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

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

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

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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

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TO: An Bord Pleanála

FROM:

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54 North Main Street
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[Evolve:c3cb5688-6a90-4d1b-8edb-5487abc9cc6d]

Noonan Linehan Carroll Coffey

SOLICITORS
54 North Main Street
Cork

T12WY2D
www.nlcc.ie
DX 2044 Cork

Telephone: 021 4270518
Fax: 021 4274347
Email: jnoonan@nlcc.ie

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*

Dick Bowdler
Acoustic Consultant

01383 882 644
077 8535 2534
dick@dickbowdler.co.uk

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*

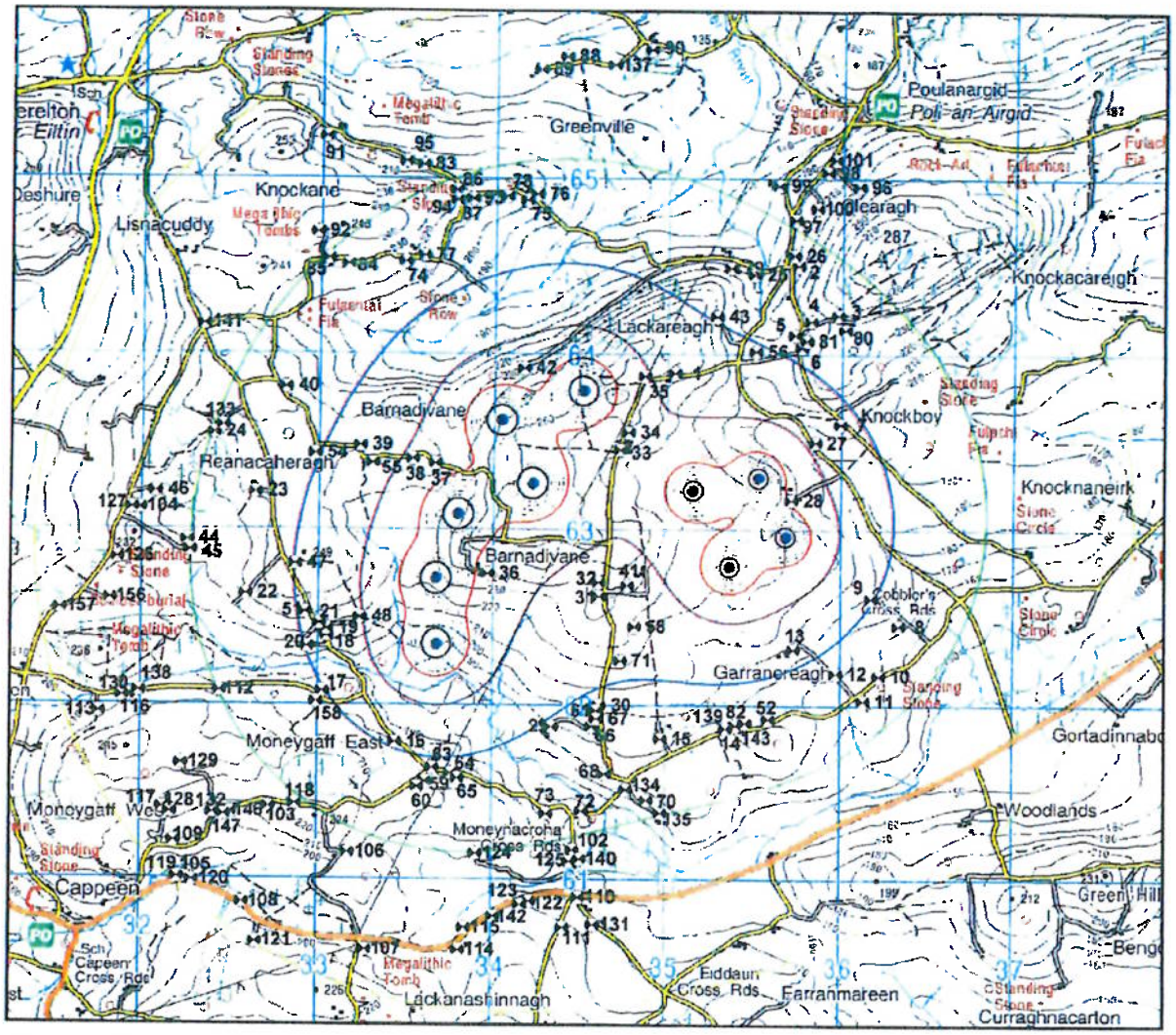


Figure 2.3: Predicted Cumulative Noise Levels at 10 m/s Standardised 10 m Height Wind Speed

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)

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

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

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

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.

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

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.

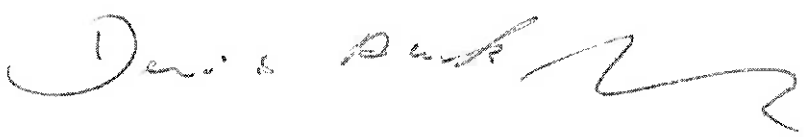
An Bord Pleanála have received objections from horse breeder Aidan O'Brien in relation to proposed wind farm developments near his farm where he has highlighted that horses are very sensitive to noise from wind turbines.

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



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

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

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.

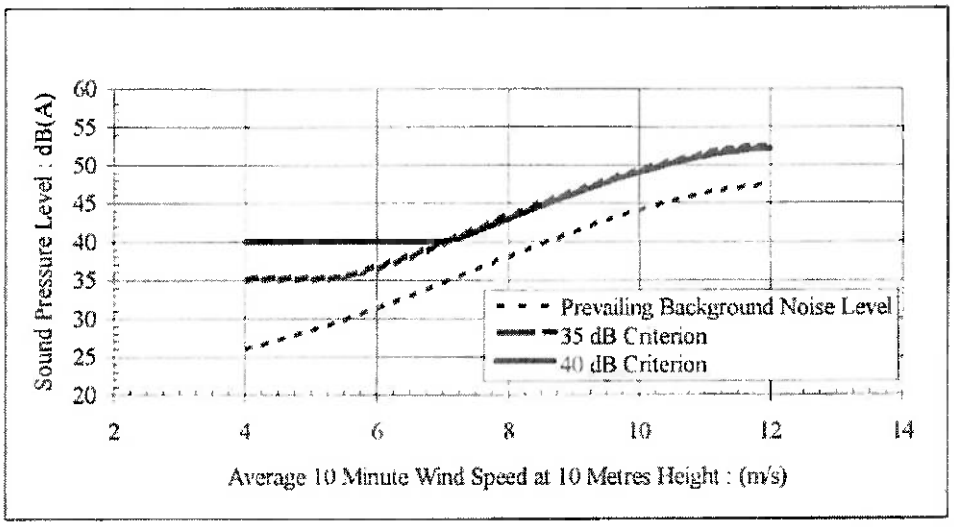
5.3 Whilst I recognise that in a subsequent appeal for the Ardglass site (246824) the inspector took a different view, the inspector for the earlier appeal (PL 04.243630) said in his report [DB11] at the top of p60 that:

> "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.

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)

Introduction by Chair

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).

Terms of Reference

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 2km² (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 8km^2. 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 30km^2. 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 (360º). In the vertical plane the lighting shall be limited to the sector between 15º below and 30º 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.

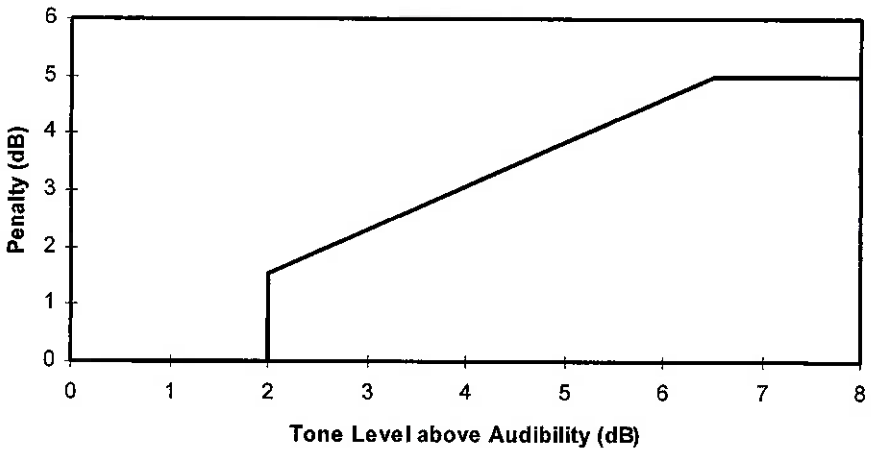
(a) For each 10-minute interval for which $L_{A90,10min}$ data have been obtained as provided for in Note 1 a tonal assessment is performed on noise immissions during 2 minutes of each 10 minute period. The 2 minute periods should be regularly spaced at 10 minute intervals provided that uninterrupted 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

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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

Department for Communities and Local Government
Julian Pitt, Decision Officer
Planning Central Casework Division,
1/J1, Eland House
Bressenden Place
London
SW1E 5DU

Tel: 030 4441630
Fax: 020 7944 5824
Email: PCC@communities.gsi.gov.uk

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 2^{nd} 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.

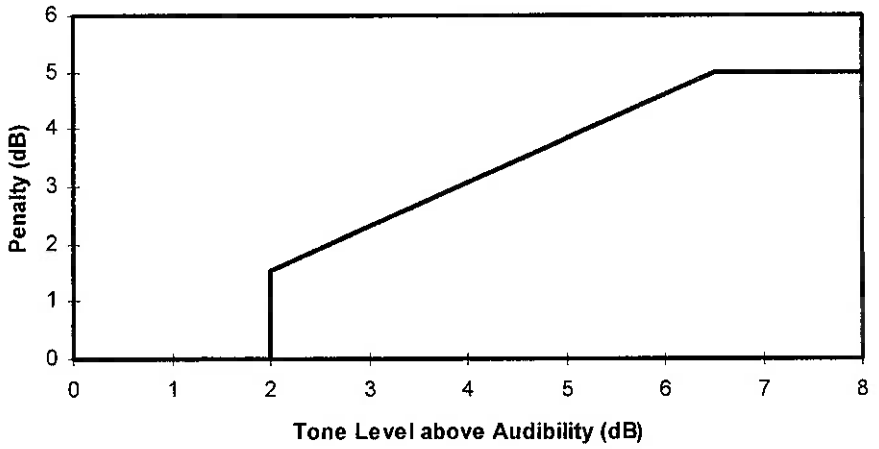
(a) For each 10-minute interval for which $L_{A90,10min}$ data have been obtained as provided for in Note 1 a tonal assessment is performed on noise emissions during 2 minutes of each 10 minute period. The 2 minute periods should be regularly spaced at 10 minute intervals provided that uninterrupted 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

Department for Communities and Local Government
Planning Casework Division,
1/H1, Eland House
Bressenden Place
London
SW1E 5DU

Tel: 0303 444 1634
Email: PCC@communities.gsi.gov.uk

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.

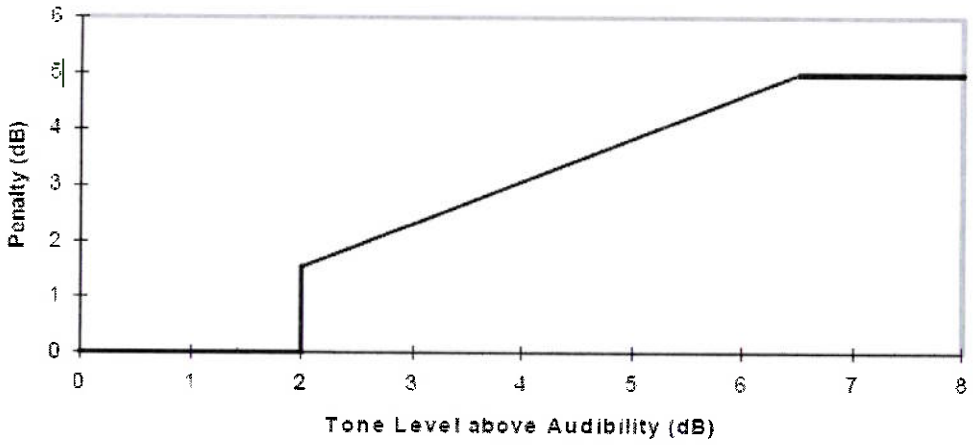
(a) For each 10-minute interval for which $L_{A90,10\text{-minute}}$ data have been determined as valid in accordance with Guidance Note 2 a tonal assessment shall be performed on noise immissions during 2 minutes of each 10-minute period. The 2-minute periods should be spaced at 10-minute intervals 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 2

Preliminary matters 4

Planning policy 5

The appeal site and surroundings 6

The proposal development 8

Statement of Common Ground 9

The case for SIEGE 10

The case for Maldon District Council 15

The case for the appellant 22

Written representations 30

Conditions and obligations 32

Conclusions 33

Preliminary matters 33

Main considerations 33

1a Character and appearance 34
1bi Living conditions outlook 42
1bii noise and disturbance 47
1biii other considerations 50
1c Heritage assets 51
1d Air safety 53
1e Nature conservation 54
1f Highway safety 54
1g Other considerations 55

2 Alternative marine delivery route for abnormal loads 55
3 Renewable energy 56
4 Planning balance 57
5 Development Plan 58
6 National Planning Policy Framework 58
7 Conditions and obligations 59

8 Overall conclusions 61

Recommendations 62

ANNEX1 Summary of Local Plan policies cited in the SoCG 63
SCHEDULE OF CONDITIONS – Appeal A 65
SCHEDULE OF CONDITIONS – Appeals B and C 75
APPEARANCES 76
PROOFS OF EVIDENCE, WRITTEN REPRESENTATIONS and SoCG 77
DOCUMENTS SUBMITTED AT INQUIRY 77
DOCUMENTS SUBMITTED AFTER THE CLOSE OF THE INQUIRY 79
LIST OF PLANS 80
CORE DOCUMENTS 81

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

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[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

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[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

[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

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[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

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[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

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[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.

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[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

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[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

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[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

[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.

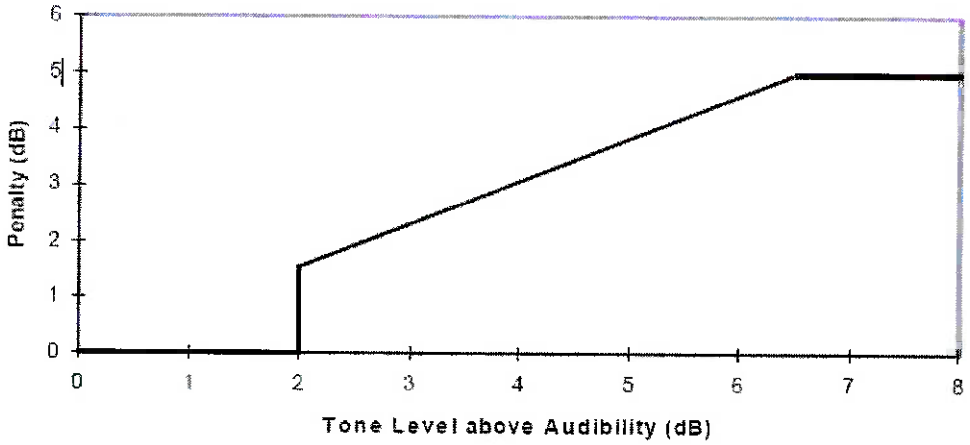
(e) Prior to the commencement of measurements the wind farm operator shall submit for the approval in writing of the local planning authority details of the proposed location of a data logging rain gauge which shall be installed during the course of the assessment of the levels of noise immissions. The 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.

