Second Owner the Third Owner and the Fourth Owner shall jointly and severally covenant to comply with the Alternative Levels in place of the levels specified in the said Clauses.

(v) Clause X of this Agreement (*an arbitration provision*) shall apply to any disagreement between the First Owner and the Council arising under Clause 7 (iv) hereof.

(vi) For the purposes of this Agreement the change over speed from low (32rpm) to high (48 rpm) or from high to low speed operation shall not occur at a wind speed of less than 8 metres per second at hub height (25 metres above ground).

8. For the avoidance of doubt it is hereby agreed that this Agreement does not prevent the Council or the Owners or any of them from exercising any other powers or taking any legal proceedings under any other legislation including the Environment Protection Act 1990 in respect of any noise nuisance.

Cold Northcott
(North Cornwall District Council)

A2 (a) The following conditions were attached to a planning permission issued by the Council on 12 February 1992 for the erection of 23 horizontal axis wind turbines:

1. The cut in wind speed for wind turbine generator operations shall not be less than 5 metres per second measured at hub height of 25 metres above ground level unless otherwise agreed with the Local Planning Authority.

2. The noise level expressed on a ten minute L50 basis from the cumulative site of the wind turbine generators as measured at any dwelling beyond a distance of 380 metres from any of the turbines shall not exceed levels of 40dB(A) during low speed operation or 45dBA during high speed operation when the ambient noise level at the location is not greater than 35dB(A) when measured in accordance with the following method: the level of noise emissions referred to in this Agreement shall be measured over a ten minute period with a precision grade sound level meter (of at least a Type 1 quality) using a half-inch diameter microphone in free field conditions 1.2 metres above ground level and at least 4 metres from any wall or other reflective surface (using a slow time weighted response). If after the Turbines commence operation variations to these limits are agreed in writing by the Planning and Development Officer (on the grounds that it would appear that no noise nuisance would be created at the varied levels) then such agreed variations shall be complied with.

3. Subject to the provisions of Condition 2 noise emitted from the Turbines as measured at any dwelling beyond 380 metres and when measured over a ten minute period with a precision grade sound level meter of at least a Type 1 quality using a half inch diameter microphone in free field conditions 1.2 metres above ground level and at least 4 metres from any wall or other reflective surface using a slow time weighted response shall not exceed the ambient L50 plus 5dBA.

4. The change-over speed from low (32 rpm) to high (48 rpm) or from high to low speed operation shall not occur at a wind speed of less than 8 metres per second measured at hub height 25 metres above ground.

5. There shall be no audible tonal component to the noise emitted by the turbines so as to cause a nuisance to the occupiers of any dwelling

beyond a distance of 380 metres from any of the wind turbine generators.

6. The Best Practicable Means shall be employed to the satisfaction of the Local Planning Authority in order to prevent and minimise the creation of any nuisance by noise emission during the erection operation and use of the wind turbine generators "Best Practicable Means" shall have the meaning given to it by Section 79(9) of the Environmental Protection Act 1990.

All the above planning conditions were imposed for the following reason:

To ensure that noise emitted by the operation of the turbines does not have a detrimental effect on the amenities of the locality and in particular on the local residents living in the vicinity of the site.

(b) In addition to the planning conditions the following covenants and agreements were made in a Section 106 TCPA 1990 Obligation (the clause numbering has been altered for this Report):

1. No turbines shall be erected on the Site until details and engineering specifications of the precise type of turbine have been agreed in writing by the Planning and Development Officer for the time being of the Council and thereafter no other type of turbines shall be erected unless it has been subsequently approved in writing by the Planning and Development Officer (such approval not to be unreasonably withheld).

2. No wind turbine generator shall be erected in a position which is closer than 380 metres from any dwelling existing at the date of this Agreement.

3. Before any of the Turbines are brought into use the Leaseholder shall submit and obtain the written approval of the Planning and Development Officer (such approval not to be unreasonably withheld) for a scheme for the measurement of machine noise emissions and for the keeping of records of such noise emissions and thereafter the said records shall be kept in accordance with the said scheme and shall be made available at all reasonable times for inspection by the Planning and Development Officer and it is hereby agreed that in the event that the scheme is not approved in writing by the Planning and Development Officer within 28 days of such submission the question of whether the scheme is reasonable can be referred to arbitration in accordance with Clause X hereof

4. To comply with the following requirements relating to noise:

   (i) Subject to the provisions of Clause 5(iv) hereof the L50 noise level resulting from the combined effect of the wind turbine generators as measured at any dwelling beyond a distance of 380 metres from any of the Turbines shall not exceed 40dB(A) during low speed operations or 45dB(A) during high speed operation when measured in accordance with the method described in Clause 5(i).

(ii) The noise emitted from the Turbines as heard at any such dwelling within the area defined in Clause 4(i) shall not be irregular enough to attract attention, contain distinguishable discrete continuous notes or distinct impulses such as to cause (in the reasonable opinion of the Planning and Development Officer) a nuisance to the occupiers of any such dwelling beyond a distance of 380 metres from any of the Turbines within the area defined in Clause 4(i).

(iii) The best practical means shall be employed to the reasonable satisfaction of the Planning and Development Officer in order to minimise the creation of any nuisance by noiseemission during the erection operation and use of the turbines. "Best Practicable Means" shall have the meaning given to it by Section 79 (9) of the Environmental Protection Act 1990.

Ag reemen t

5(i) The level of noise emissions referred to in this Agreement shall be measured over a ten minute period with a precision grade sound level meter (of at least a Type 1 quality) using a half inch diameter microphone in free field conditions 1.2 metres above ground and at least four metres from any wall, hedge or reflective surface (using a slow time weighted response).

5(ii) If the Turbines in operation on the Site shall be of a 2-speed type measurements under this Agreement of noise levels at the slowest speed of operation and the hig herspeed of operation of the Turbines shall be made with average hub height wind speeds of 6 metres and 9 metres per second respectively.

5(i i) If the Turbines in operation on the Site shall be of a type other than the 2-speed type the scheme to be submitted under Clause 3 shall include proposals for an alternative basis of measurement to that described in Clause 5(ii) to the satisfaction of the Planning and Development Officer.

5(iv) Following a reasonable period of operation of the Turbines if upon representations by the Owner and Leaseholder the Planning and Development Officer is of the opinion that other levels of noise emission ("the Alternative Levels") than specified in Clause 4(i) would give rise to no nuisance to dwellings beyond a distance of 380 metres from any of the Turbines the parties hereto shall conclude a Supplemental Agreement whereby the Owner covenants to comply with the Alternative Levels in place of the levels specified in the said Clauses.

5(v) Clause X of this Agreement (*an arbitration provision*) shall apply to any disagreement between the Owner and/or the Leaseholder and the Council arising under Clause 5(iv) hereof.

5(vi) For the purposes of this Agreement the changeover speed from low (32 rpm) to high (48 rpm) or from high to low speed operation shall not occur at a wind speed of less than 8 metres per second measured at hub height of 25 metres above ground.

Rhyd-y-Groes, Ynys Mon/Anglesey
(Cyngor Bwrdeistref Ynys Mon)

A.3 The following conditions relating to noise were attached to a planning permission issued by the Council on 2 November 1992 for the erection of 24 wind turbines:

1. No wind generator shall be erected in a position which is closer than 400 metres from any dwelling existing at the date of this permission.

2. The level of noise emissions referred to in condition 5 shall be measured over six periods of ten minutes within a total of one hour with a precision grade sound level meter (incorporating best current practice) using a half inch diameter microphone in free field conditions, 1.2 metres above ground level and at least 3.6 metres from any wall, hedge or reflective surface (using a slow time weighted response).

3. In order to evaluate compliance with the level of noise emissions referred to in condition 5 background sound pressure level measurements shall be made:

(a) during the hour before or the hour after the measurements referred to in condition 2 and

(b) such background sound pressure level measurements shall be expressed on an L(a)eq index.

4. The measurements made in accordance with conditions 2 and 3 shall both be correlated with wind speeds measured at hub height over the same periods as described in condition 3.

5. When measured in accordance with the method described in condition 2 the level of noise emissions resulting from the combined effect of the wind generators as measured at any dwelling existing at the date of this permission beyond a distance of 400 metres from any of the turbines shall not exceed 40dBL(a)eq measured at 5 metres per second at hub height.

6. The level noise emitted by the combined effect of the wind generators (when measured and correlated in accordance with condition 2, 3 and 4) shall be demonstrated at the request of the Local Planning Authority on commissioning and thereafter every twelve months.

The reason given for the position of the above planning conditions is:

> To ensure that the development will be satisfactory from an amenity and architectural point of view

Penrhys, Rhondda
(Rhondda Borough Council)

A.4 The following condition was attached to a planning permission dated 2 April 1993 granted on appeal against the refusal of the Council to grant planning permission for the erection of 12 turbines:

"The level of noise emissions resulting from the combined effect of the wind turbine generators as measured at any dwelling (in existence at the date of this letter) beyond a distance of 400 metres from any of the wind turbine generators shall not exceed 7.5dBL(A)90 above the background sound pressure levels measured in accordance with a method to be agreed by the planning authority."