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 3
2. Introduction 5
   - 2.1. Aims and objectives 5
   - 2.2. Organisation of the project 6
3. Survey of Local Authorities 7
   - 3.1. Scoping survey 8
   - 3.2. Detailed survey 10
   - 3.3. Survey results and analysis 11
     - Number of complaints and complainants 11
     - Prevalence of AM 15
     - Significance of complaints 16
     - Comments on the use of complaint statistics 19
     - Other factors arising from the survey 21
4. Further investigation of sites with AM 22
   - 4.1. First site 22
   - 4.2. Second Site 25
   - 4.3. Third Site 26
   - 4.4. Fourth Site 27
   - 4.5. Conclusions from AM sites 28
5. Worldwide literature survey 29
   - 5.1. Search terms 29
   - 5.2. Information sources 30
   - 5.3. Government reports and regulations 31
   - 5.4. Generation of wind turbine noise 32
   - 5.5. Propagation of wind turbine noise 35
   - 5.6. Amplitude Modulation of Wind Turbine Aerodynamic Noise 37
   - 5.7. Psychoacoustics 40
6. Survey of manufacturers worldwide 42
7. Conclusions 46
8. References 48
9. Appendix: Detailed survey questionnaire 54

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	

*No separate information given on number of complainants, assumed same as number of complaints.

	136	114	95	83	75	64	56	45	40	36	31	24	18	14	7

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	like 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
	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
	Y			Y	Y	Y							Y	aeroplane overhead doesn't disappear	Y	N	N	M
							Y						Y	low frequency droning	N	N	N	N
	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°.

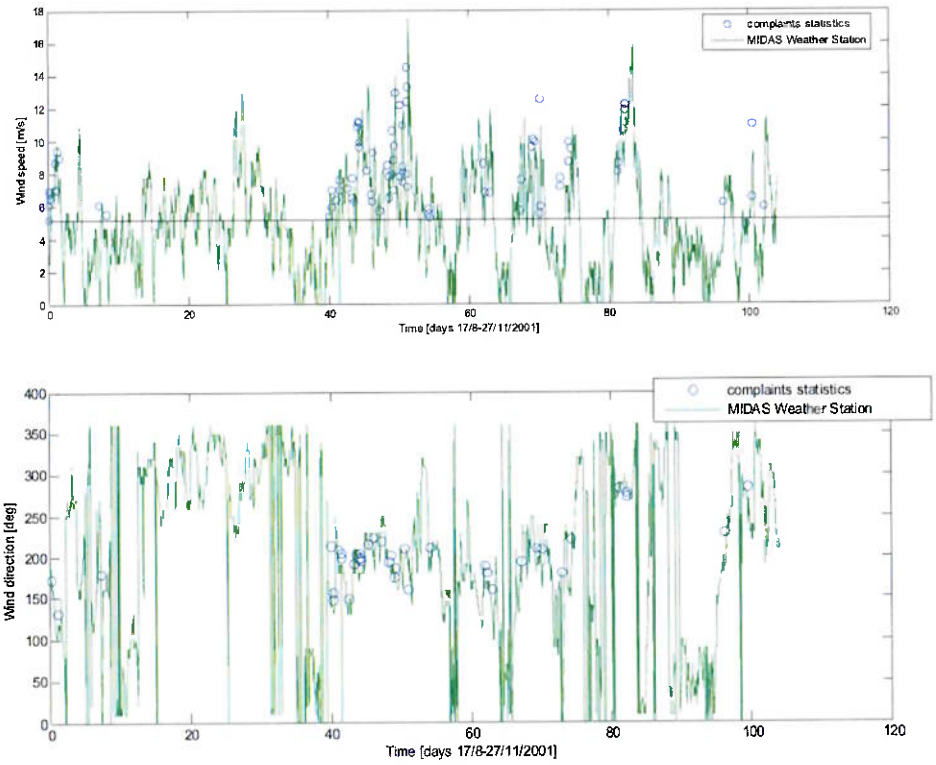

Figure 2 Time series of wind speed (top) and direction (bottom) for MIDAS data (green line) and data from the complaints log (blue circles) at first site.

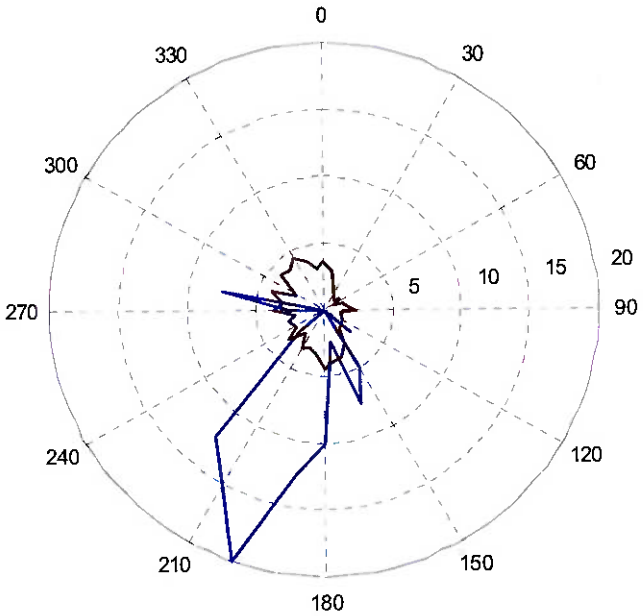

Figure 3 Distribution of hourly wind direction averages at first site: % for complaints (blue solid line); % for weather station data during the whole analysis period from Figure 2 (black dotted line).

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.

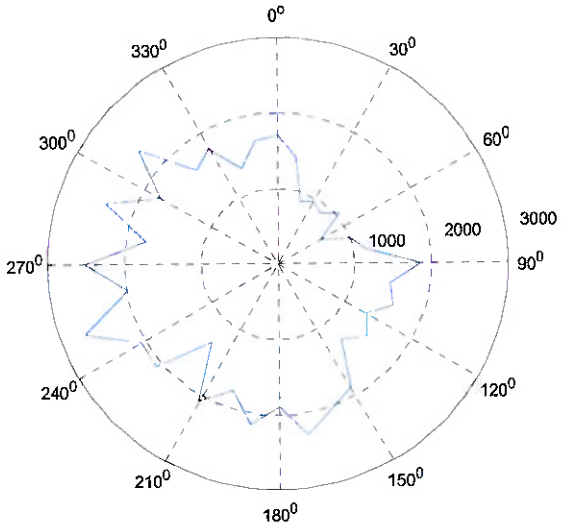

Figure 4 Distribution of hourly wind direction averages averaged over a seven year period for first site.

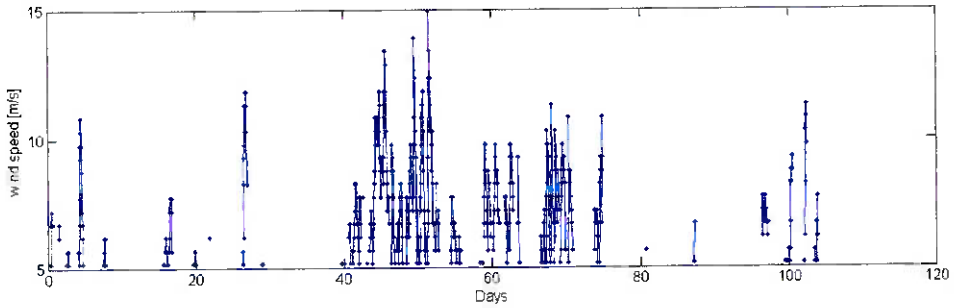

Figure 5. Wind speed for the periods when AM might occur at first site, i.e. wind speed >5m/s and direction between 140° and 270°.

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.

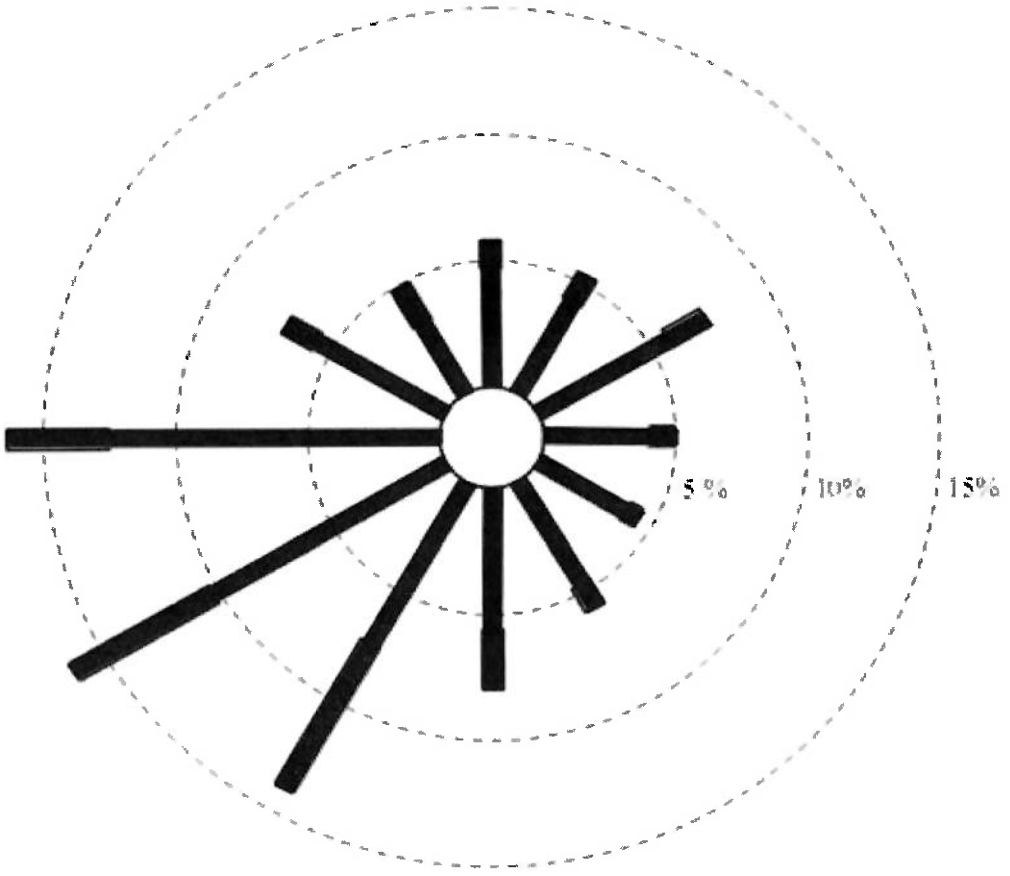

Figure 6 Wind farm rose for third site

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 $_{LFT(t)} - L_{eq(t)}$ 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.

8. References

1. Ackermann, T. and L. Söder (2002). "An overview of wind energy-status 2002." Renewable and Sustainable Energy Reviews 6: 67-128.
2. Agnolucci, P. (2007). "Wind electricity in Denmark: A survey of policies, their effectiveness and factors motivating their introduction." Renewable and Sustainable Energy Reviews 11: 951-963.
3. Allanson, J. and A. Newell (1966). "SUBJECTIVE RESPONSES TO TONES MODULATED SIMULTANEOUSLY IN BOTH AMPLITUDE AND FREQUENCY." JOURNAL OF SOUND AND VIBRATION 3(2): 135-146.
4. Ammari, H. and A. Al-Maaitah (2003). "Assessment of wind-generation potentiality in Jordan using the site effectiveness approach." Energy 28: 1579-1592.
5. AusWEA Wind Farms and Noise. Melbourne, AusWEA.
6. Baumgart, A. (2002). "A Mathematical Model For Wind Turbine Blades." JOURNAL OF SOUND AND VIBRATION 251(1): 1-12.
7. Björkman, M. (2004). "Long time measurements of noise from wind turbines." JOURNAL OF SOUND AND VIBRATION 277: 567-572.
8. Bolin, K. (2005). Masking Of Wind Turbine Sound By Vegetation Noise. Wind Turbine Noise, Berlin.
9. BWEA (2005). Public Attitudes to Wind Energy in the UK, BWEA.
10. Damborg, S. Public Attitudes Towards Wind Power, Danish Wind Industry Association.
11. Devlin, E. (2002). Factors affecting public acceptance of wind turbines in Sweden. Mölndal, Lunds Universitet.
12. Drwiega, A. (2003). "Economic and technical issues affecting the development of the wind-power industry in Poland." Applied Energy 74: 239-246.
13. DTI (2006) The measurement of low frequency noise at three UK wind farms: URN No: 06/1412" issued by the DTI in July 2006

14. Embleton T. F. W., 1996. "Tutorial on sound propagation outdoors", *Journal of the Acoustical Society of America 100, 31-48.* Good general overview over sound propagation effects.
15. ETSU-R-97, (1997) The assessment and rating of noise from wind farms:
16. Fedorchenko, A. (2005). Two-Medium Theory Of Aerodynamic Sound Sources And The Practical Problems Of Wind Turbine Noise. Wind Turbine Noise, Berlin.
17. Filios, A., N. Tachos, et al. (2006). "Broadband noise radiation analysis for an HAWT rotor." Renewable Energy doi:10.1016/j.renene.2006.10.002.
18. Fuglsang, P. and C. Bak (2004). "Development of the Risø Wind Turbine Airfoils." Wind Energy 7: 145-162.
19. Fujii, S., K. Takeda, et al. (1984). "A NOTE ON TOWER WAKE/BLADE INTERACTION NOISE OF A WIND TURBINE." JOURNAL OF SOUND AND VIBRATION 97(2): 333-336.
20. Gleg, S., S. Baxter, et al. (1987). "THE PREDICTION OF BROADBAND NOISE FROM WIND TURBINES." JOURNAL OF SOUND AND VIBRATION 118(2): 217-239.
21. Golec, M., Z. Golec, et al. (2005). Noise Of Wind Power Turbine V80 In A Farm Operation. Wind Turbine Noise, Berlin.
22. Harders, H. and H. Albrecht (2005). Analysis Of The Sound Characteristics Of Large Stall-Controlled Wind Power Plants In Inland Locations. Wind Turbine Noise, Berlin.
23. Hayes, M. (2006) Low Frequency Noise Report, DTI.
24. Hird, M. (2000). "Wind Energy Literature Survey No.1." Wind Energy 3: 165-166.
25. Hird, M. (2001). "Wind Energy Literature Survey No. 2." Wind Energy 4: 39-41.
26. Hird, M. (2003). "Wind Energy Literature Survey No. 4." Wind Energy 6: 197-200.
27. Hoffer, R. (1996). "Processes of buffeting and vortex forces in turbulent wind." Journal Of Wind Engineering and Industrial Aerodynamics 64: 203-220.