FourBurrows, Cornwall
(Carrick District Council)

A.5 The following conditions relating to noise were imposed on the grant of planning permission dated 6 August 1993 on appeal against the refusal of the Council to grant planning permission for the erection of 15 wind turbine generators:

1. The level of noise emissions referred to in condition 4 shall be measured using the LA90 10 minutes level over a minimum of 6 consecutive periods of 10 minute with a precision grade sound level meter of at least type 1 quality, (incorporating best current practice), using a half inch diameter microphone in free field conditions, 1.2 metres above ground level and at least 3.6 metres from any wall, hedge or reflective surface (using a slow time weighted response). The LA90 ten minute

level at a hub height wind speed of 5m/sec shall be derived using a linear regression of the measured noise levels.

2. In order to evaluate compliance with the level of noise emissions referred to in condition 4 background sound pressure level measurements shall be made: (a) during the hour before or the hour after the measurements referred to in condition 1; and (b) such background sound pressure measurements shall be made on an LA90 10 minute index.

3. The measurements made in accordance with conditions 1 and 2 shall both be correlated with wind speeds measured at hub height over the same periods as described in condition 1. The background noise level shall be derived for a hub height wind speed of 5m/sec by use of a linear regression undertaken upon the measured noise levels.

4. When measured in accordance with the method described in condition 1 the level of noise emissions resulting from the combined effect of the wind turbine generators as measured at any dwelling existing at the date of this permission shall not exceed the following LA90 10 minute noise levels with the on-site measured wind speed of 5m/sec at hub height:

Four Burrows	42dB(A)
Four Burrows Farm	40dB(A)
Silver Valley	37dB(A)
Chybucca	37dB(A)
Causilgey	37dB(A)
Carvinack Brake	40dB(A)
Carvinack	37dB(A)
Creegmeor Farm	40dB(A)

5. The level of noise emitted by the combined effect of wind generators (when measured and correlated in accordance with conditions 1 to 3), shall be demonstrated at the request of the local planning authority on commissioning and thereafter every 12 months.

6. If the noise emissions resulting from the wind farm as measured at any residential property referred to in condition 4 contain a distinguishable tonal character as defined in "The Assessment of Audible Tones Second Draft, Carrick District Council", the noise limits specified in condition 4 shall be reduced by 5dB.

Bryn Ti tl, Powys
(Radnors hire District Co uncil)

A.6 The following conditions relating to noise were imposed on the planning permission granted by the Council on 9 August 1993 to erect 22 wind turbines:

1. When measurements are made in accordance with the method described in condition 2 the level of noise emissions resulting from the combined effect of the wind turbine generators as measured at any dwelling existing at the date of this permission beyond a distance of 400 metres from any of the turbines shall not exceed 40dB(A)Leq (5 minutes) at an on-site measured wind speed of 6 metres per second at hub height, or 5dBA above the Laeq (5 minutes) background as measured in accordance with condition 3 whichever is the greater.

2. The level of noise emissions, referred to in condition 1 shall be measured over 5 periods of five minutes within a total of one hour with a precision grade sound level meter of at least type one quality (incorporating best current practice) using a half inch diameter microphone in free field conditions 1.2 metres above ground level and at least 3.6 metres from any wall, hedge or reflective surface (using a fast time weighted response). The wind farm sound pressure measurements shall be recorded as LAeq 5 minute values.

3. In order to evaluate compliance with the level of noise emissions referred to in condition 1 background sound pressure level measurements shall be made:

   (a) Over 5 x 5 minute periods during the hour before or the hour after the measurements referred to in condition 2.

   (b) Such background sound pressure measurements shall be recorded as LAeq, 5 minute values.

   (c) Measurements of the LA90, 5 minute noise levels shall also be monitored throughout the measu rement period to assist in the validation of the LAeq, 5 minute measurements.

4. The measurements made in accordance with conditions 2 and 3 shall both be correlated with wind speeds measured at hub height over the same periods as described in conditions 2 and 3. The target wind speed for the measurements shall be 6 metres per second. The data pairs shall be used to determine a best fit relationship between LAeq and hub height wind speed.

5. The level of noise emitted by the combined effect of the wind generators shall be demonstrated at the request of the Local Planning

Authority on commissioning. The tests shall be carried out in the vicinity of Dolhelfa Ganol or other relevant dwelling as may be agreed.

6. Tonal noise shall be measured for audibility using the methodology described in BS 7135: Part I Annex D (or equivalent) and shall be measured at a distance of not less than 550 metres from the nearest wind turbine.

7. The tonal (narrow band) spectrum shall be measured in accordance with condition 6 over a period 2 minutes between the frequencies of 0Hz (Hertz) and 2kHz (Kilohertz) and with a maximum measurement bandwidth of 6.25Hz (Hertz).

8. If tonal noise from any of the wind turbines (when measured in accordance with conditions 6 and 7) exceeds the threshold of audibility by more than 8dB then the level of permissible noise emission referred to in condition 1 shall be reduced by 5dB.

The reason given for the imposition of the above planning conditions is:

In order to secure a satisfactory means of noise measurement to safeguard the residential amenity of local residents.

St Breock Downs, Wadebridge
(North Cornwall District Council)

A.7 The following conditions were imposed on the planning permission granted on 1 September 1993 on an appeal against the failure of the Council to determine a planning application for the erection of 11 wind turbines:

1. No wind turbine generators shall be erected in a position closer than 550m from any dwelling existing at the date of this permission.

2. No wind turbine generator shall start producing electricity at a wind speed of less than 5 metres per second measured at a hub height of 35 metres above ground level without the prior written approval of the local planning authority.

Trysglwyn Fawr, Amlwch, Ynys Mon/Anglesey
(Cyngor Bwrdeistref Ynys Mon)

A.8 The following condtions relating to noise were imposed on the grant of planning permission on appeal dated 10 December 1993 against the refusal of the Council to grant planning permission for the erection of 15 wind turbines:

1. No wind turbines shall be erected in a position which is less than 400 metres from any occupied dwelling existing at the date of this permission, except the participating properties of Trysglwyn Fawr and Taldrwst Mawr unless otherwise agreed in writing with the local planning authority.

2. The level of noise emissions resulting from the combined effect of the wind turbines hereby approved as measured at any dwelling existing at the date of this permission, except the participating properties Trysglwyn Fawr and Taldrwst Mawr, shall not exceed 40dB(A) L(A)eq 5 minutes at an on-site measured wind speed of 5 metres per second at hub height.

3. The level of noise emissions, referred to in condition 2, shall be measured in accordance with a noise monitoring scheme to be agreed in writing with the local planning authority.

4. If tonal noise from any of the turbines hereby permitted, when measured in accordance with condition 3, exceeds the threshold of audibility by more than 8dB then the level of permissable noise emission referred to in condition 2 shall be reduced by 5dB.

5. The level of noise emitted by the combined effect of the turbines hereby permitted shall be demonstrated at the request of the local planning authority on commissioning and annually thereafter in accordance with the noise monitoring scheme referred to in condition 3.

Carland Cross, Mitchell, Cornwall
(Carrick District Council)

A.9 No conditions relating to noise were imposed on the planning permission issued by the Council on 29 April 1992. Control over noise emissions is exercised through a Planning Obligation dated 29 April 1992 and the following covenants were given to the developer (the clause numbering has been altered for this Report):

1. No Turbines shall be erected on the site until the details and engineering specifications of the precise type of Turbine have been approved in writing (such approval not to be unreasonably withheld) by the Chief Planning Officer for the time being of the Council ("the Chief Planning

Officer") and thereafter no other type of Turbine shall be erected unless it has been approved in writing by the Chief Planning Officer (such approval not to be unreasonably withheld or delayed).

2. No Turbines shall be erected in a position which is closer than 350 metres from any dwelling existing at the date of this Agreement.

3. None of the Turbines shall be brought into use until:

(i) a scheme for the measurement of machine noise emissions and hub height wind speeds to operate for a period of two years from the date of the Turbines coming into use and for the keeping of records of such noise emissions and wind speeds ("the Scheme") is submitted for the approval of the Chief Planning Officer and

(ii) written approval to the Scheme is provided by the Chief Planning Officer (such approval not to be unreasonably withheld or delayed) and upon the Turbines being brought into use the Scheme as approved shall be implemented and the said records shall be kept in accordance with the Scheme and shall be made available at all reasonable times for inspection by the Chief Planning Officer.

4. (i) Subject to the provisions contained in clause 5(c) hereof the L90dB(A) noise level resulting from combined effect of the Turbines as measured within 10 metres of the facade at any dwelling at or beyond a distance of 350 metres from any of the Turbines shall not cause the prevailing background noise level to be increased by more than 7.5dB(A) when measured in accordance with the method described in clause 5 hereof; and

(ii) notwithstanding clause 4(i) above if the noise emitted from the Turbines as heard and measured at any such dwelling at or beyond a distance of 350 metres from any of the Turbines contains distinguishable discreet continuance (sic) notes or distinct impulses as specified in paragraph 7.2 of BS 4142 1990, then the noise from any of the turbines shall not cause the prevailing background noise level (L90dB(A)) to be increased by more than 2.5dB(A) when measured in accordance with the method described in clause 5 hereof.