28. Hubbard, H. and K. Shepherd (1991). "Aeroacoustics of large wind turbines." Journal of the Acoustical Society of America 89(6): 2495-2508.
29. Hunter, R., Ed. (1997). Wind Energy Conversion: From Theory to Practice. Proceedings of the BWEA Wind Energy Conference. Edinburgh, Mechanical Engineering Publications Limited.
30. ISVR Consultancy Service University of Southampton, (1991) 'The prediction of propagation of noise from wind turbines with regard to community disturbance'. Contract report for ETSU
31. Jakobsen, J. (2005). "Infrasound Emission from Wind Turbines." JOURNAL OF LOW FREQUENCY NOISE, VIBRATION AND ACTIVE CONTROL 24(3): 145 – 155.
32. Joselin Herbert, G., S. Iniyan, et al. (2007). "A review of wind energy technologies." Renewable and Sustainable Energy Reviews 11: 1117–1145.
33. Kantarelis, C. and J. Walker (1988). "THE IDENTIFICATION AND SUBJECTIVE EFFECT OF AMPLITUDE MODULATION IN DIESEL ENGINE EXHAUST NOISE." JOURNAL OF SOUND AND VIBRATION 120(2): 297-302.
34. Klug, H. (2002). NOISE FROM WIND TURBINES STANDARDS AND NOISE REDUCTION PROCEDURES. Forum Acusticum, Sevilla, Spain.
35. Klug, H. (2005). A Review Of Wind Turbine Noise. Wind Turbine Noise, Berlin.
36. Leventhall, G. (2004). Notes on Low Frequency Noise from Wind Turbines with special reference to the Genesis Power Ltd Proposal, near Waiuku NZ, Genesis Power/ Hegley Acoustic Consultants.
37. Leventhall, G. (2005). How The "Mythology" Of Infrasound And Low Frequency Noise Related To Wind Turbines Might Have Developed. Wind Turbine Noise, Berlin.
38. Limited, D. C. (2000). Wind Turbine Environmental Assessment. Toronto, Toronto Hydro and TREC.
39. Ltd, M. R. W. (2002). Public attitudes to wind energy in Wales, Friends of the Earth Cymru.
40. Moore, B(2004). *"An Introduction to the Psychology of Hearing(5th Edition)"* Elsevier Academic Press. P138-139

41. Mitchell, A. (2004). Wind Turbine Noise. Department of Mechanical Engineering. Christchurch, University of Canterbury.
42. MORI-Scotland (2003). Public Attitudes to Wind farms, Scottish Executive.
43. Nanahara, T., M. Asari, et al. (2004). "Smoothing Effects of Distributed Wind Turbines. Part 1. Coherence and Smoothing Effects at a Wind Farm." Wind Energy 7: 61-74.
44. Nii, Y. (2003). "Effects of splitting a ground board on wind turbine noise measurements." Acoustic Science & Technology 24(2): 90-92.
45. Nii, Y., H. Matsumiya, et al. (2003). "Acoustic performances of a vertical board for wind turbine noise immission measurements." Acoustic Science & Technology 24(2): 83-89.
46. Oerlemans, S. and B. Méndez López (2005). Localisation And Quantification Of Noise Sources On A Wind Turbine. Wind Turbine Noise, Berlin.
47. PAN45 (2002) Planning Advice Note 45: Renewable Energy: January 2002: Scottish Executive
48. Pedersen, E. (2003). Noise annoyance from wind turbines - a review, SWEDISH ENVIRONMENTAL PROTECTION AGENCY.
49. Pedersen, E. and K. Persson Waye (2004). "Perception and annoyance due to wind turbine noise—a dose–response relationship." Journal of the Acoustical Society of America 116(6): 3460-3470.
50. Pedersen, E. and K. Persson Waye (2005). Human Response To Wind Turbine Noise – Annoyance And Moderating Factors. Wind Turbine Noise, Berlin.
51. Pedersen, E. and K. Persson Waye (2006). EXPLORING PERCEPTION AND ANNOYANCE DUE TO WIND TURBINE NOISE IN DISSIMILAR LIVING ENVIRONMENTS. Euronoise, Tampere, Finland.
52. Persson Waye, K. and E. Ohrstrom (2002). "PSYCHO-ACOUSTIC CHARACTERS OF RELEVANCE FOR ANNOYANCE OF WIND TURBINE NOISE." JOURNAL OF SOUND AND VIBRATION 250(1): 65-73.
53. PPS2 (2004) Planning Policy Statement 22: Renewable Energy
54. Prospathopoulos, J. and S. Voutsinas (2006). "Application of a Ray Theory Model to the Prediction of Noise Emissions from Isolated Wind Turbines and Wind Parks." Wind Energy DOI: 10.1002/we.211.

55. Ratto, C. and G. Solari, Eds. (1998). Wind Energy and Landscape. Genova, A.A.Balkema.
56. Rogers, A., J. Manwell, et al. (2006). Wind Turbine Acoustic Noise. Amherst, Renewable Energy Research Laboratory.
57. Salomons, E. M. (1994) Downwind propagation of sound in an atmosphere with a realistic sound-speed profile: A semianalytical ray model. J. Acoust. Soc. Am., **95**(5)
58. Schepers, J., A. Curvers, et al. (2005). Sirocco: Silent Rotors By Acoustic Optimisation. Wind Turbine Noise, Berlin.
59. Sloth, E. (2005). Modelling of noise from wind farms and evaluation of the noise annoyance. Wind Turbine Noise, Berlin.
60. Spera, D. A. (1998) Wind turbine technology – Fundamental concepts of wind turbine engineering. ASME Press, pp. 638.
61. Stewart, J., H. Guest, et al. (2006). Location, Location, Location: An investigation into wind farms and noise by The Noise Association, The Noise Association.
62. Tagaki, Y., N. Fugisawa, et al. (2006). "Cylinder wake influence on the tonal noise and aerodynamic characteristics of a NACA0018 airfoil." JOURNAL OF SOUND AND VIBRATION 297: 563-577.
63. TAN8 (2005) Technical Advice Note 8: Planning for Renewable Energy: National Assembly for Wales
64. Van den Berg, G. (2003). "Wind turbines at night: acoustical practice and sound research." Euronoise p160.
65. Van den Berg, G. (2004). "Effects of the wind profile at night on wind turbine sound." JOURNAL OF SOUND AND VIBRATION 277: 955-970.
66. Van den Berg, G. (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.
67. Van den Berg, G. (2005a). Mitigation measures for night-time wind turbine noise. Wind Turbine Noise, Berlin.
68. Van den Berg, G. (2005b). Wind gradient statistics up to 200 m altitude over flat ground. Wind Turbine Noise, Berlin.

69. Van den Berg, G. (2006). The sound of high winds: the effect of atmospheric stability on wind turbine sound and microphone noise: http://dissertations.ub.rug.nl/faculties/science/2006/g.p.van.den.berg/ (26/3/2007)
70. Wagner, S., Bareiss, R., and Guidati, G. (1996) *Wind Turbine Noise*: Springer
71. Wilson, D. K.(2000) A turbulence spectral model for sound propagation in the atmosphere that incorporates shear and buoyancy forcings. Journal of the Acoustical Society of America, 108(5), pp 2021-2038.
72. Wolsink, M. (2007). "Wind power implementation: The nature of public attitudes: Equity and fairness instead of 'backyard motives'." Renewable and Sustainable Energy Reviews 11: 1188-1207.
73. Wood, D. (2002). "Modelling the Atmospheric Absorption of Wind Turbine Noise." Wind Engineering 26(2): 117-121.
74. Zhu, W., J. Sørensen, et al. (2005). "An aerodynamic noise propagation model for wind turbines." Wind Engineering 29(2): 129-143.

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**		
Ghostly Noises	**YES / NO**	Thumping	**YES / NO**	'like motion sickness'	**YES / NO**
Wooh Wooh	**YES / NO**	Pulsating	**YES / NO**	Whistling	**YES / NO**
Beating	**YES / NO**	Whooshing	**YES / NO**	Rhythmic al Beat	**YES / NO**
Lapping	**YES / NO**	Distant Helicopter	**YES / NO**	Other (please list):	**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
David Coles	24 Acoustics Ltd
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 1

0.1 BACKGROUND 1
0.2 DEFINITION OF AM 2
0.3 APPLICATION OF THE METRIC 2
0.4 CONSULTATION DOCUMENTS AND RESPONSES 2
0.5 REFERENCE METHOD 2

1 INTRODUCTION 4

2 AM DEFINITION 7

Scope of application 7

3 OUTCOME OF CONSULTATION RESPONSES & SELECTION OF METRIC 8

4 REFERENCE METHOD 10

4.1 INTRODUCTION 10
4.2 OVERVIEW OF METHOD 10
4.3 INPUT DATA 17
Discussion 17
Deriving band-limited input data in practice 18
Input parameters – modulation frequency range 19
4.4 ASSESSMENT TIME PERIODS 20
Minor time interval 20
Major time interval 20
Discussion 22
4.5 SIGNAL ANALYSIS 23
Reference Method 23
Possible output – individual peaks and troughs 29
4.6 PROMINENCE NOISE EXCLUSIONS 29
4.7 DISCUSSION 31
Input data: 33
Analysis parameters: 33
4.8 INDICATIVE METHOD (AFTER 'TACHIBANA' ET. AL.) 35
Limitations of the Indicative Method 37

5 INSTRUMENTATION 38

5.1 GENERAL REQUIREMENTS 38
5.2 NOISE MEASURING EQUIPMENT 39
5.3 ON-LINE AM MEASUREMENT 39
5.4 SOUND LEVEL LOGGING EQUIPMENT 39
5.5 AUDIO RECORDING EQUIPMENT 40

6 MEASUREMENT PROCEDURE 40

7 EVALUATION OF METHOD AGAINST ADOPTED SUCCESS CRITERIA 41

8 APPLICATION OF THE REFERENCE METHOD TO TEST STUDY STIMULI 42

8.1 BACKGROUND 42
8.2 RENEWABLEUK SALFORD STIMULI 43
8.3 TACHIBANA STIMULI 45

9 SOFTWARE 45

10 REFERENCES 46

Appendix A – Terms of Reference
Appendix B – Scope of Work
Appendix C – AMWG Response to Consultation Document

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

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[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

[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.

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[3] The stall source mechanism radiates equally upwind and downwind, but propagation effects reduce noise levels upwind.

[4] see http://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

[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.

[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.

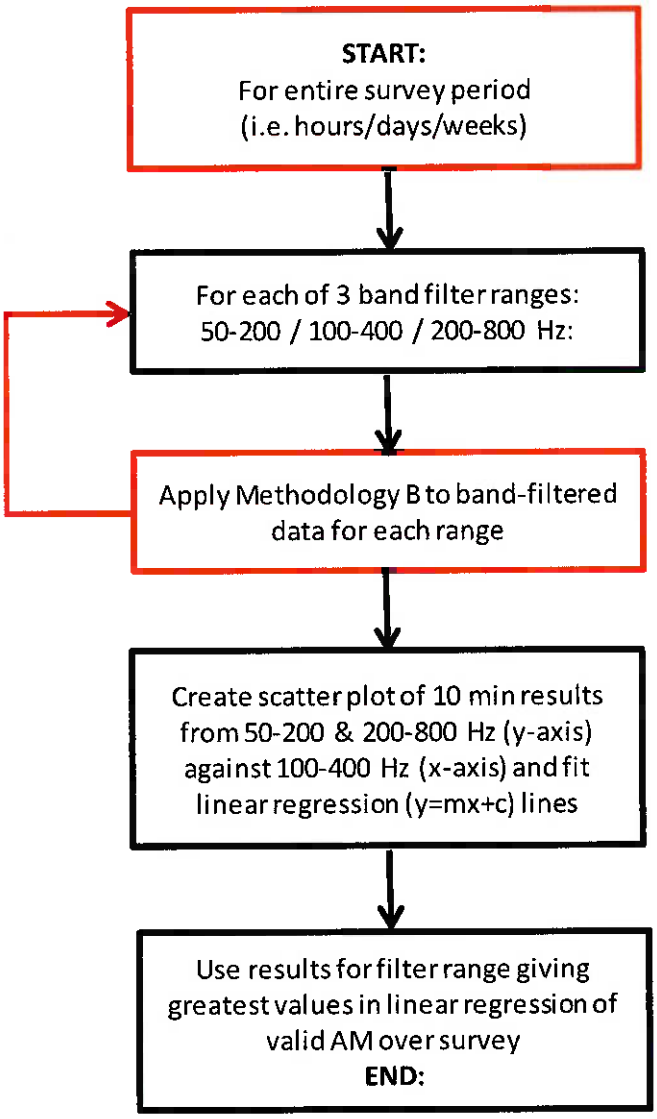

Figure 4.2.1 - 'Overall' Methodology

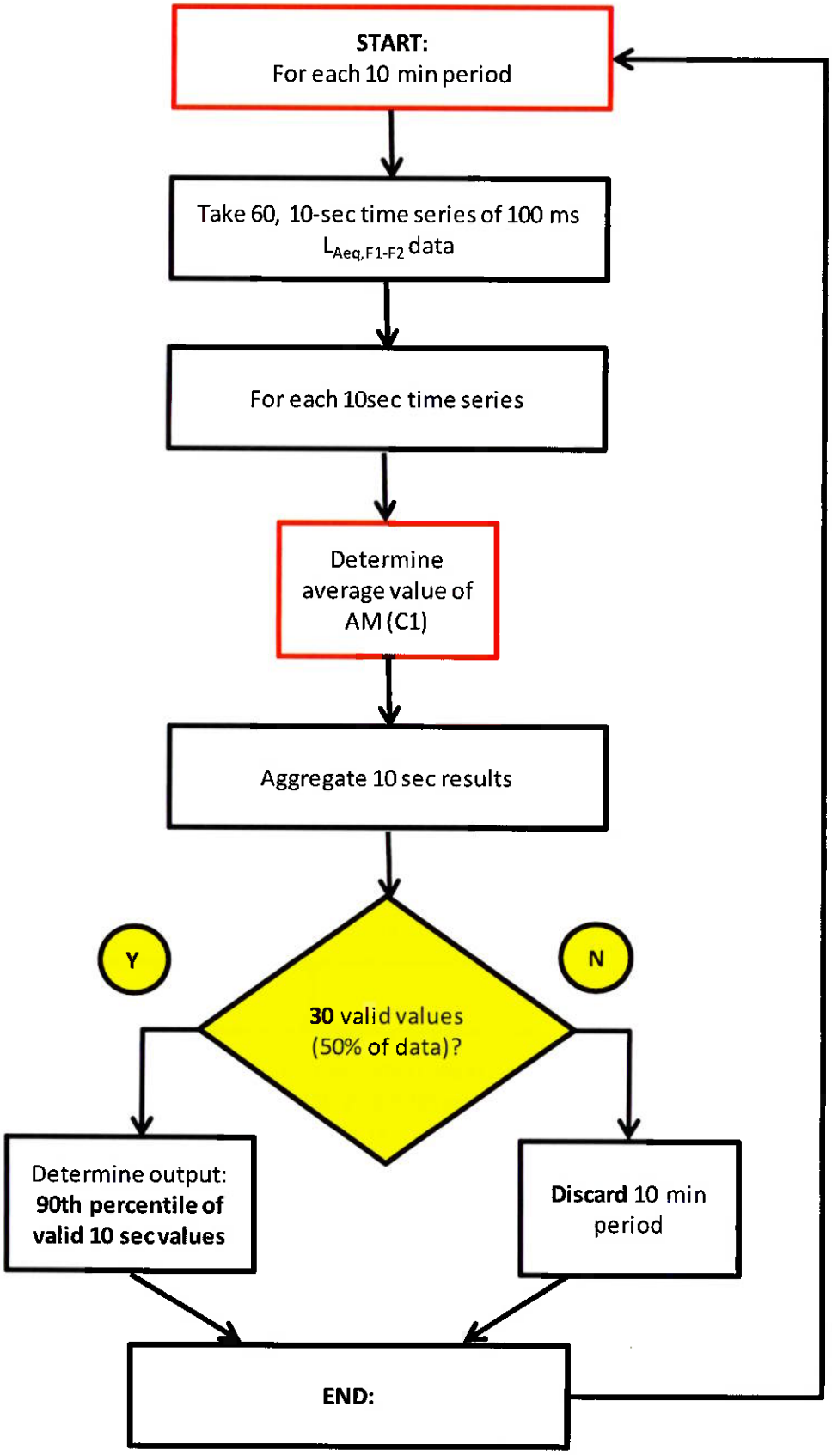

Figure 4.2.2 - B: 10 Minute Methodology

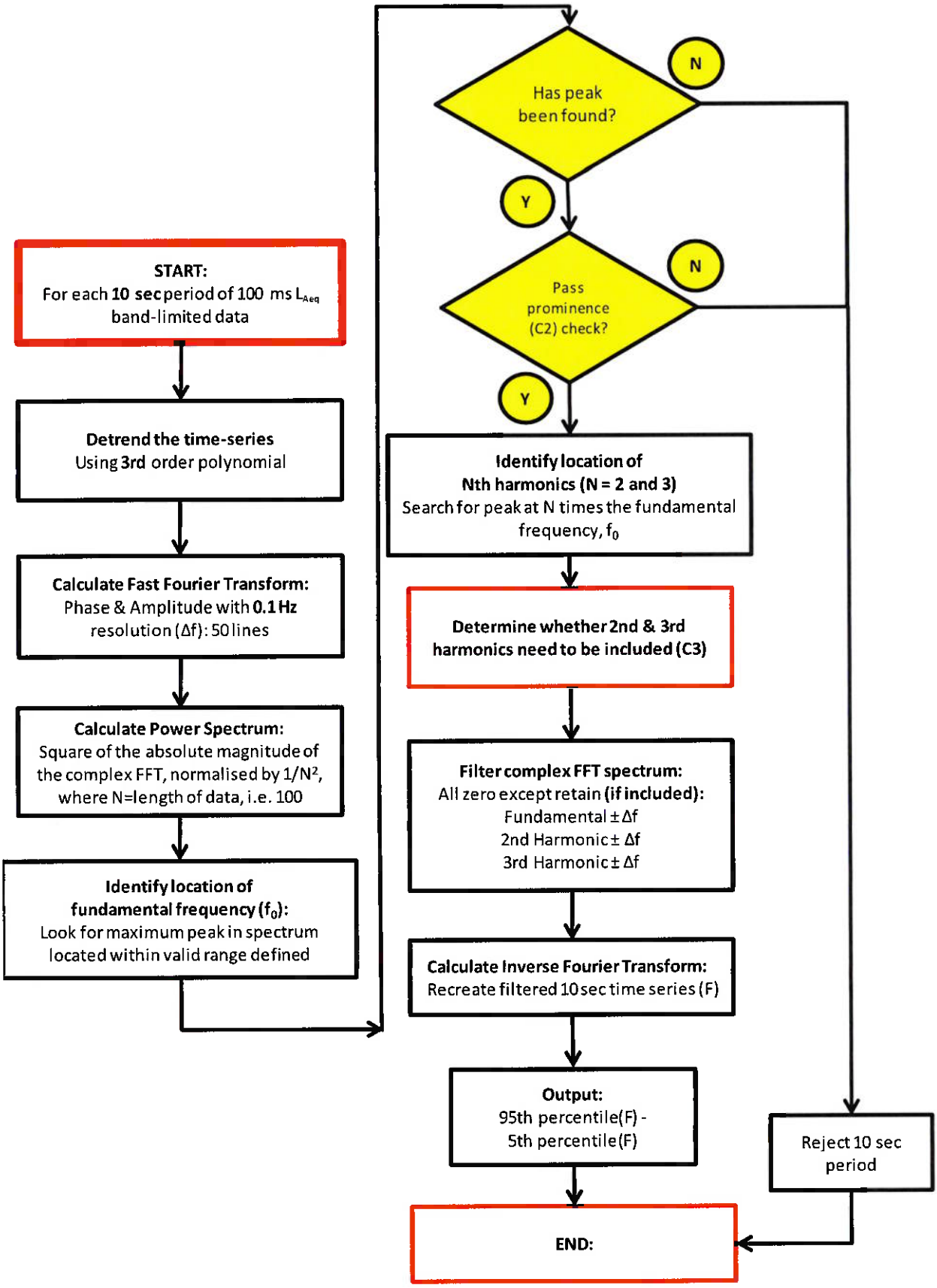

Figure 4.2.3 - C1: 10 Second Methodology

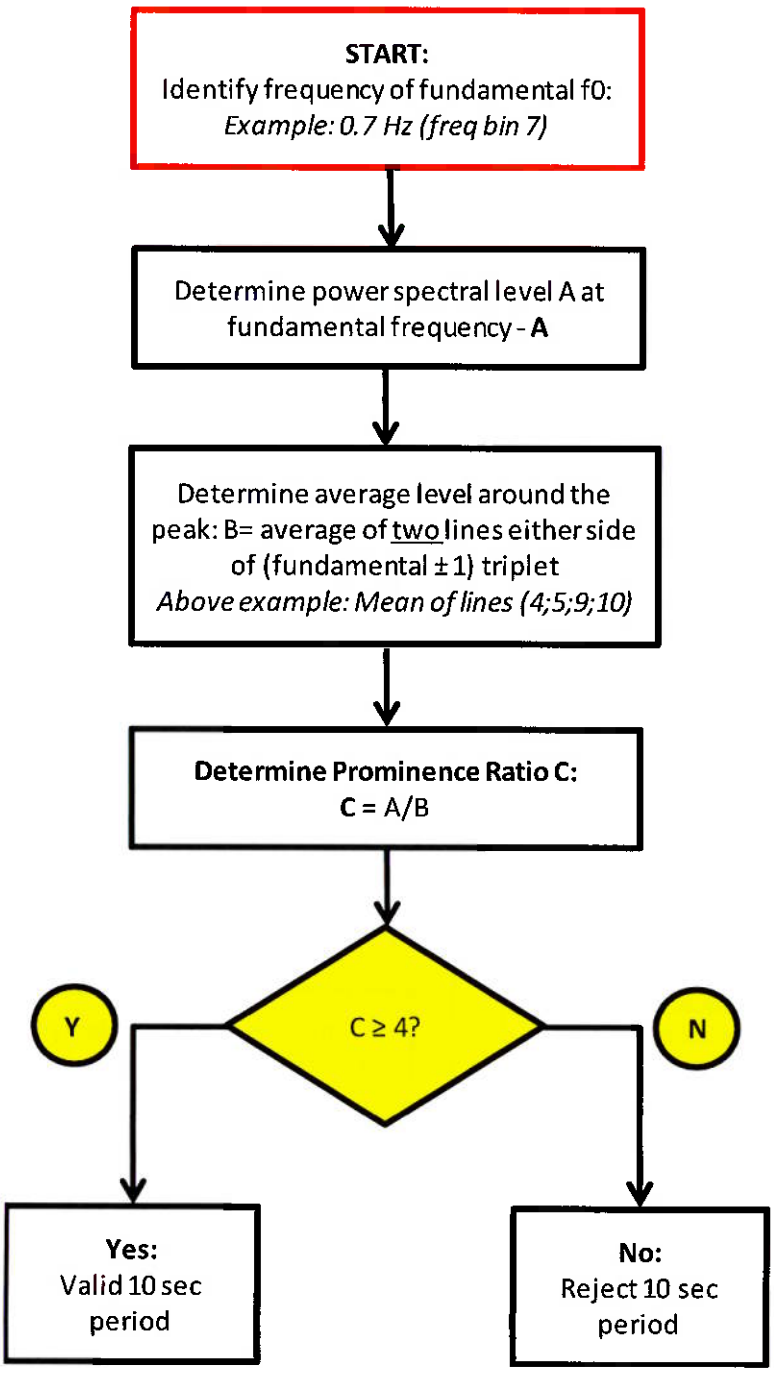

Figure 4.2.4 - C2: Prominence Check Methodology

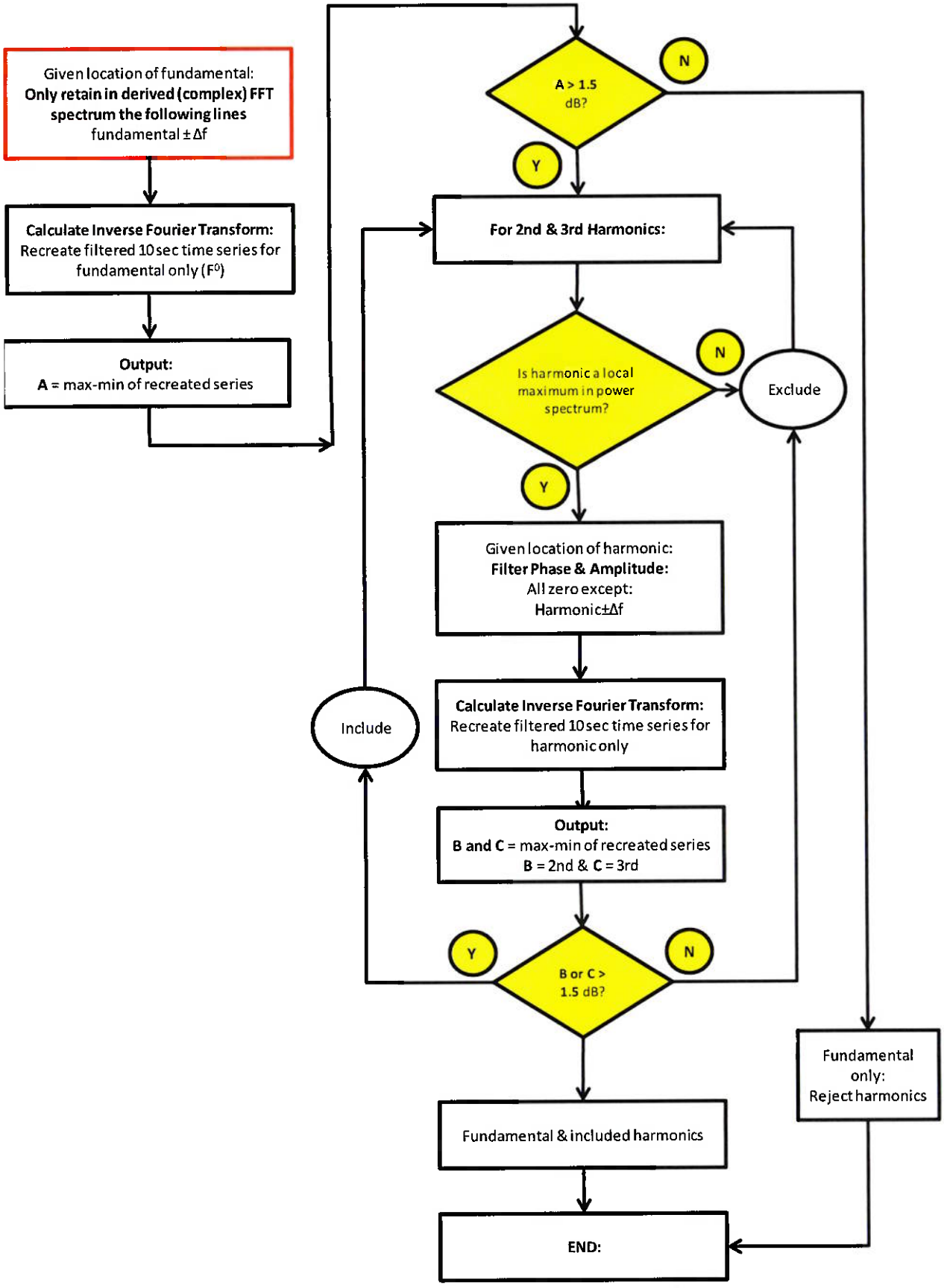

Figure 4.2.5 - C3: Decision Methodology for Including Harmonics

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.

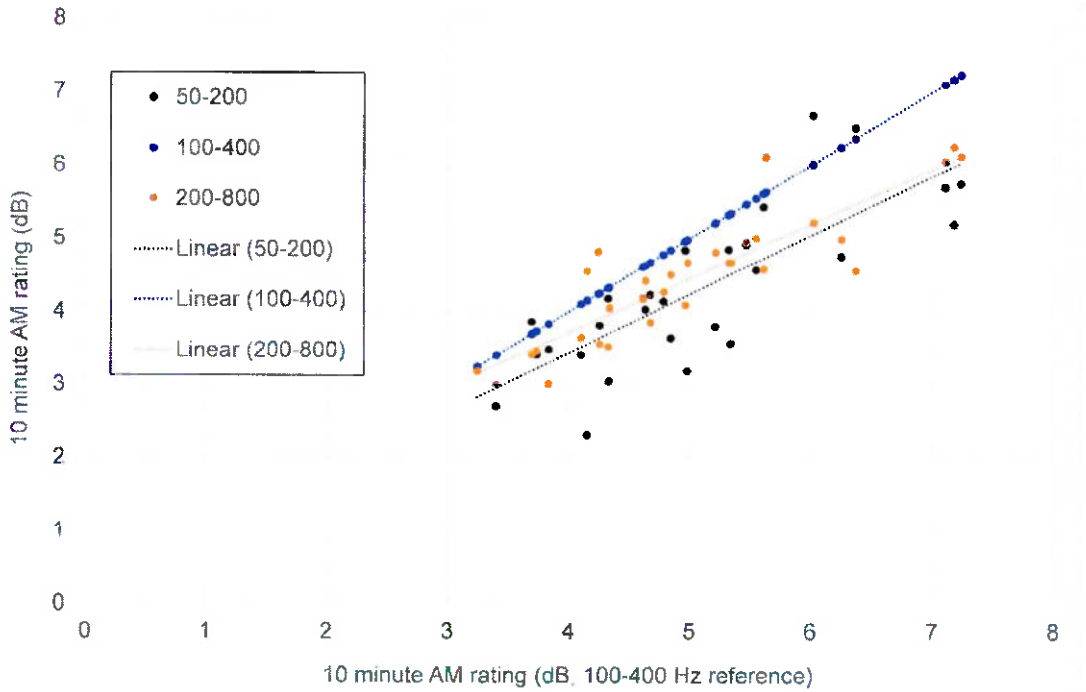

Fig 4.3.1 Comparison of ratings obtained with different frequency bands. This example shows that the 100-400Hz range should be used

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].

[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.

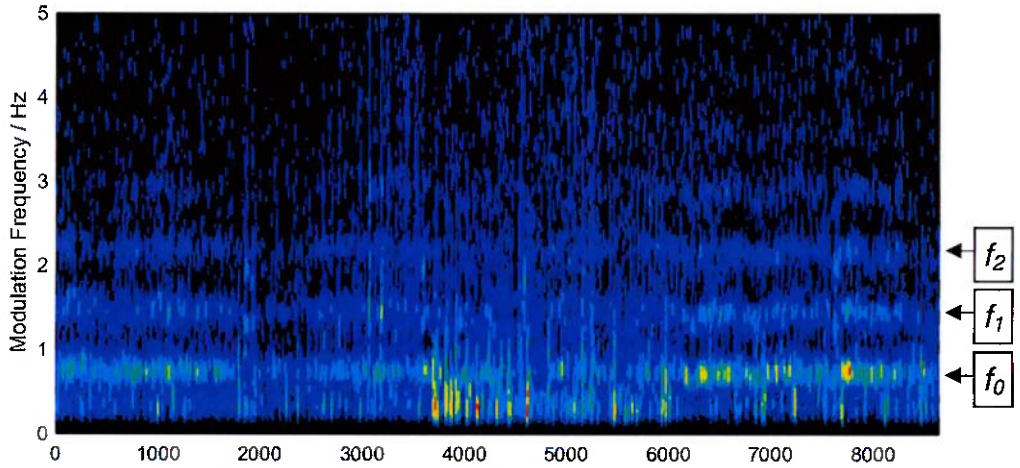

Figure 4.3.2 Typical waterfall plot (showing evolution of the modulation frequency (vertical axis) with time (horizontal axis, 10 s blocks) with a clear trend of modulation apparent at times just below 1 Hz – see the horizontal lines. The harmonics are also visible. Spurious non-modulating events tend 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.