(iii) (a) In the event that the noise levels specified in the sub-clauses 4(i) or 4(ii) above or both whichever apply are exceeded when measured in accordance with the method described in clause 5 the best practical means shall be employed to the reasonable satisfaction of the Chief Planning Officer in order to reduce within 14 days of the date of the completion of the said measurement or within such longer period as may be allowed by the Chief Planning Officer the noise emission to the levels specified in sub-clauses 4(i) or 4(ii) hereof or both whichever apply during the operation and use of the Turbines. "Best Practicable Means" shall have the meaning given to it by Section 79(9) of the Environmental Protection Act 1990.

(b) If at the expiry of the period specified in sub-clauses 4iii(a) above the noise levels specified in sub-clause 4(i) or 4(ii) or both whichever apply continue to be exceeded then the Owners and Leaseholder shall forthwith use whatever means are necessary to comply with sub clauses 4(i) or 4(ii) or both whichever apply.

5. (a) The L90dB(A) noise level emissions referred to in this Agreement shall be measured over a ten minute period with a precision grade sound level meter of at least Type 1 quality using a half inch diameter microphone calibrated in accordance with paragraph 4.1 and 4.2 of BS4142 1990 positioned in free field conditions 1.2 metres above ground level and at least 3.6 metres from any wall hedge or reflective surface using a fast time weighted response.

(b) The standard of measurement applied in this Agreement shall be as specified in paragraph 5.4.1 of BS4142 1990 with regard to prevailing weather conditions over the measurement period.

(c) The increase in the L90dB(A) background noise level referred to in this Agreement shall be determined as the difference of the noise levels measured in accordance with the method described in Clause 5(a) and 5(b) with the Turbines in operation and the Turbines stopped. The measurement period shall be consecutive where practicably possible and the average of 4 such measurements shall constitute a result.

Gonnhilly, Cornwall
(Kerrier District Council)

A.10 (a) The following condition relating to noise was attached to a planning permission issued by the Council on 7 December 1992 for the erection of 14 wind turbine generators:

"All practicable means shall be employed by the developer for preventing and minimising the emission of dust or smell or the creation of noise during the tipping of excavated material derived from carrying out the development hereby permitted".

(b) In addition to the planning conditions the following covenants were given in a Planning Obligation (the clause numbering has been altered for this Report):

1. All practicable means shall be employed by the owner and/or the operator of the wind turbine generators for preventing and minimising the emission of dust, smoke and fumes and the creation of noise during the approved use of site. The word "practicable" and the phrase "practical means" in this Agreement shall have the meanings assigned to them in Section 79(9) of the Environmental Protection Act, 1990, as defined hereafter. The provisions of this paragraph include the installation of and maintenance of effective silencers on all plant and machinery.

Definition

Section 79(9) of the Environmental Protection Act, 1990:

"Practicable" means reasonably practicable having regard among other things to local conditions and circumstances, to the current state of technical knowledge and to the financial implications; the means to be employed include the design, installation, maintenance and manner and periods of operation of plant and machinery, and the design, construction and maintenance of buildings and structures.

2. Each of the wind turbine generators the subject of this Agreement shall be erected within 10 metres of the positions shown on the submitted drawings and shall not be relocated from such positions without the prior written approval of the Council, such approval being within the absolute discretion of the Council.

3. Notwithstanding the provisions of Paragraph 2 of this Schedule no wind turbine generators shall be sited closer than 370 metres to any residential premises existing at the date of this Agreement, which the Owner shall identify on a 1:2500 scale plan to be submitted to the Council for approval within two months of the date of this Agreement.

4. No wind turbine generator shall commence productive operation at a wind speed of less than 5 metres per second at a hub height of 32 metres above existing ground level without the prior written approval of the Council.

5. If the noise emitted by the wind farm at any distance greater than 370 metres from an individual wind turbine generator contains:

(i) any distinguishable, discrete, continuous notes (whine, hiss, screech, hum or similar noise);

(ii) distinct impulses (bangs, clicks, clutters, thumps or similar noises);

(iii) a characteristic noise sufficiently irregular to attract attention;

an arbitrary reduction of 5dB(A) shall be applied to the noise limit defined in Paragraph 8 of this Schedule.

6. The Sound Power Level of any wind turbine generator during the approved use of the site calculated from measurements at 50 metres from that wind turbine generator by the method in the attached IEA booklet 4 "Acoustics Measurement of Noise Emission from Wind Turbines" shall not exceed a value of 99dBA for a hub height wind speed of 8.8 metres per second. Alternatively, if wind speed is available at a height of 10 metres then the corresponding wind speed is 8 metres per second. The calculation shall be made using at least 5 measurements over individual time periods of not more than 10 minutes, to be agreed in advance by the Council within a wind speed range of plus or minus 2 metres per second of the reference wind speed noted of either 8.8 or 8 metres per seconds respectively.

7. When measured in accordance with the method described in Paragraph 8 hereof the combined level of noise from all the wind turbine generators at any time shall not exceed 36dBA as measured at any dwelling existing at the date of the grant of the Planning Permission beyond a distance of 370 metres from any wind turbine generator.

8. The noise level shall be measured 1.2 metres above the ground at least 3.6 metres from any wall, hedge or reflective surface using a Precision grade sound level meter of Type 2 or better equipped with a ½" microphone. The measurement shall be made as LA90 for a time period of not more than 10 minutes, to be agreed in advance by the Council.

At least five measurement periods in the hub height wind speed range of 5 to 8 metres per second shall be used to provide a regression line for predicting the noise level at 5 metres per second.

The noise measurement may be carried out only when all wind turbine generators are operating and the wind speed in any measurement period is averaged over all the wind turbine generators if agreed in advance by the Council.

Llangwyryfon, Dyfed
(Cyngor Dosbarth Ceredigion)

A.11 The following conditions relating to noise were attached to a planning permission issued by the Council in 1992 for the erection of 20 wind turbine generators:

1. At the critical wind speed (ie the speed at which the noise radiated by the total complement of wind turbines and blades is most substantially in excess of ambient noise) the noise from the wind park, as measured externally at any dwelling house, shall not exceed 45dB(A).

2. In the event of any noise complaint, investigated and judged by the authority to be justified, the developer will demonstrate that the best practical means are being, or will be, employed to limit and/or reduce noise emissions.

3. Notwithstanding conditions 1 and 2 above the basis for the reasonableness of a noise complaint shall be L50 plus 5dB(A) at the external wall of any dwelling house.

4. The developer will undertake measurements of noise levels during the first year of the operation of the wind turbines in a scheme to be agreed by the local planning authority to determine the characteristics of noise radiation. The data produced in accordance with the scheme shall be forwarded to the local planning authority on request.

The reason given for the imposition of the above planning conditions is:

To ensure a minimum level of noise disturbance.

APPENDIX B

PRACTICE TO DATE IN CONTROLLING NOISE EMISSIONS FROM WIND GENERATORS IN THE USA

Alameda County (Resolution Z-7500, February 1992)

- *No electric wind generator shall be located closer than 1000 feet (304.8 metres) in an upwind (generally south-westerly to west-south-westerly) direction or closer than 300 feet in any other direction from any existing dwelling or building site. These setbacks may be reduced by a maximum of 50% with the written, notarised and recorded concurrence of the affected property owner.*

- *The following procedures should be adhered to in the event of a reasonable complaint that noise levels from an operating wind turbine or wind farm exceed the levels described in the application, or that noise levels from a rebuilt wind turbine or wind farm exceed either 55dB(A) (L_{dn}) or 70dB(C) (L_{dn}) at the exterior of any dwelling unit within a minimum distance of 1000 feet:*

  1. *A hearing shall be scheduled between the Permittee and the Zoning Administrator*

  2. *A qualified firm shall be engaged to make a site-specific study and furnish a report and recommendation as to the Permittee's conformance with all applicable noise regulations.*

  3. *The permittee shall attempt in good faith to negotiate a resolution of this matter with the party making the allegation.*

  4. *Until the conclusion of the complaint proceedings, one fourth of the wind turbines authorised to be constructed and maintained in closest proximity to the dwelling or building site of the party making the allegation shall not be operated.*

- *Acoustic measurement and reporting procedures shall attain or exceed the minimum standards for precision described in AWEA First Tier standard. The Zoning Administrator, in consultation with the County Environmental Health Services, shall establish criteria for noise samples and measurement parameters (e.g., the duration of the data collection, time of day, wind speed, atmospheric conditions and direction) following the guidelines established by Wyle Research.*

Contra Costa County

In 1985, Contra Costa County adopted a WECS (Wind Energy Conversion System) ordinance as Chapter 88-3 of the County code. This ordinance can be summarised as follows:

- *According to Section 88-3.404, a WECS located on residential property may operate only between the hours of 08:00 Hrs and 1800 Hrs.*

- *According to Section 88-3.602, a minimum WECS setback of three times overall machine height (measured from grade to the top of the structure, including the uppermost extension of any blades) or 500 feet, which ever is the greater, shall be maintained from exterior project boundaries. A minimum WECS setback of 1000 feet shall be maintained from any existing legal off-site residence or General Plan designated residential areas.*

- *According to Section 88-3.612, no WECS shall create noise which exceeds 65dB(A) L_{eq} (over any averaging time), as measured at the lot line.*

Solano County

The *Wind Turbine Siting Plan & Environmental Impact Report*, prepared in 1987, found that:

- *Although the majority of the county was already at 50dB(A) CNEL or greater, a 50dB(A) CNEL standard for noise generated at neighbouring residencies was adopted as a standard for WECS to preserve compatibility with other General Plan criteria for stationary noise sources.*

- *A 47dB(A) Leq standard was established under the assumption that, under typical WECS operating conditions, it would be equivalent to a 50dB(A) CNEL (i.e. a wind turbine operating 50 % of the time, as is typical during the productive season in the Altamont area, would produce a CNEL about 3dB(A) higher than the 24-Hour average L_{eq}).*

- *Typical noise impact areas adjacent to WECS extend from 1000 {305 m} to 1800 {550 m} feet from the nearest wind turbines based upon standards described above. Actual setbacks are determined on a case-by-case basis, based on computer noise modelling for the specific turbine models and array patterns proposed.*

- *WECS developers must develop a noise monitoring program in co-operation with the County Division of Environmental Management and, if necessary, impose noise mitigations (eg revised spacing patterns of turbine).*

The final recommendations contained within the report are a compromise between all of the standards which have been adopted by the Tri-Counties.