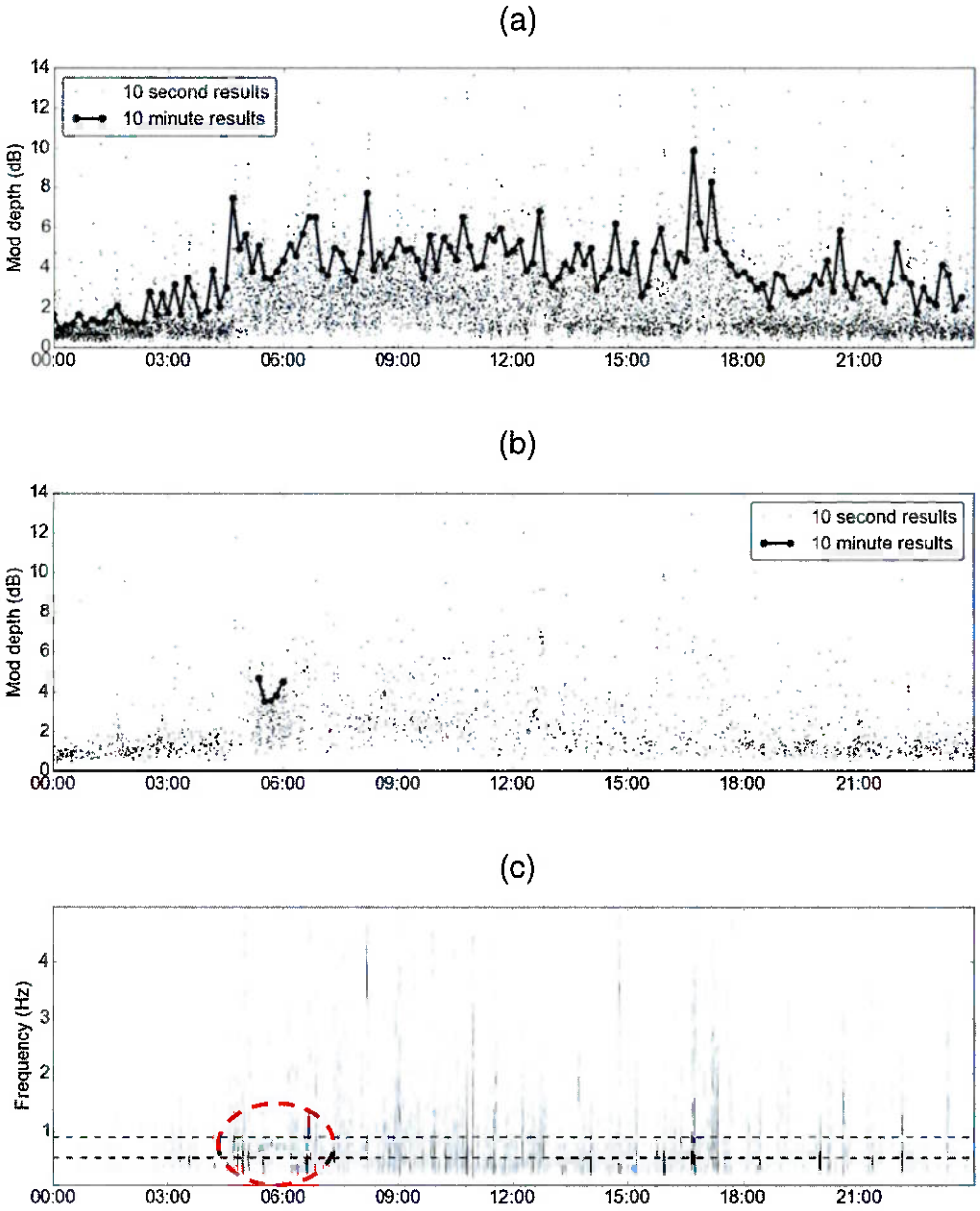

Fig. 4.4.1 Results of the analysis using the reference method over one day at a site with a relatively large amount of corruption from non-turbine sources (birds, trees etc.) The 10-minute results are shown both without (a) and with (b) the above criteria of sufficient valid data with high prominence, 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).

[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 (2^{nd} and 3^{rd}), 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 2^{nd} and 3^{rd} 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.

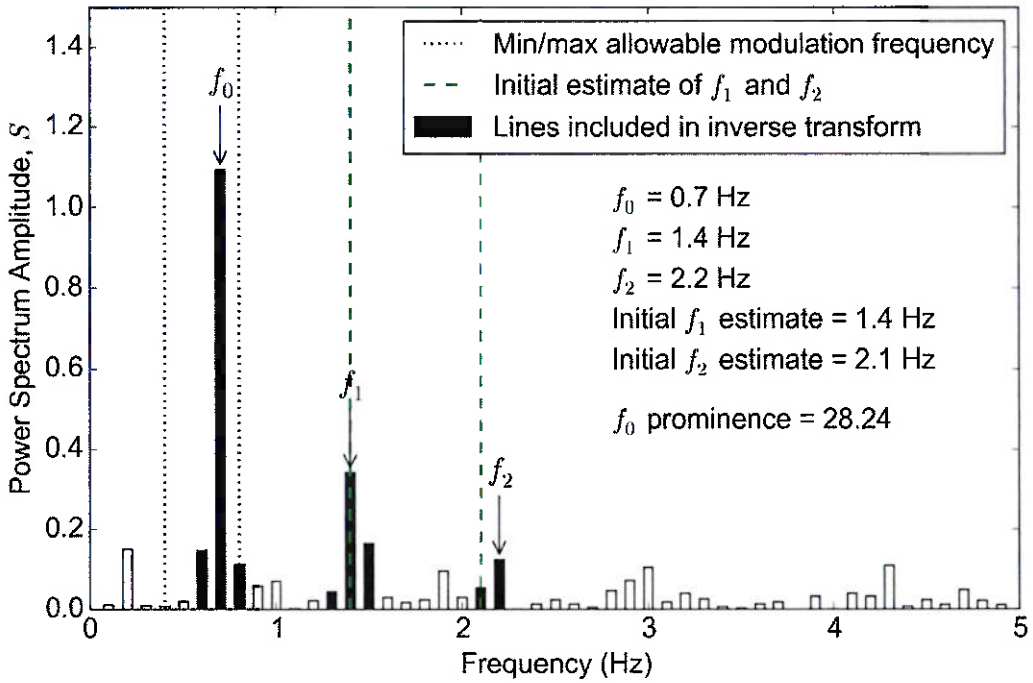

Figure 4.5.1: The power spectrum for a 10-second block. The fundamental frequency, f_0, has been identified within the range of allowable modulation frequencies (marked as dotted lines). Initial estimates of the frequencies of the second and third harmonics are shown as dashed green lines. The estimated 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).

[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.

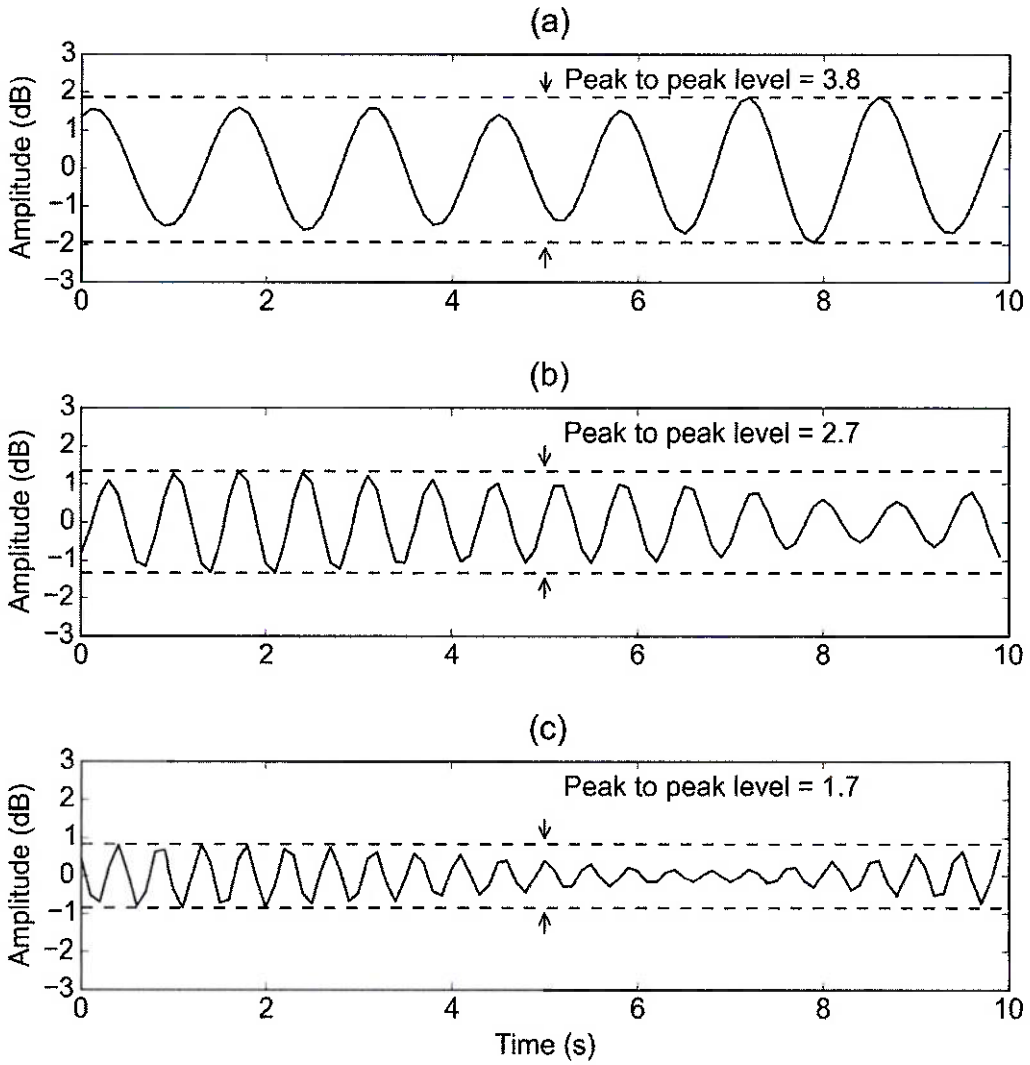

Figure 4.5.2: The inverse Fourier transform of energy at the fundamental frequency and the second and third harmonics, shown in panels (a), (b) and (c) respectively. The figure shows that the peak to peak levels for all harmonics exceeds the criterion specified in Step 6c(ii) of the method description and therefore energy at all harmonics should be included in the final inverse Fourier transform.

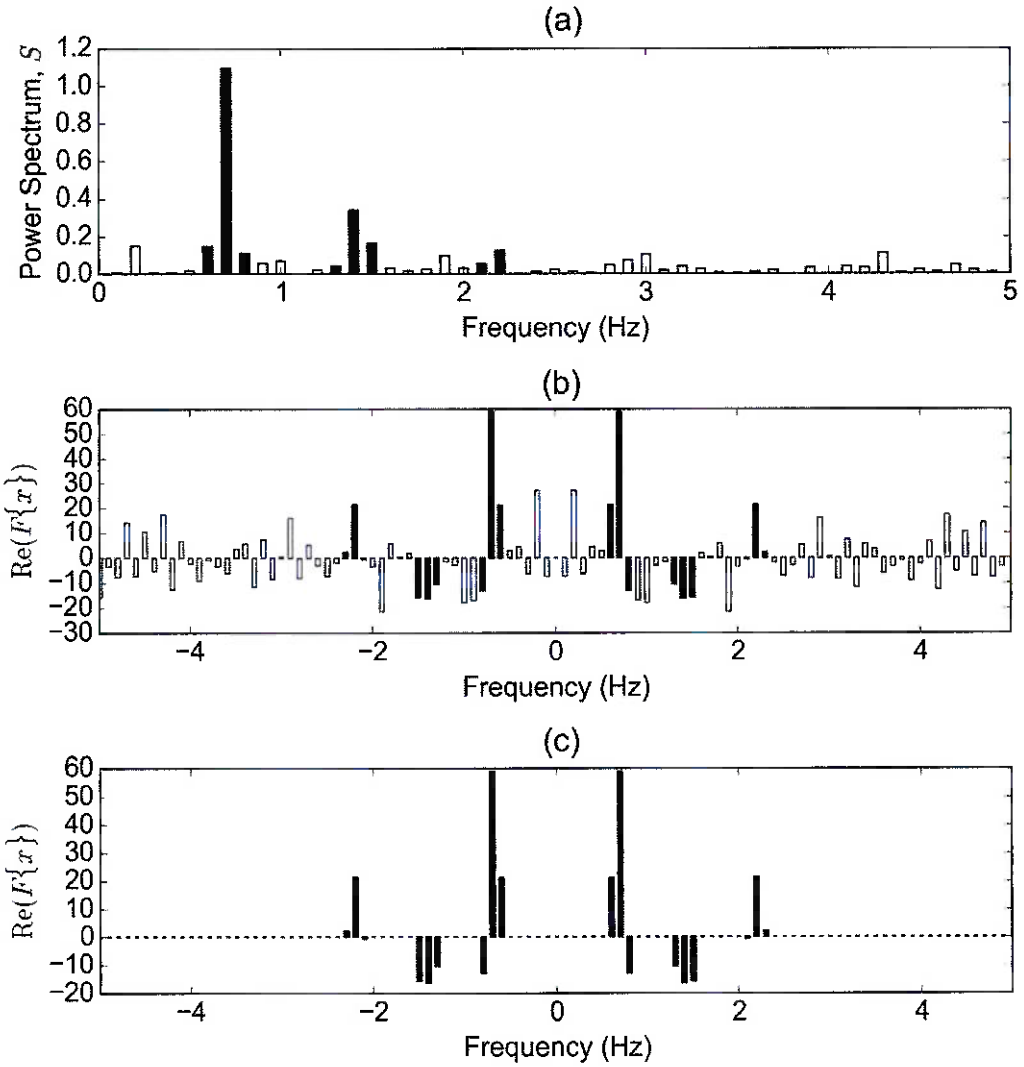

Figure 4.5.3: A clarification on indices to include in the inverse Fourier transform. Panel (a) shows the power spectrum and the identification of indices to include. Panel (b) shows the original output from the DFT (only the real part is shown here) with the identified indices shown as black lines. 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.

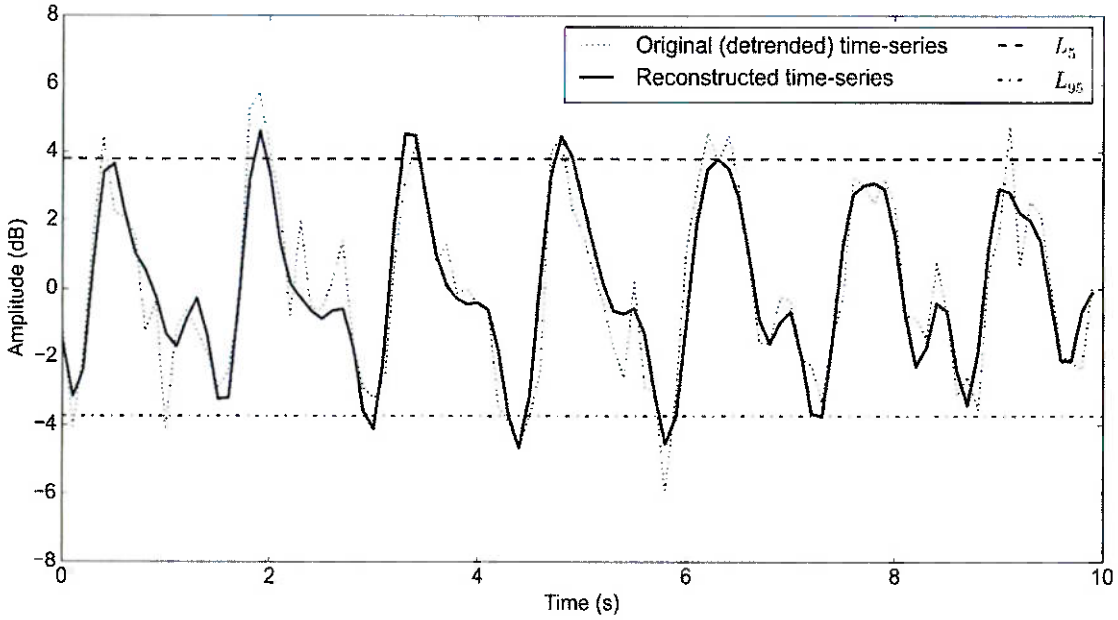

Figure 4.5.4: The original time-series (detrended with a 3rd order polynomial) and the reconstructed time-series. The modulation depth is calculated by subtracting the L_{95} from the L_5.