The recommendations on noise are as follows:

Establish a consistent noise level standard for WECS near residencies. A noise level standard of 55dB(A) CNEL should be established, measured at existing residencies or potential residential development sites.

This standard would be a compromise between Solano County's 50dB(A) CNEL (47dB(A) L_{eq}) and Contra Costa County's 65dB(A) L_{eq}.

The use of a 55dB(A) noise level standard would provide for a slight increase above ambient noise levels in many cases, but would not exceed state exposure standards for residential areas or significantly deteriorate the rural atmosphere of the wind resource areas, given the natural noise of the wind and other activity in the area. Wyle Research WR 88-19 provides that 60dB(A) may be appropriate, but a 55dB(A) standard should be considered in areas that were especially quiet prior to installation of wind turbines.

The L_{dn}, day-night average noise level, is a 24-hour average L_{eq} with a 10dB(A) weighting added to noise which is emitted during the hours of 22:00-07:00 to account for the greater nocturnal sensitivity of people.

The CNEL (Community Noise Equivalent Level) allows a correction to be applied for increased sensitivity during the evening as well as the night. A 5dB penalty is applied for noise emitted during the 19:00-22:00 period.

If we compare these criteria levels in terms of 24-hour L_{eq} then the table below details the relative levels:

L_{eq} dB(A)	L_{dn} dB(A)	CNEL dB(A)
25	31.40	31.66
35	41.40	41.66
45	51.40	51.66

Riverside County

Resolution No. 93-378
Amending and Superseding Resolution No. 86-180
Adopting Technical Specifications and Criteria for the Measurement and Projection of Noise from Commercial WECS Projects.

The County of Riverside is within the state of California. On the 5th October 1993 the above resolution was passed concerning the development of wind turbines and the assessment of noise that they radiate. This resolution covers the testing and assessment of the noise that is emitted by wind turbines, and proposes a method for the determination of the noise levels that may be expected from the development of a wind farm.

Included within the resolution are the following definitions:

a) *Observed representative noise level: the measured noise level excluding pseudo-noise, wind noise, vegetation noise and transient noise events from sources other than the subject noise source.*

b) *Pseudo-noise: the noise perceived by the microphone and originating from the air flow turbulence around the diaphragm of the microphone.*

c) *Vegetation noise: the noise resulting from the rattling of leaves and other vegetation excited by the wind.*

d) *Wind noise: the noise of the wind itself originating from turbulence in the air.*

Recommendations are made for the measurement of the emitted noise from the wind turbines. However, these follow neither the guidance that is given within the IEA method of turbine evaluation nor the Danish Statutory Order, measurements being performed at a height above ground level of 5'. This compares with the ground board measurement method that is used for the determination of the sound power level of a wind turbine within the IEA and Danish Statutory Order.

Measurements are required of the L_{A90}, L_{A50} and L_{Aeq} noise levels using a slow time weighting. The procedure for determining the A-weighted noise level from the turbine considers the measured L_{A90} noise levels to determine the signal to noise ratio of the measured noise. This allows any corrections to be assessed and applied to the measured noise if the background noise level at the measurement position is near that of the wind turbine when it is operating. It is proposed within the resolution that if the turbine noise level is greater than 10dB above the background noise level then no correction need be applied. If the noise level is between 3dB and 10dB above the background noise level when the wind turbine is not operating then the intensity subtraction should be used. This method is outlined within BS 4142 for the correction of measured noise levels when performing an assessment. When the measured noise level from the turbine is not more than 3dB above the background noise level then cross-correlation techniques should be used. However, it is also stressed that this procedure is not preferred and will not be accepted if other procedures are feasible.

Measurements are also required to determine the directivity of the emitted noise from the wind turbines. This requires that measurements are made at the four positions around the wind turbine and are correlated with the downwind measurement position.

To assess the tonal characteristics of the wind turbines, one-third octave noise measurements are also required. These measurements are required to cover the frequency bands from 20 Hz up to at least 8000 Hz. These measurements are to be performed for an operating condition of an average power output of 30 % ± 15 % of the maximum rated power of the wind turbine.

Noise measurements of the wind turbine are required to cover three operating conditions. These are defined as low (20 % ± 5 % of maximum rated power {MRP}), medium (50 % ± 10 % MRP) and high (90 % ± 10 % MRP) wind speed conditions. However, although a minimum measurement period of 30 minutes is proposed there is no attempt to correlate the measured wind speed with the measured noise level. Therefore, the measurements would appear to be an attempt to obtain an indicative noise level rather than a precise measurement of the emitted noise from the wind turbine.

Measurements are also proposed to determine the reference level of the wind turbine noise at a distance of 400' downwind of the wind turbine. These measurements are to be made when the low wind speed conditions are prevailing. It is then proposed to use the near-turbine noise measurements to predict the noise level from the wind turbine at the high wind speed condition. It is this level that is then used to determine the maximum noise level from the wind farm. These noise levels are determined by the use of the L_{A90} noise level that has been measured.

The County proposes to use this data to determine the noise level from the proposed wind farm development at the high wind speed condition. This is because the noise limits that are proposed for Riverside County are set as not to be exceeded noise levels. The prediction of the noise levels by the County will be used for the granting of permits to build. However, a measurement methodology is proposed for the assessment of a working wind farm where measurements of the L_{A90} noise level should be performed for a minimum of 30 minutes. The noise criteria are set out as follows:

TECHNICAL SPECIFICATIONS AND CRITERIA FOR SUBSTANTIAL CONFORMANCE

For wind farms with an original residential noise limit of 50 or more dB(A), the replacement WECS shall result in substantially fewer potential cumulative noise impacts as projected at the nearest residence on land designated residential in December, 1985 version of the Western Coachella Valley Plan (WCVP).

For wind farms with an original residential noise limit of 45 or less dB(A), the replacement WECS shall result in the same or substantially fewer potential cumulative noise impacts as projected to the nearest residence regardless of the underlying WCVP designation. "Same or substantially fewer potential cumulative noise impacts" shall be defined as follows:

A NON-MEASUREMENT METHOD

To elect this method the project shall comply with the following criteria:

a) The foundation of each replacement WECS including tower shall be topographically elevated above the nearest appropriate residence less than the height specified in Table A.

b) More than half of the permitted turbines shall be removed.

c) The permitted noise level for the original WECS permit shall not be less than 60dB(A)

d) The replacement WECS shall not exceed a maximum power output of 500kW. The maximum rated power output of each replacement WECS shall be provided along with tower height, total height, hub height and rotor diameter.

e) Minimum distance (as measured from the nearest WECS to nearest appropriate residence), associated maximum number of turbines and associated maximum height of WECS above the nearest appropriate residence shall conform to Table A

Table A		
Minimum Distance in feet	*Maximum Number of Turbines*	*Maximum Height (topographical) in feet*
2,000	*10**	*100*
3,000	*25**	*125*
4,000	*50**	*150*
5,000	*110**	*175*
6,000	*200**	*200*

** Can be increased (based upon the reference noise value of 70dB(A), includes 5dB(A) pure tone penalty at a slant distance of 150 feet per turbine), if noise level of the array of turbines projected (use model specified in Section 2.C. hereof with atmospheric absorption loss of 1dB(A) per 1,000 feet) to nearest appropriate residence does not exceed 55dB(A).*

B MEASUREMENT METHOD

The measurement for each replacement and remaining WECS shall be made in accordance with Section 2. hereof in terms of L_{A90} at 90% of rated power, or in accordance with the latest committee's approved version of AWEA - "Standard Procedure for Measurement of Acoustic Emissions from Wind Energy Conversion Systems" reporting the reference noise in terms of L_{Aeq} (-2dB for ground reflection) at wind velocity of 10 metres per second.

a) A-Weighted Criteria

Using the replacement and remaining WECS noise reference data for single wind turbines the modelling for projected noise levels from commercial WECS shall be done in accordance with Section 2. hereof with reference noise levels adjusted to 100 metres slant distance. Pure tone shall be defined as specified in Ordnance No. 348, Subsection d(12) of Section 18.41, a.2.

The new noise limit shall be the greater of one of the following:

a. No more than that allowed by present County ordinance (45dB(A) and pure tone criteria), or

b. 5dB(A) below original noise limit or latest substantial conformance noise limit, and

if WECS exhibit pure tone , a 5dB(A) penalty shall apply, and

if replacement WECS are at a greater height (topographically) above the nearest appropriate residence than specified in Table A, a 5dB(A) penalty shall apply, and

if less than four WECS are available for field verification, a 5dB(A) penalty shall apply.

b) Low Frequency Noise Criteria

The projected cumulative low frequency noise to the nearest appropriate residence shall not exceed the following criteria using the model specified in B deleting those sections on atmospheric attenuation loss.

The PC weighted level (as designated in "A Proposed Metric for Assessing Potential of Community Annoyance from Wind Turbine, Low Frequency Noise Emissions" SERI November 1987) of 75dB for non-impulsive and 67dB for impulsive sources representing annoyance thresholds shall be the criteria.

To determine the "PC Weighted" level at the interior of the building, steps 1 through 4 shall be adhered to as outlined in the above test under the heading of "Suggested procedure for estimating the interior LF annoyance potential of a given turbine design" and in addition, a 5dB penalty shall be added to the results of step 4.

Kern County, California

Kern County has a number of wind farms within its district. Noise has been addressed within Section 16.64.140 of the County Ordinance. It reads as follows:

J Where a residence , school, church, public library or other sensitive or highly sensitive land use, as identified in the noise element of the county general plan, is located within one (1) mile in a prevailing downwind direction or within one-half (½) mile in any other direction of a project's exterior boundary, an acoustical analysis shall be prepared by a qualified acoustical consultant prior to the issuance of any building permit. The consultant and the resulting report shall be subject to review and approval by the county health department. The report shall address any potential impacts on sensitive or highly sensitive land uses.

In addition, the acoustical report shall demonstrate that the proposed development shall comply with the following criteria:

1. *Audible noise due to wind turbine operation shall not be created which causes the exterior noise level to exceed forty-five (45) dB(A) for more than five (5) minutes out of any one (1) hour time period ($L_{8.3}$) or to exceed fifty (50) dB(A) for any period of time when measured within fifty (50) feet of any existing residence, school, hospital, church or public library.*

2. *Low frequency noise or infrasound from wind turbine operations shall not be created which causes the exterior noise level to exceed the following limits when measured within fifty (50) feet of any existing residence, school, hospital , church or public library.*

One-third Octave Band Centre Frequency (Hz)	*Sound Pressure Level (dB)*
2 to 16	*70 (each band)*
20	*68*
25	*67*
31.5	*65*
40	*62*
50	*60*
63	*57*
80	*55*
100	*52*
125	*50*

3. *In the event audible noise due to wind turbine operations contains a steady pure tone, such as a whine, screech or hum, the standards for audible noise set forth in subparagraph (1) of this subsection shall be reduced by five (5) dB(A). A pure tone is defined to exist if the one-third octave band sound pressure level in the band, including the tone, exceeds the arithmetic average of the sound pressure levels of the two (2) contiguous one-third octave bands by five (5) dB(A) for centre frequencies of five hundred (500) Hz and above, by eight (8) dB(A) for centre frequencies between one hundred sixty (160) Hz and four hundred (400) Hz , or by fifteen (15) dB(A) for centre frequencies less than or equal to one hundred twenty-five (125) Hz.*

4. *In the event the audible noise due to wind turbine operations contains repetitive impulsive sounds, the standards for audible noise set forth in subparagraph (1) of this subsection shall be reduced by five (5) dB(A).*

5. *In the event the audible noise due to wind turbine operations contains both pure tone and repetitive impulsive sounds, the standards for audible noise set forth in subparagraph (1) of this subsection shall be reduced by a total of five (5) dB(A).*

6. *In the event the ambient noise level (exclusive of the development in question) exceeds one (1) of the standards given above, the applicable standard shall be adjusted so as to equal the ambient noise level. For audible noise, the ambient noise level shall be expressed in terms of the highest whole number sound pressure level in dB(A) which is exceeded for no more than five (5) minutes per hour ($L_{8.3}$). For low-frequency noise or infrasound, the ambient noise level shall be expressed in terms of the equivalent level (L_{eq}) for the one-third octave band in question, rounded to the nearest whole decibel. Ambient noise levels shall be measured within fifty (50) feet of potentially affected existing residences, schools, hospitals, churches or public libraries. Ambient noise level measurement techniques shall employ all practical means of reducing the effects of wind-generated noise at the microphone. Ambient noise level measurements may be performed when wind velocities at the proposed project site are sufficient to allow wind turbine operation, provided that the wind velocity does not exceed thirty (30) mph at the ambient noise measurement location.*

7. *Any noise level falling between two (2) whole decibels shall be the lower of the two.*

APPENDIX C

BACKGROUND NOISE

This appendix presents results from a background noise survey and discusses the issues involved in obtaining reliable data.

Fig A1 details a time history of measurements performed at a dwelling neighbouring a proposed wind farm site, these measurements undertaken using a 5-minute time period. Wind speed measurements were also measured in 5-minute periods at an anemometer position approximately 400 metres from the dwelling. Measurements were performed over 10 days. During this time the wind blew from the south, west and north.

Fig A2 details the wind speed and direction data that were collected. The dwelling was situated to the north and east of the proposed wind turbines. Therefore, during the survey period the wind direction was such that the worst-case propagation conditions would be expected from the turbines towards the dwelling.

Fig A3 details the regression analysis performed upon all the measureddata, with rainfall removed, to derive the prevailing background noise level at the measurement position. The wind speed data have been corrected to provide the expected hub height wind speed for the proposed wind turbines that were to be installed. It will be noted that a high order polynomial has been used to derive the prevailing background noise level. Care must be used when deriving the prevailing background noise level at the extremes of the data, ie at the low and high speed ends of the curve. It may be seen from Figure 3 that at very low wind speeds the derived line is increasing with decreasing wind speed. An alternative to a polynomial is a log curve of the form

$$L_{pb} = 10 \log (10^{A/10} + 10^{(B+C \log V)/10})$$

where L_{pb} = background noise le velas a function of wind speed, dB(A)
A = constant equal to the background noise present with no wind, dB(A)
B and C = constants describing the contribution to the background noise from wind induced sources.
V = wind speed at turbine hub-height, m/s.

This curve has been derived by assuming the background noise is made up of a fixed level which does not vary with wind speed plus a contribution from wind-induced sources whose sound power varies with V^x. Curves of this form have the advantage that they tend to predict reliable levels for wind speeds at which no experimental data have been obtained.

Fig A4 details the spread of the measured data around the derived prevailing background noise level. It may be seen that the spread indicates a normal distribution around the line. It may also be seen from this Figure that the derived prevailing background noise level is 5dB higher than the measured background noise level for about 9% of the measurements. If the allowable turbine noise level above the background noise level were 5dB and it is assumed the turbine noise is constant, then it would be expected that for 9% of the operating period of the wind farm, wind turbine noise levels may exceed the prevailing background noise levels by 10dB or more.

Fig A5 details the regression analysis performed for the data collected during the evening and night-time periods. It may be seen that a lower correlation exists for this data than that derived for the all data regression line shown in Fig A3.

Fig A6 details the spread of the measured data around the derived regression line. Again, it may be seen that the derived prevailing background noise level is 5dB higher than the measured background noise level for about 9% of the time.

Fig A7 details the regression analysis performed upon the evening and night-time noise data when the wind was blowing from the development towards the dwelling, a south-westerly wind. This would be the wind direction from which the maximum noise impact from the proposed site may be expected to occur because the dwelling would be downwind of the development, although comparison with the curve for all directions shows the background noise levels to be about 2dB greater when the wind is in this direction than on average. The correlation between the measured background noise levels and the measured wind speed has greatly improved and there is a significant reduction in the scatter of the noise data around the derived line.

Fig A8 details the spread of the measured data around the derived regression line. It may be seen that the spread is greatly reduced. Furthermore, it may be seen that the derived prevailing background noise level is 5dB higher than the measured background noise level for less than 1% of the time. If an allowable turbine noise level is set at 5dB above the derived prevailing background noise level, then it should be expected that the actual background noise level will be exceeded by 10dB or more for less than 1% of the operating time at the most sensitive operating condition, ie approximately 5 minutes in every 8 hours for the critical wind speed.

The example that has been given in Figs A1 to A8 is for a dwelling that does not have any significant noise sources from sources not associated with the wind. (It may be noted that a single high L_{A90} noise level is plotted within Figs A3 and A5. This was most likely due to the running of an engine within the farmyard which was adjacent to the measurement position.) Steady sources like water were not audible at this position. Such sources can significantly change the scatter of the measured data.

Figs A9 and A10 detail the regression analysis for a dwelling positioned close to a water source. It may be seen that a significant proportion of the measurements are centred around 33-35dB L_{A90}. Fig A10 detailing the spread of the measured data around the derived prevailing background noise level indicates that measured data never fall below the derived prevailing background by more than 4dB. However, the figure also indicates that a criterion of + 5dB upon the prevailing background noise level will result in the background noise level being exceeded by 8dB or more for 30% of the operating period.