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.

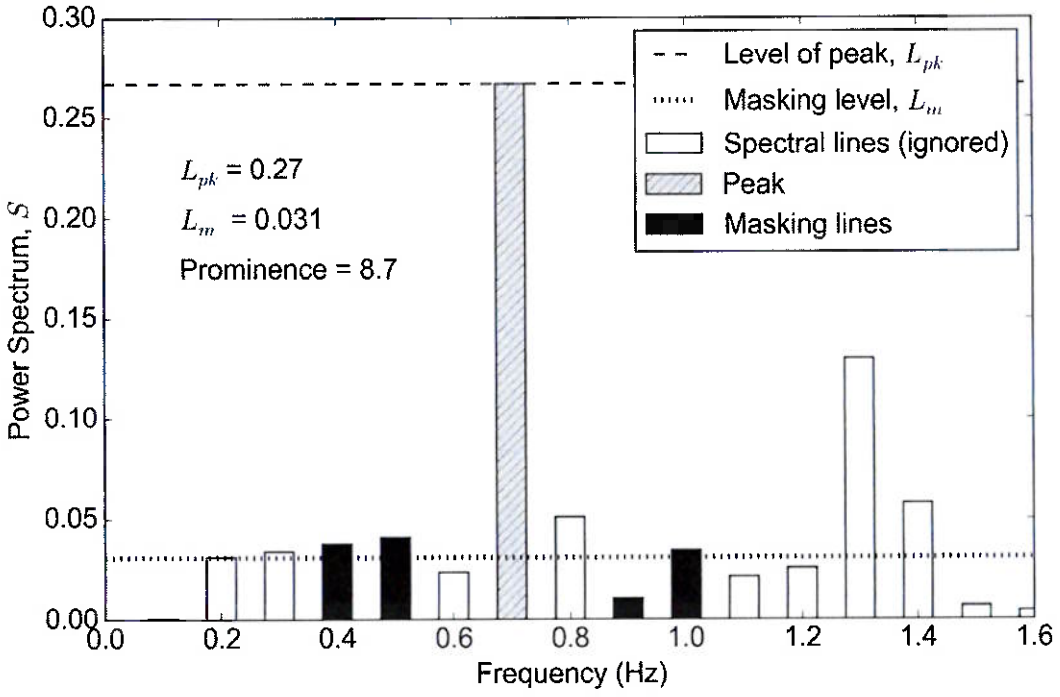

Figure 4.6.1: An example calculation of the peak prominence

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.

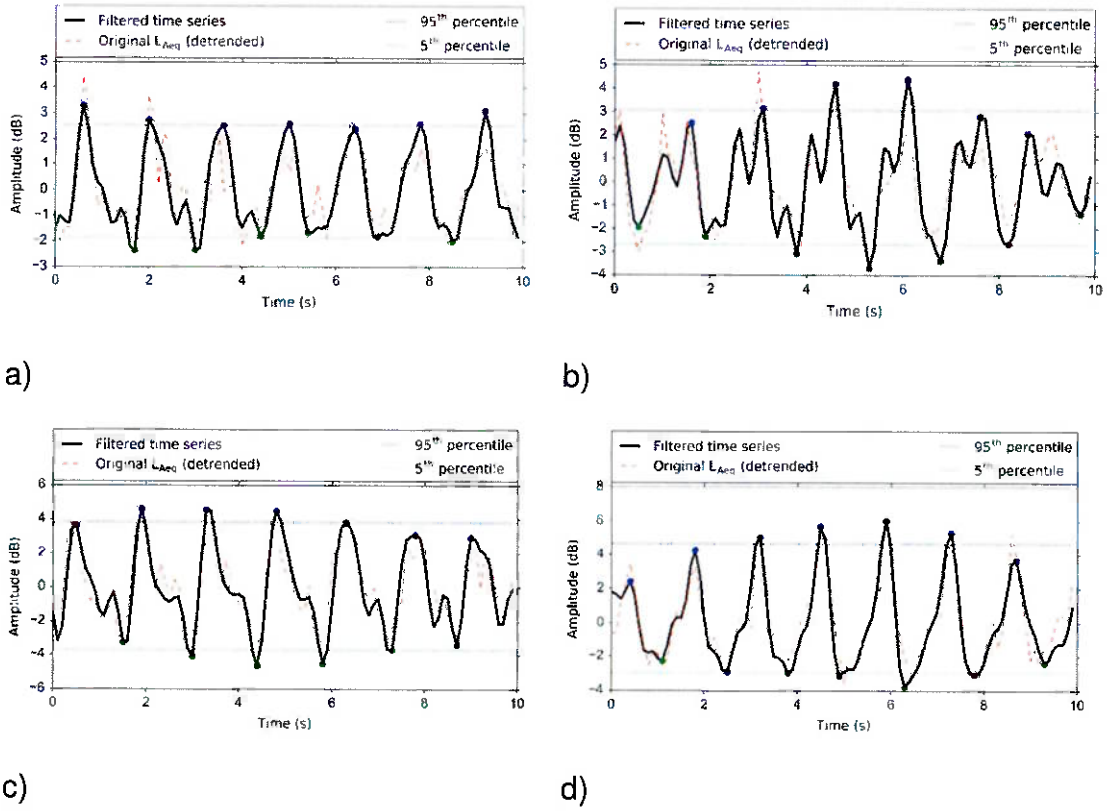

Figure 4.7.1 Examples (a to d) of 10-second blocks of AM time-series reconstructed using the reference method compared with the (unfiltered) $L_{Aeq,\ 100ms}$ signal

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).

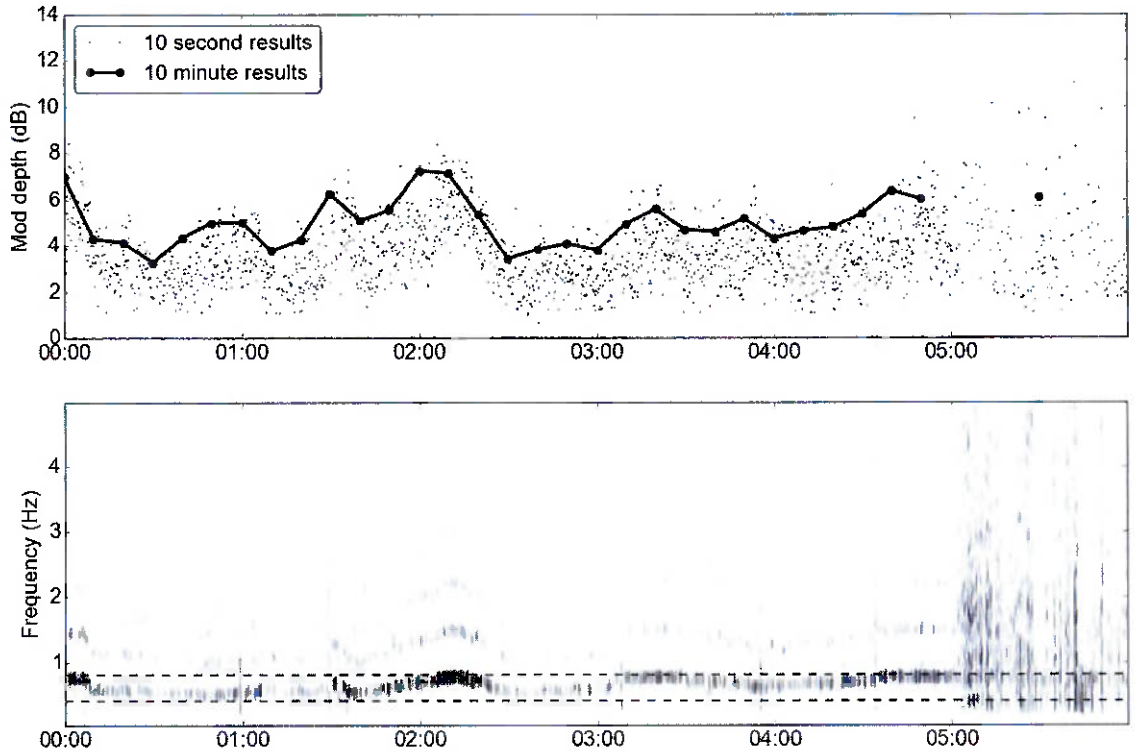

Figure 4.7.2 – Example of AM analysis results for a six-hour period

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;

[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.

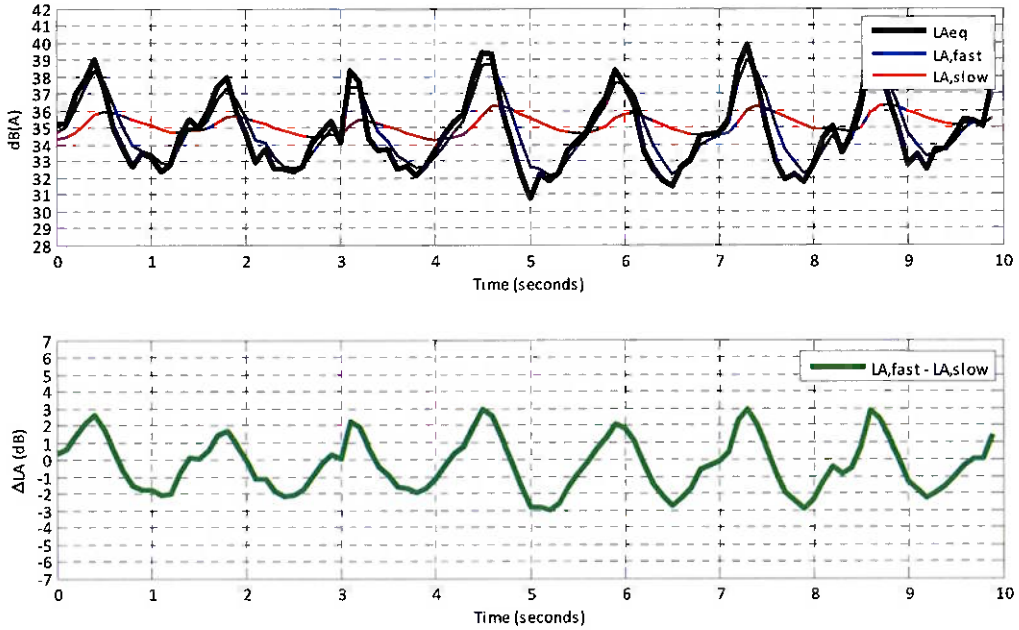

Figure 4.8.1 Derivation of $\Delta L_A(t)$

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.

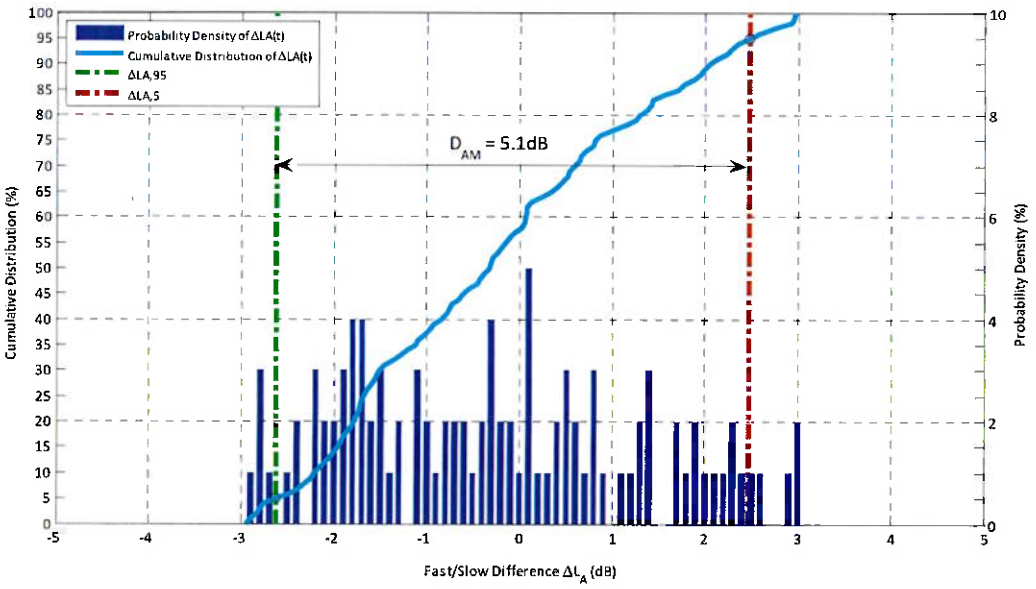

Figure 4.8.2 Cumulative distribution of $\Delta L_A(t)$ and derivation of DAM

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.

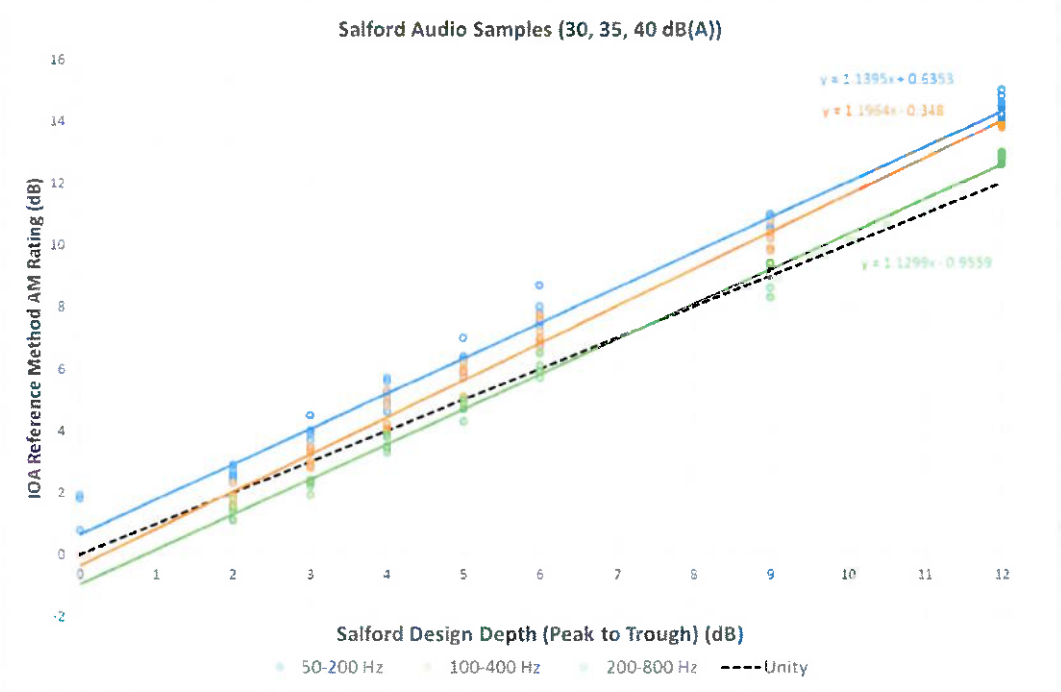

Figure 8.2.1 Analysis of Salford Stimuli with the IOA Reference Method

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.

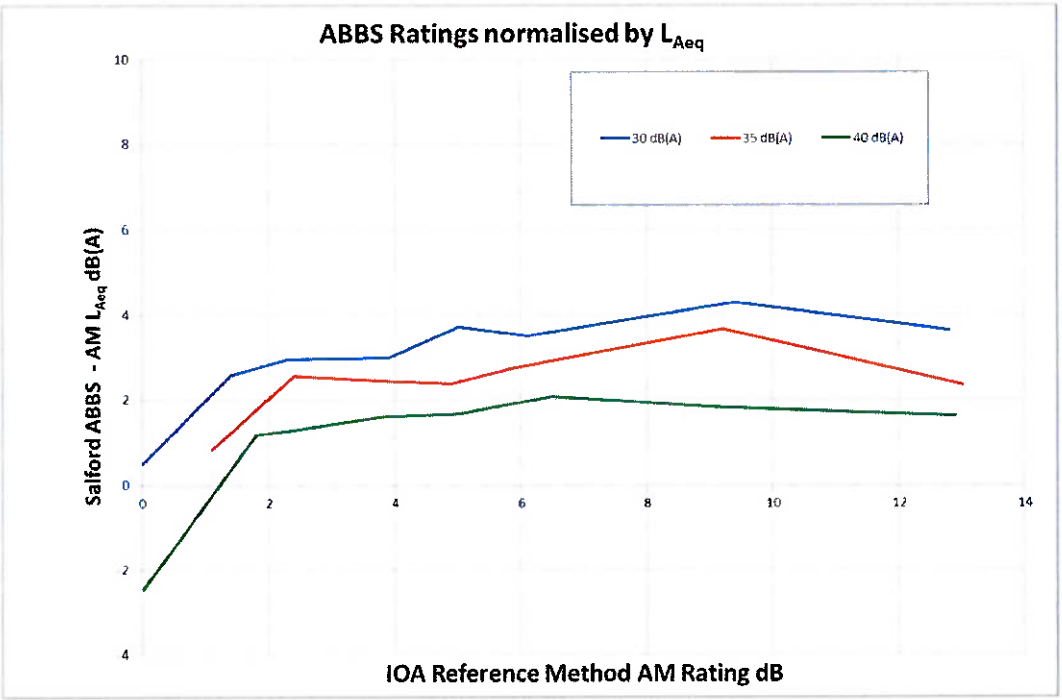

Figure 8.2.2 Comparison of Salford ABBS – AM L_{Aeq} results for IOA AM Rating (average values only 30, 35 & 40 dB(A), error bars omitted)

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.

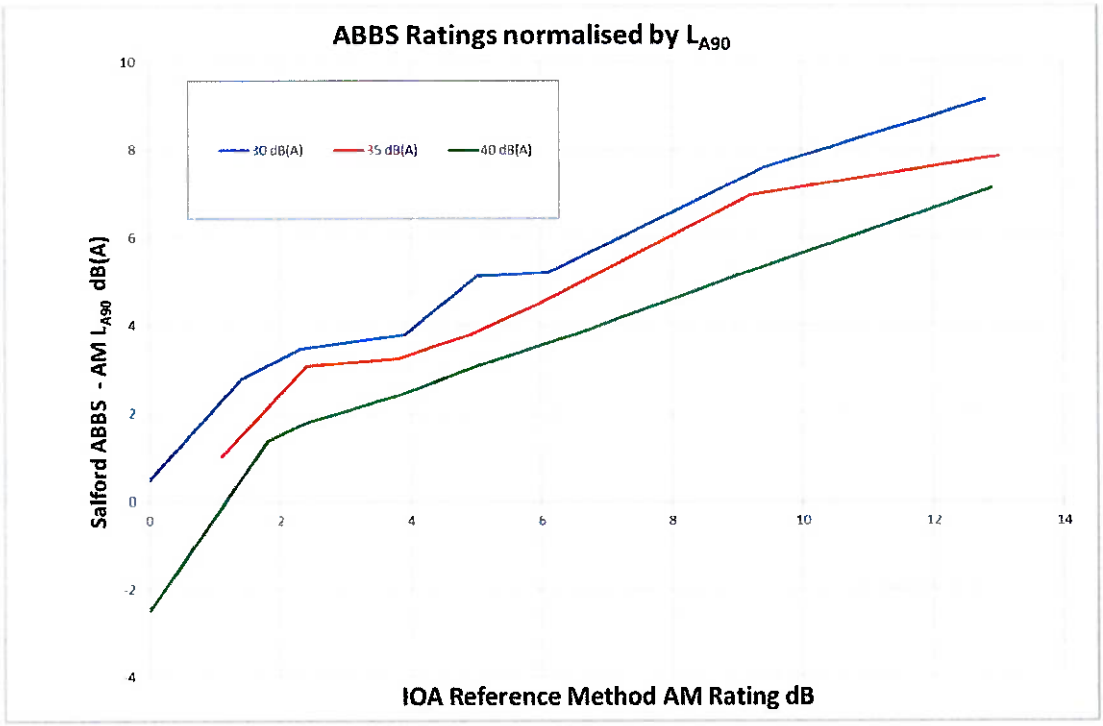

Figure 8.2.3 Comparison of Salford ABBS – AM L_{A90} results for IOA AM Rating (average values only 30, 35 & 40 dB(A), error bars omitted)

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 then allow a translation to the Tachibana AM results based on the IOA Reference Method.

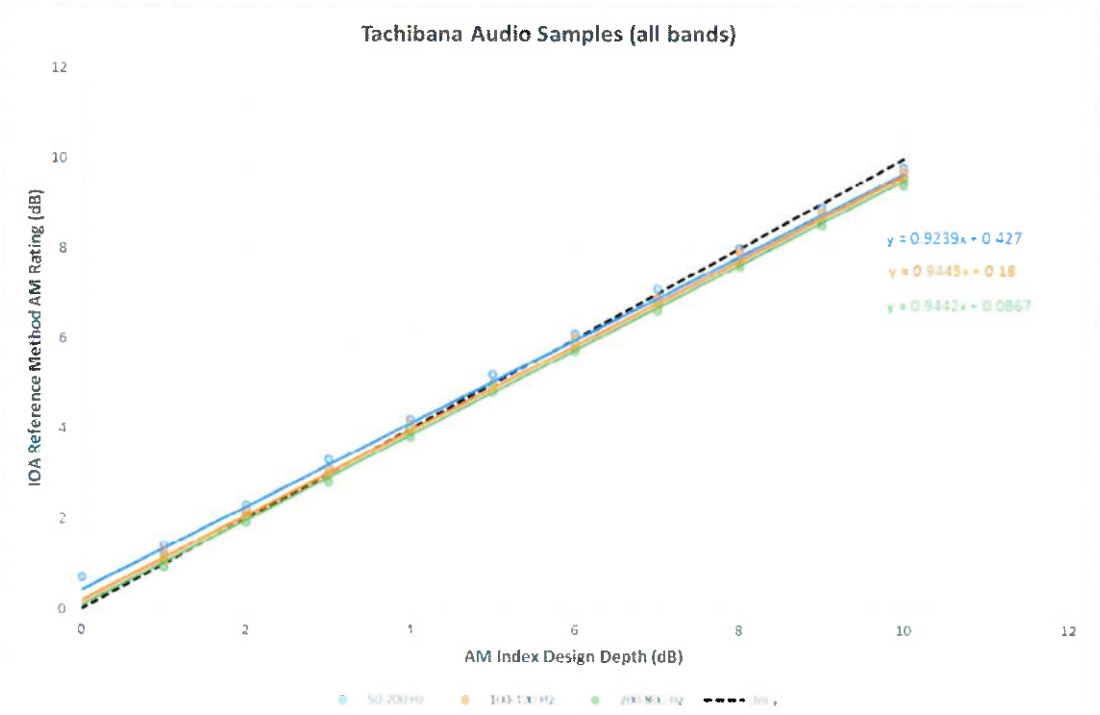

Figure 8.3.1 Analysis of Tachibana audio samples with the IOA Reference Method

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

[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.

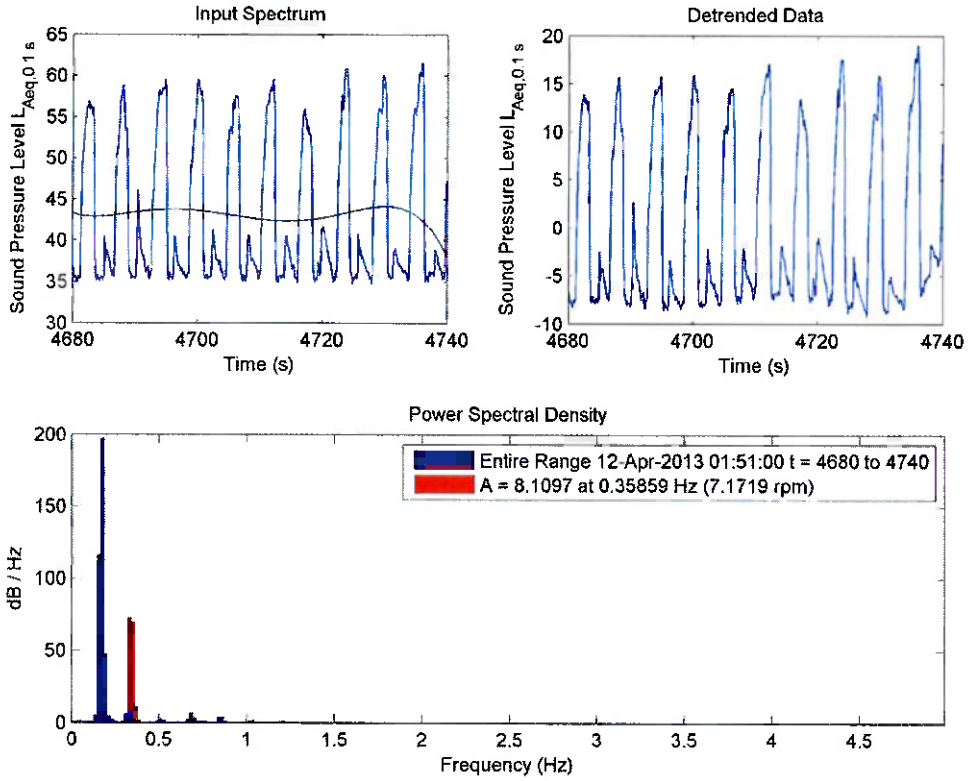

Figure C1 – 'AM' in noise from snoring

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

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WSP | Parsons Brinckerhoff
Kings Orchard
1 Queens St
Bristol
BS2 0HQ

Tel: +44(0) 1179 306300

www.wsp-pb.com

WSP | PARSONS BRINCKERHOFF

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PRODUCTION TEAM

DEPARTMENT OF ENERGY AND CLIMATE CHANGE (DECC)

Client	James Burt

WSP | PARSONS BRINCKERHOFF (INTERNAL RESEARCH TEAM)

Project Director	Ross Singleton
Project Manager	Richard Perkins
Researcher	Michael Lotinga

INDEPENDENT EXTERNAL 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

NON TECHNICAL SUMMARY 1

EXECUTIVE SUMMARY 2

1 INTRODUCTION 6

1.1 GENERAL 6

1.2 STUDY AIMS 7

2 METHODOLOGY 8

2.1 APPROACH 8

2.2 STAKEHOLDER CONTACT 8

2.3 EVIDENCE REVIEW METHODOLOGY 10

OVERVIEW 10
PROCESS 10
STUDY LIMITATIONS 12

3 REVIEW SUMMARY 14

3.1 STAKEHOLDER RESPONSES 14

3.2 CATEGORY 1 PAPERS 14

INTRODUCTION 14
REVIEW 16
STUDY A 16
STUDY B 18
STUDY C 21
STUDY D 25
STUDY E 27
CATEGORY 1 CONCLUSIONS 27

3.3 CATEGORY 2 PAPERS 28

INTRODUCTION 28
ASPECTS OF THE HUMAN RESPONSE TO AMPLITUDE-MODULATED WIND TURBINE NOISE EXPOSURE 28
CASE-STUDIES INVESTIGATING UN-SCALED HUMAN RESPONSE TO AMPLITUDE-MODULATED WIND TURBINE NOISE EXPOSURE 31
HUMAN RESPONSE TO NON-WIND-TURBINE AMPLITUDE-MODULATED NOISE EXPOSURE 36
HUMAN RESPONSE TO WIND TURBINE NOISE EXPOSURE (HEALTH EFFECTS) 39

FURTHER RELEVANT STUDIES 43
WIND FARM PUBLICATIONS PRODUCED BY AN 'INDEPENDENT NOISE WORKING GROUP' 43
CATEGORY 2 CONCLUSIONS 58

3.4 LIMITATIONS OF EVIDENCE 58
CATEGORY 1 PAPERS 58
CATEGORY 2 PAPERS 59
SUMMARY 59

3.5 INSTITUTE OF ACOUSTICS METHOD FOR RATING AM 60

4 FACTORS AFFECTING DEVELOPMENT OF A PLANNING CONDITION 62

4.1 PLANNING POLICY GUIDANCE 62

4.2 FURTHER PLANNING CONDITION CONSIDERATIONS SUGGESTED BY THE INWG 64

4.3 EXISTING PLANNING CONDITIONS 64

4.4 OTHER POTENTIAL PLANNING CONDITION METHODS 65

4.5 DISCUSSION 65

4.6 OPERATIONAL IMPACTS AND MITIGATION 72

5 CONCLUSIONS 74

5.1 AM 74

5.2 PROPOSAL FOR PENALTY SCHEME 74

6 REFERENCES 76

APPENDICES

APPENDIX A GLOSSARY & CONCEPTS
APPENDIX B FULL LIST OF PUBLICATIONS
APPENDIX C REVIEW RESPONSE CATEGORIES

ANNEXES

ANNEX 1

CATEGORY 1 STUDY F

ANNEX 2

CATEGORY 1 STUDY G

ANNEX 3

HEALTH CANADA COMMUNITY NOISE AND HEALTH STUDY LITERATURE

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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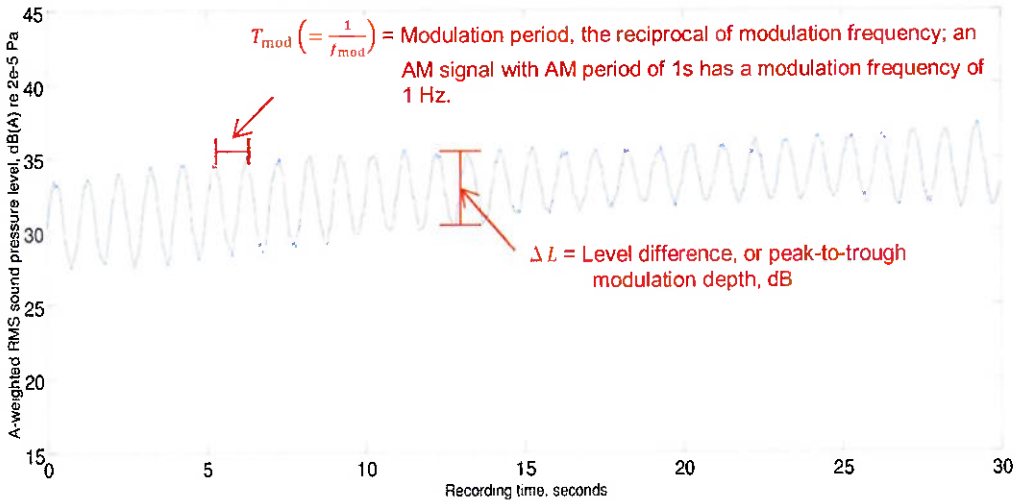
[1] *ETSU-R-97 The assessment and rating of noise from wind farms,* The Working Group on Noise from Wind Turbines Final Report September 1996

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.

---

[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.

---

[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

[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 in 2015, 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

[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	RenewableUK
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).

[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 turbine 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).