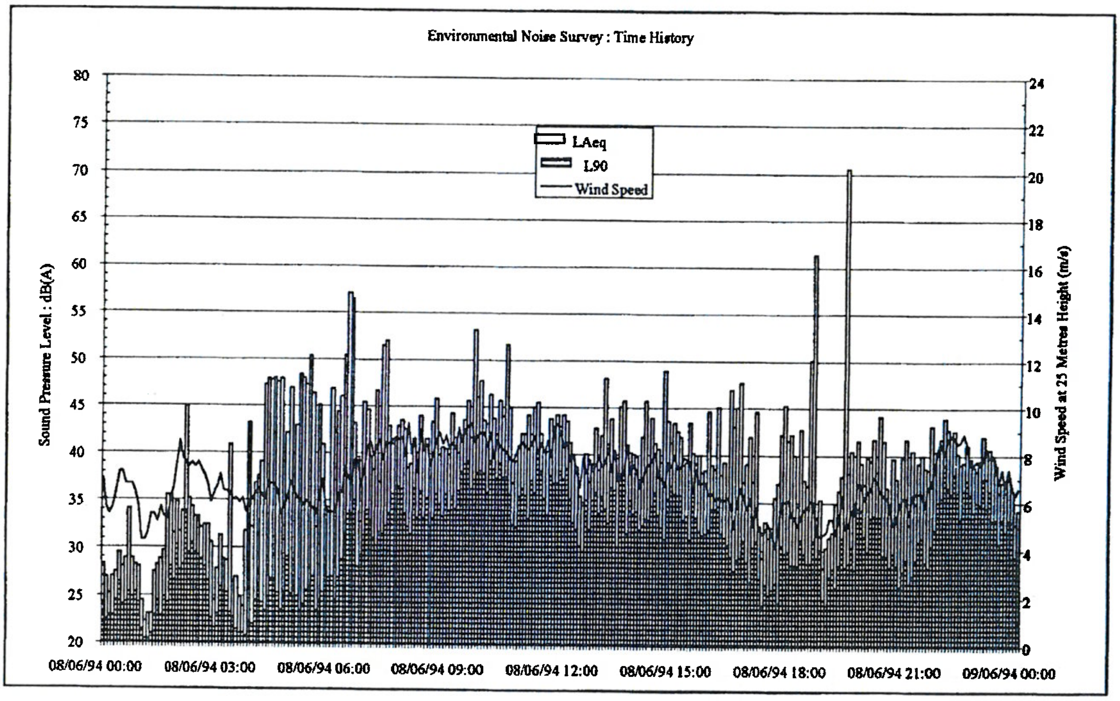


Figure A1 Typical time history measurements: singe day shown only

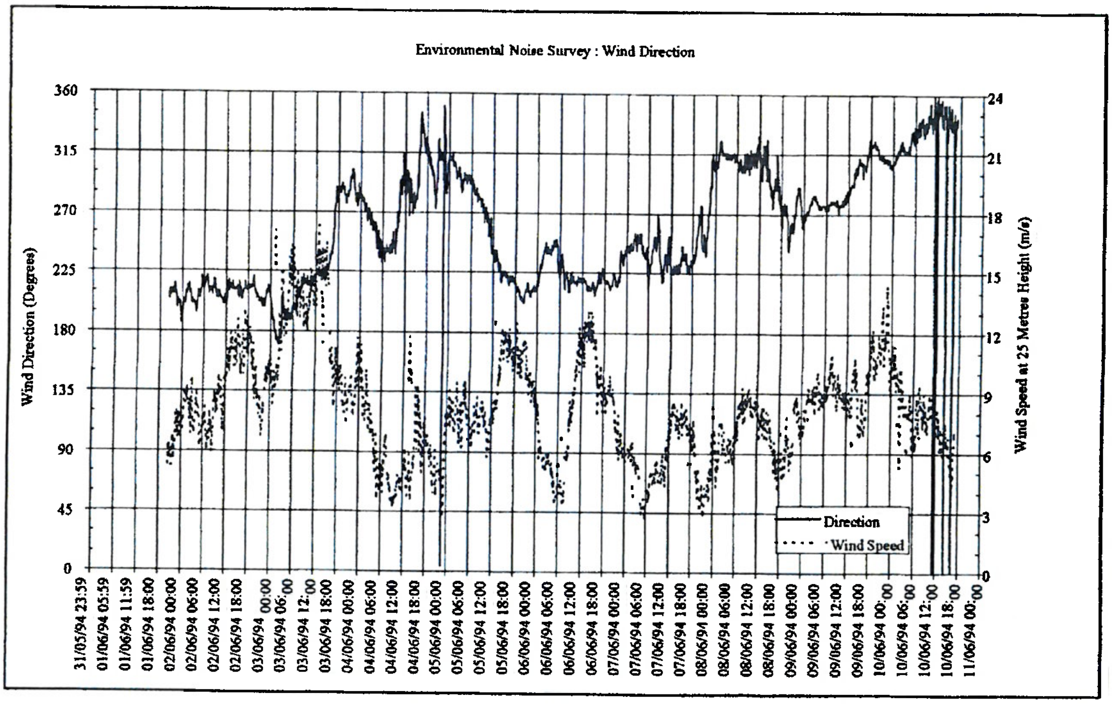


Figure A2 Typical time history of measured wind data from anemometer before site construction

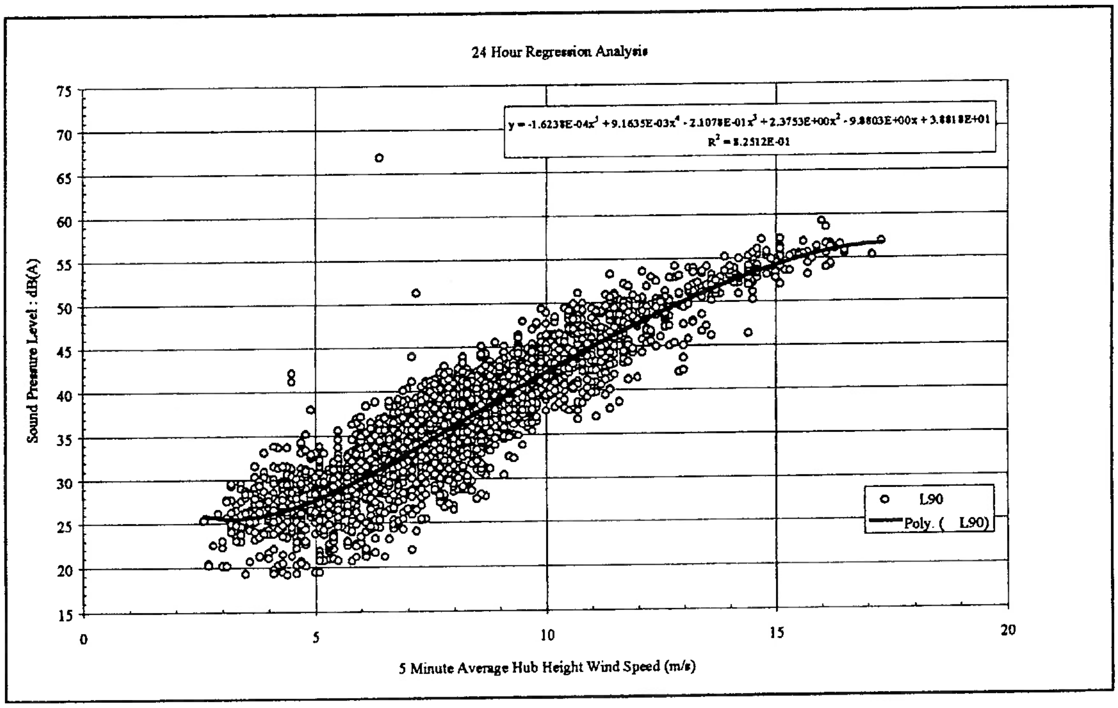


Figure A3 Regression analysis of all measured wind speed and noise data to determine the prevailing background noise level

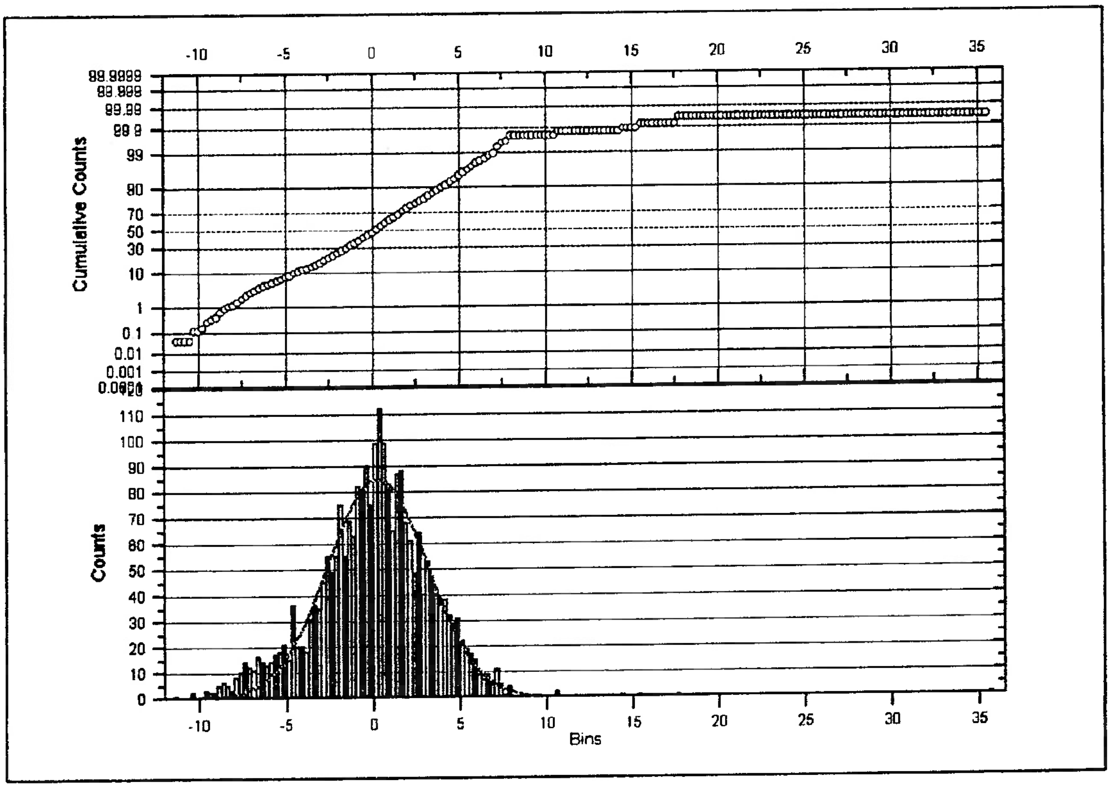


Figure A4 Deviation of measured levels around derived regression line plotted in Figure A3

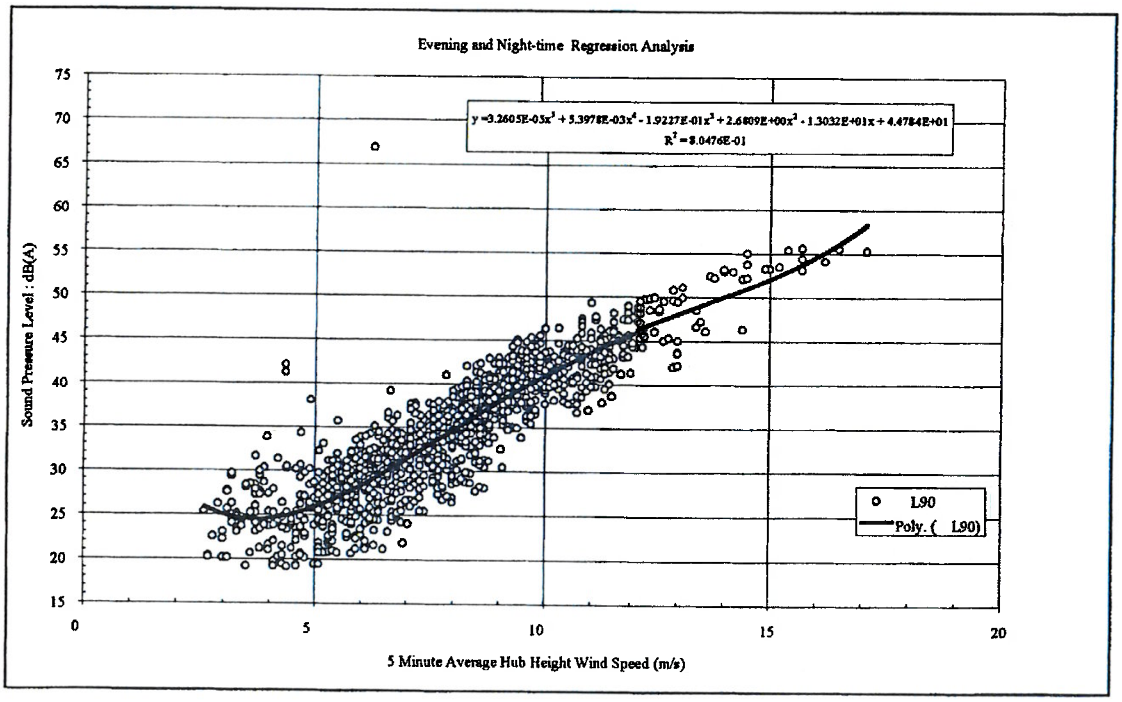


Figure A5 Regression analysis of evening and night-time measured wind speed and noise data to determine the prevailing evening and night-time background noise level

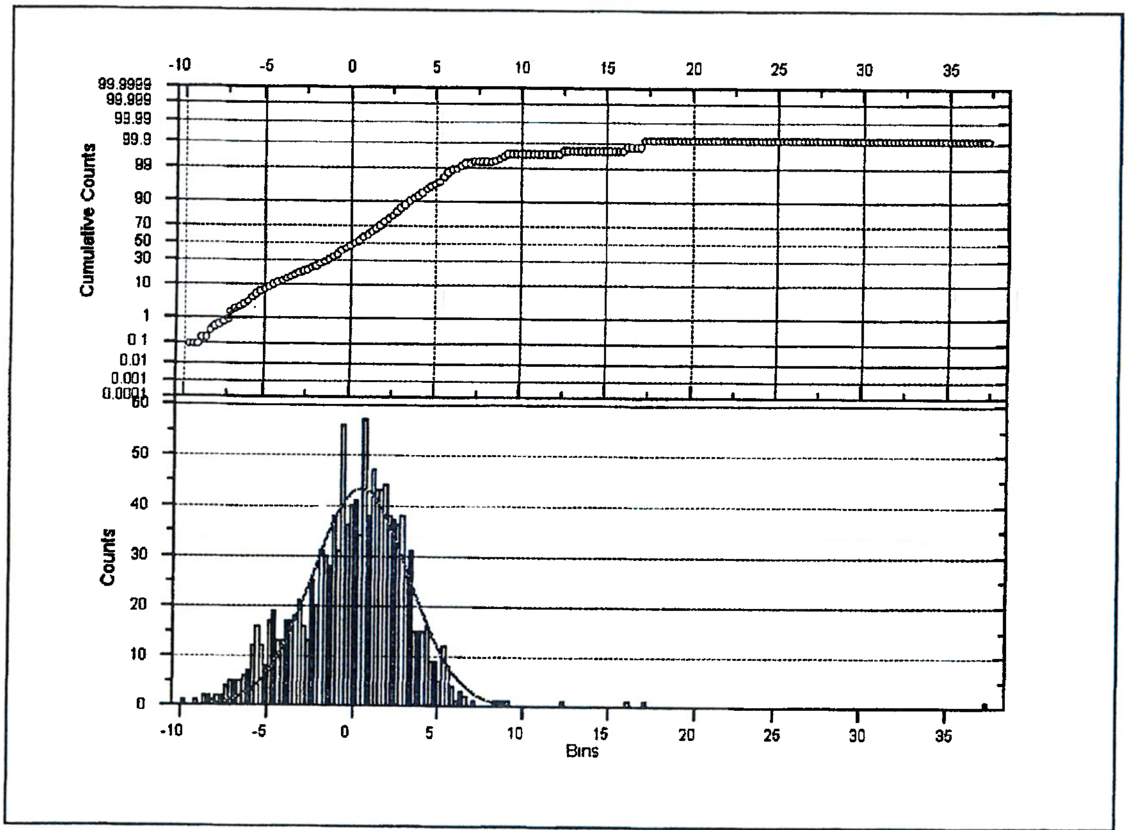


Figure A6 Deviation of measured levels around derived regression line plotted in Figure A5

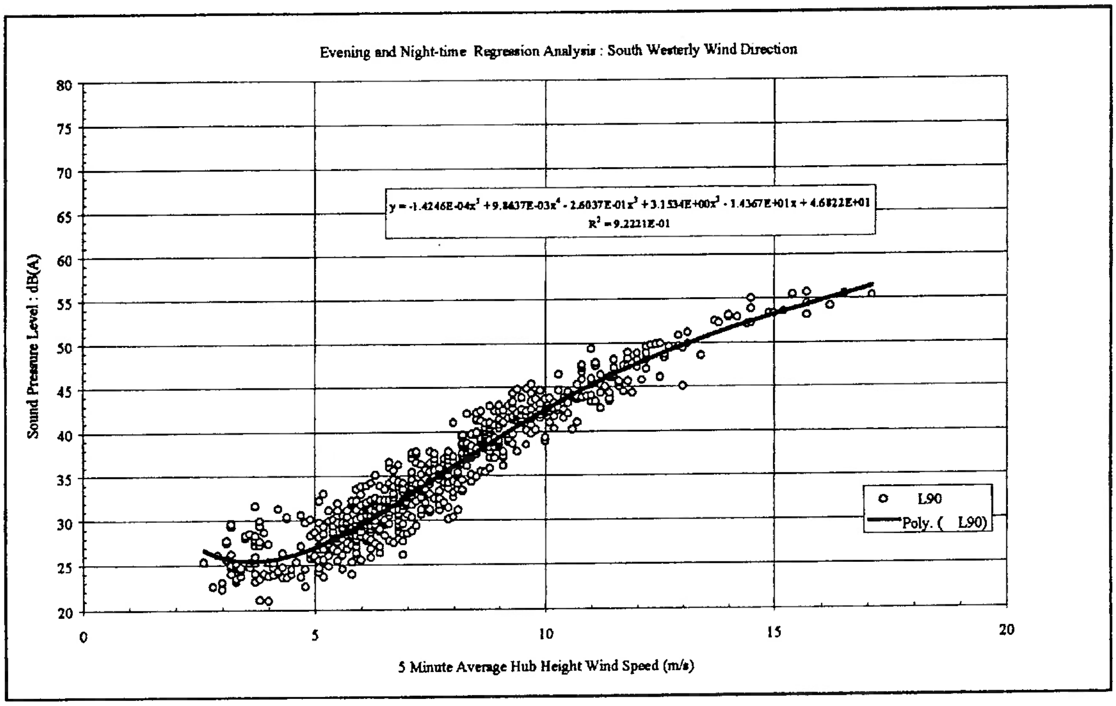


Figure A7 Regression analysis of all measured wind speed and noise data for south-westerly wind direction to determine the prevailing background noise level

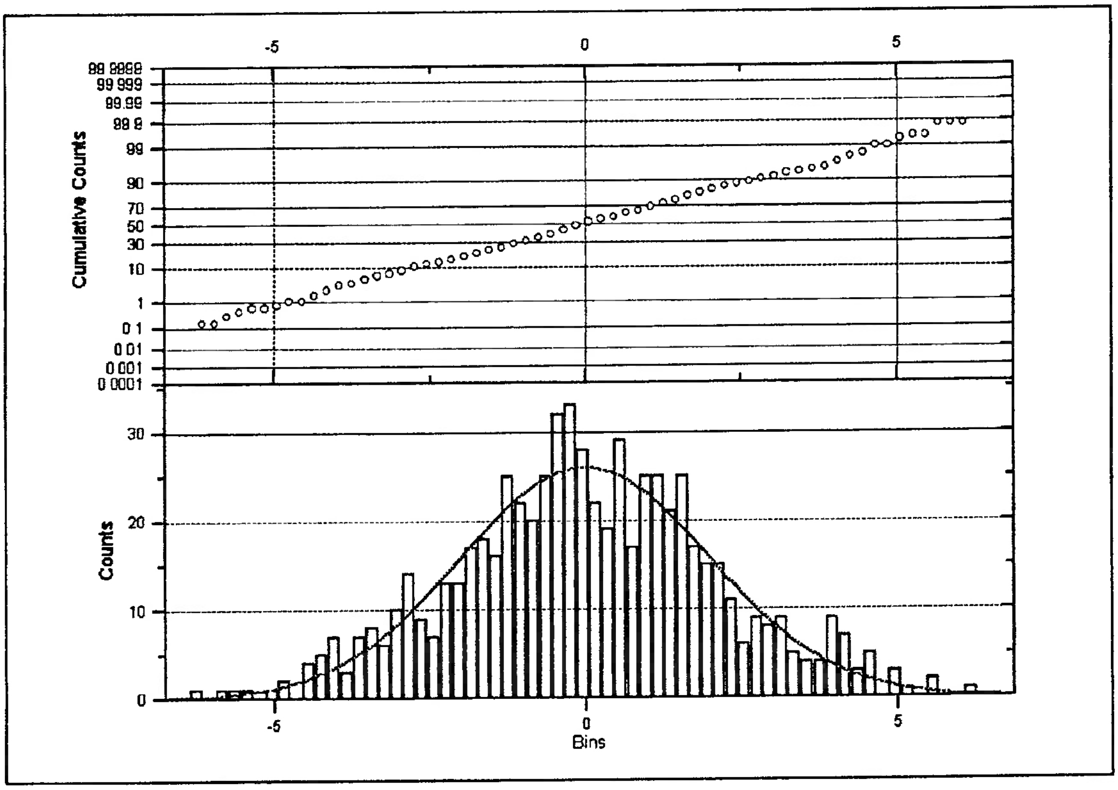
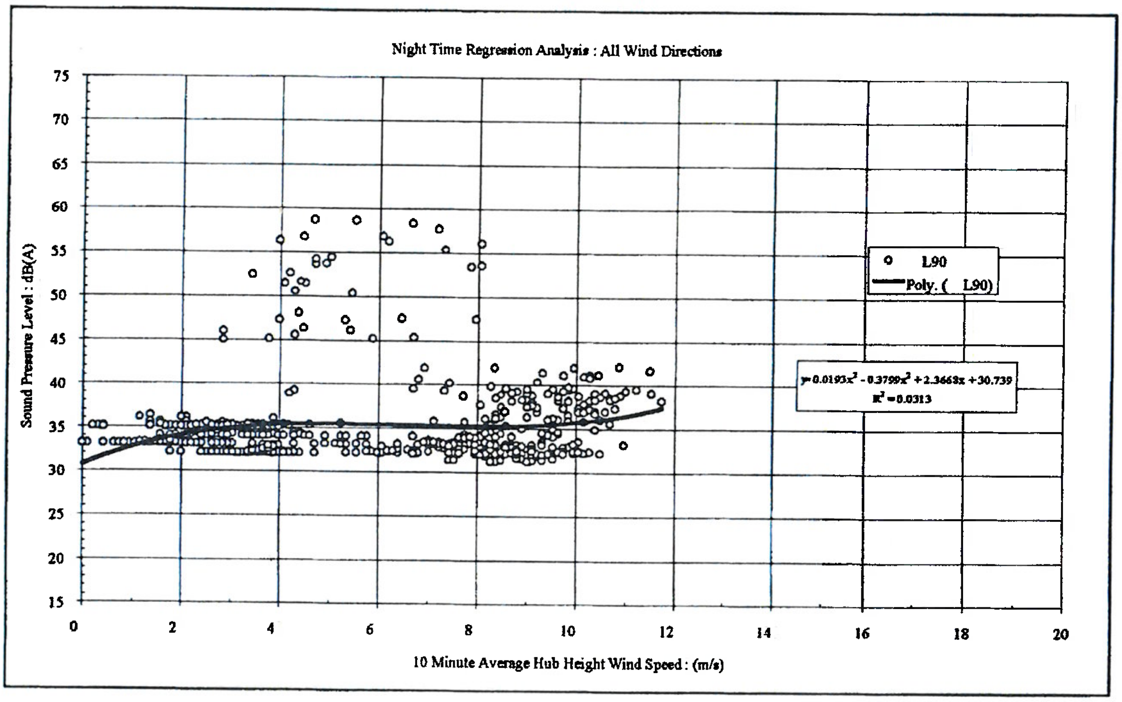
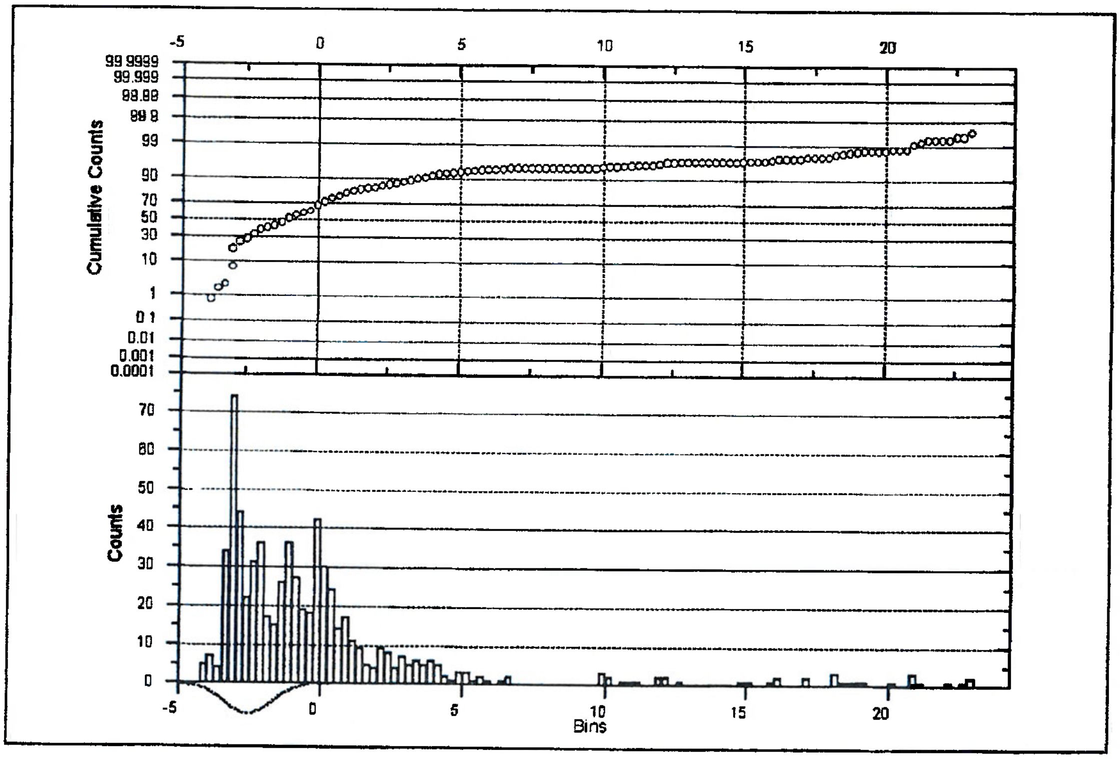


Figure A8 Deviation of measured levels around derived regression line plotted in Figure A7



Figu reA9 Regressi on a nalysis of evening and night-time wind s peed a nd noise datato determine the prevai lingevening and night-time background noise level



Figu reA10 Devi atio nof meas ured levels around derived regression line plot tedin Figure A9

FURTHER INFORMATION

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