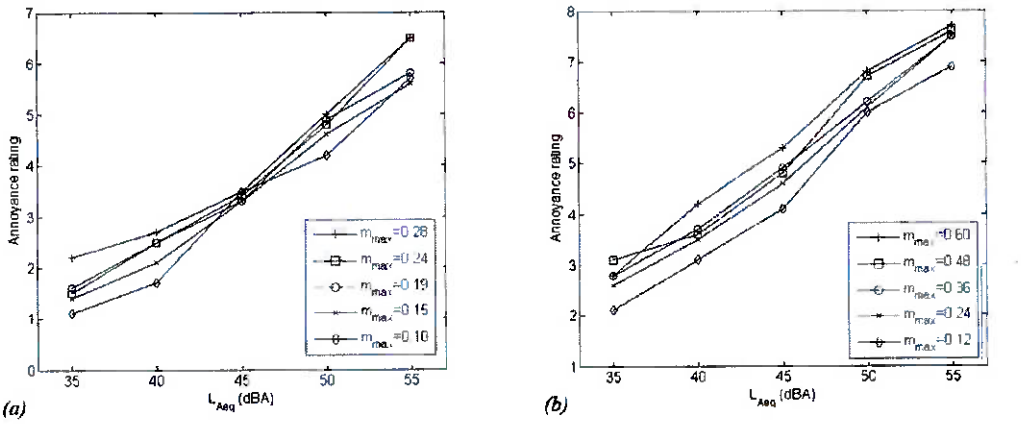

Figure 1: Association of amplitude-modulated wind turbine noise level with mean annoyance ratings over a range of modulation depths (as parameter) for two sample sets, one with higher low-frequency spectral content (left) and one with higher mid and high-frequency content (right), from (Lee, Kim, Lee, 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.

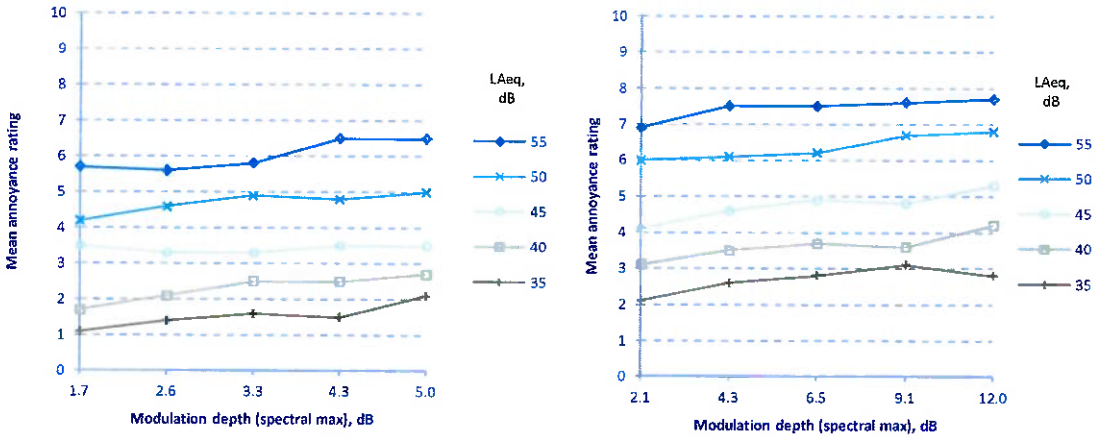

Figure 2: Estimated relationship between wind turbine noise amplitude modulation (maximum spectral modulation depth) and mean annoyance ratings corresponding with the results in Figure 1 with overall average level (L_{Aeq}[17]) as parameter, reanalysed from (Lee, Kim, Lee, Kim, & Lee, 2009)

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.

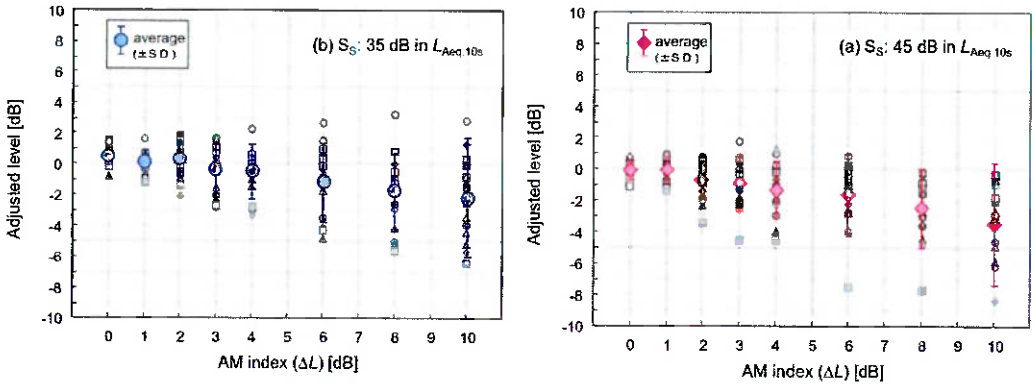

Figure 3: Level adjustments of amplitude-modulated noise to achieve equivalent perceived noisiness with a steady-state noise, from (Yokoyama, Koboyashi, Sakamoto, & Tachibana, 2015)

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 Δ*L*; this is in agreement with the earlier findings of Vos et al. (2010a) [grey], as reported by van den Berg et al. (2011) [grey].

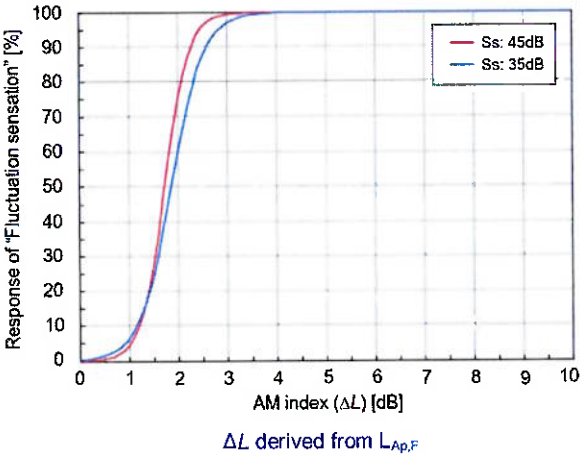

Figure 4: Perception of Fluctuation in synthesised amplitude-modulated wind turbine noise, from (Yokoyama, Koboyashi, Sakamoto, & Tachibana, 2015)

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.

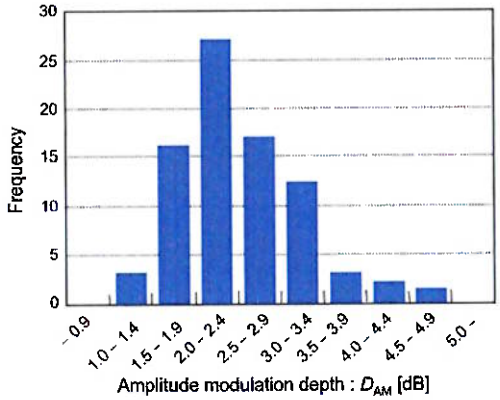

Figure 5: Distribution of D_{AM} in the field data from 18 Japanese wind farm sites, from (Tachibana, Yano, Fukushima, & Sueoka, 2014)

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).

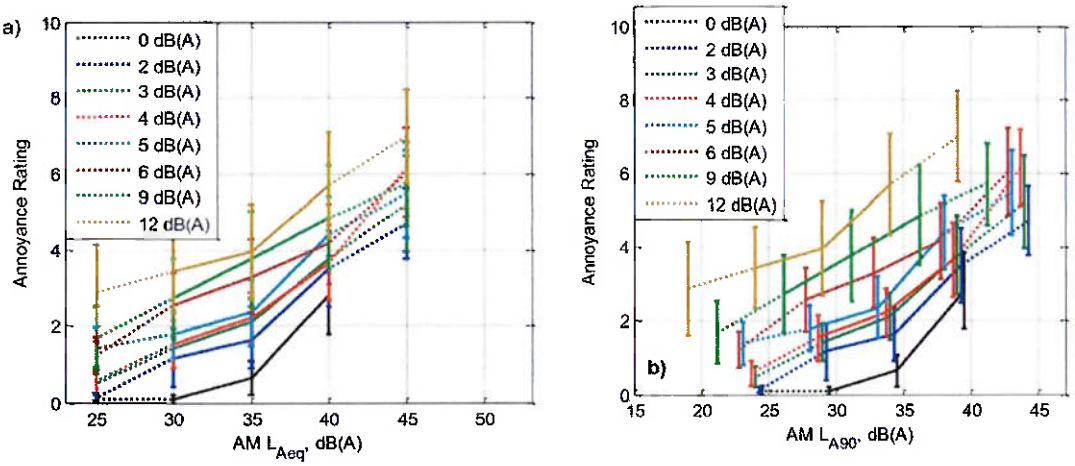

Figure 6: Association of amplitude-modulated wind turbine noise level measured as L_{Aeq} (left) and L_{A90}[20] (right) with annoyance ratings, with modulation depth as parameter, from (von Hünerbein, King, Piper, & Cand, 2013) – dotted lines indicate results from reduced sample, error bars: 95% confidence intervals (CI)

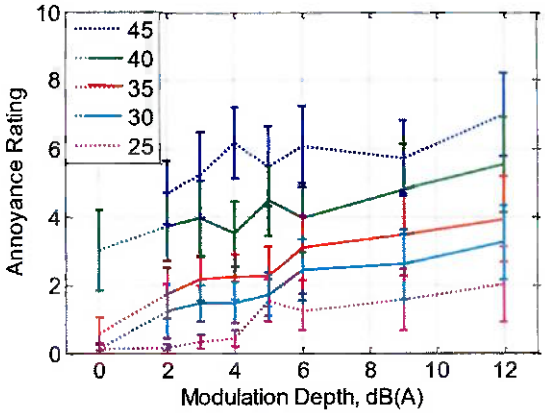

Figure 7: Relationship between modulation depth and annoyance rating with overall average level (L_{Aeq}) as parameter, from (von Hünerbein & Piper, 2015) – dotted lines indicate results from reduced sample, error bars 95% CI

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).

[20] A-weighted sound pressure level exceeded for 90% of the measurement interval.

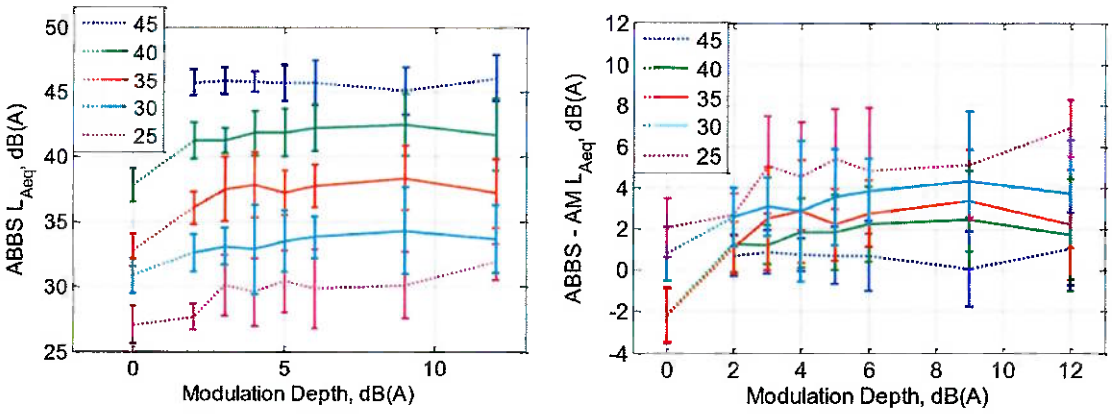

Figure 8: Level adjustments of broadband noise to achieve equivalent annoyance compared with amplitude-modulated noise of a fixed average level (as parameter), as adjusted levels (left), and normalised to adjustment level differences by subtracting the average level (L_{Aeq}) of the amplitude-modulated 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.

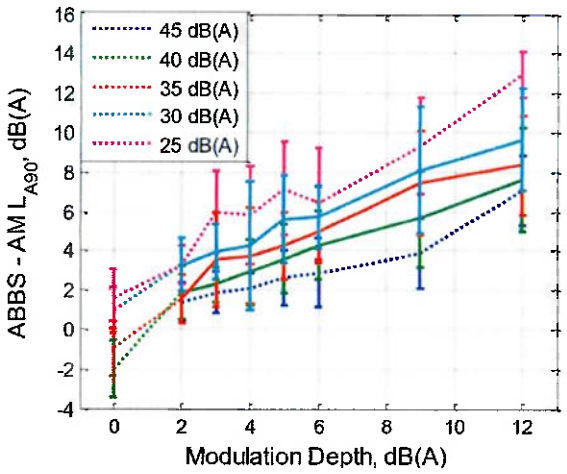

Figure 9: Level adjustments of broadband noise to achieve equivalent annoyance compared with amplitude-modulated noise of a fixed average level (L_{Aeq} as parameter), as normalised by subtracting the 90% exceeded level (L_{A90}) of the amplitude-modulated noise (right), from (von Hünerbein, King, Piper, & 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.

3.2.40 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.

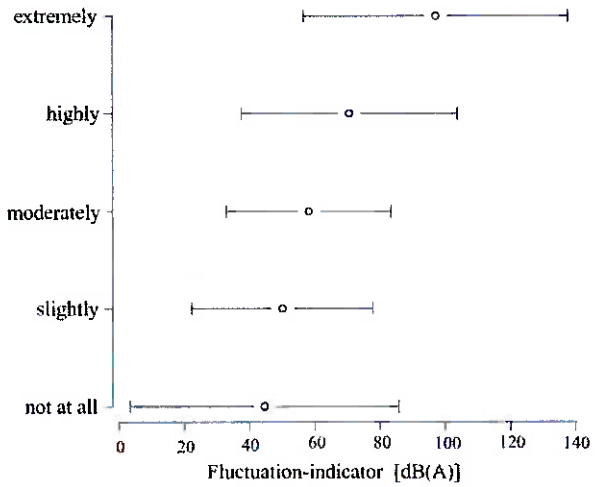

Figure 10: Relationship between fluctuation indicator and reported annoyance (error bars show +/-σ), from (Bockstael, Dekoninck, Can, Oldoni, de Coensel, & Botteldooren, 2012)

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.

[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.

[23] Heating, ventilation and air-conditioning

Perception and annoyance due to wind turbine noise – a dose-response relationship (Pedersen & 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.

3.3.8 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.

[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

[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 angle 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

[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;

[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.

[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

[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*

[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.

[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.

[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 authorities (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 will 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

[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 relatively 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 in a 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 In order to meet the 'six tests', the following aspects are considered by the project team to be important:

- → 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 OTHER POTENTIAL PLANNING CONDITION METHODS

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.

IDENTIFICATION 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.

4.5.4 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

[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

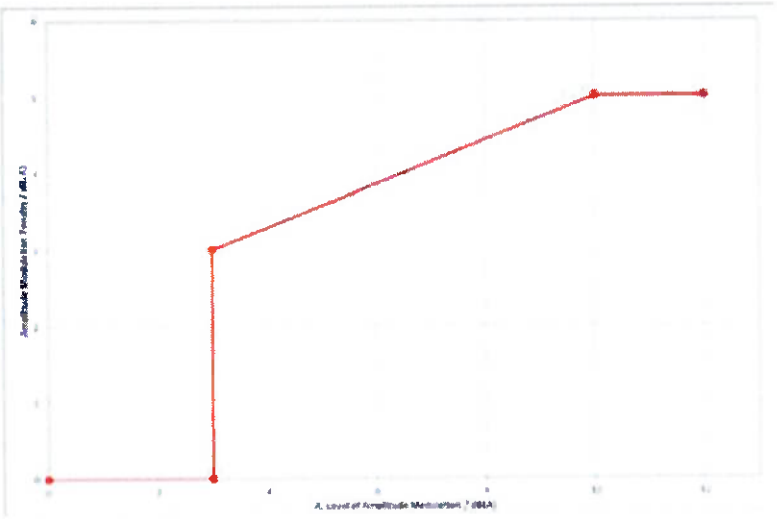
4.5.21 As noted in paragraph 4.1.5, the main purpose of the control or 'penalty' is to bring about a reduction in the impact as a result of the period of unacceptable AM, and as currently proposed this consists of a two-tiered approach. The first tier would be seeking a reduction in the depth and/or 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.

[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

[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

[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.

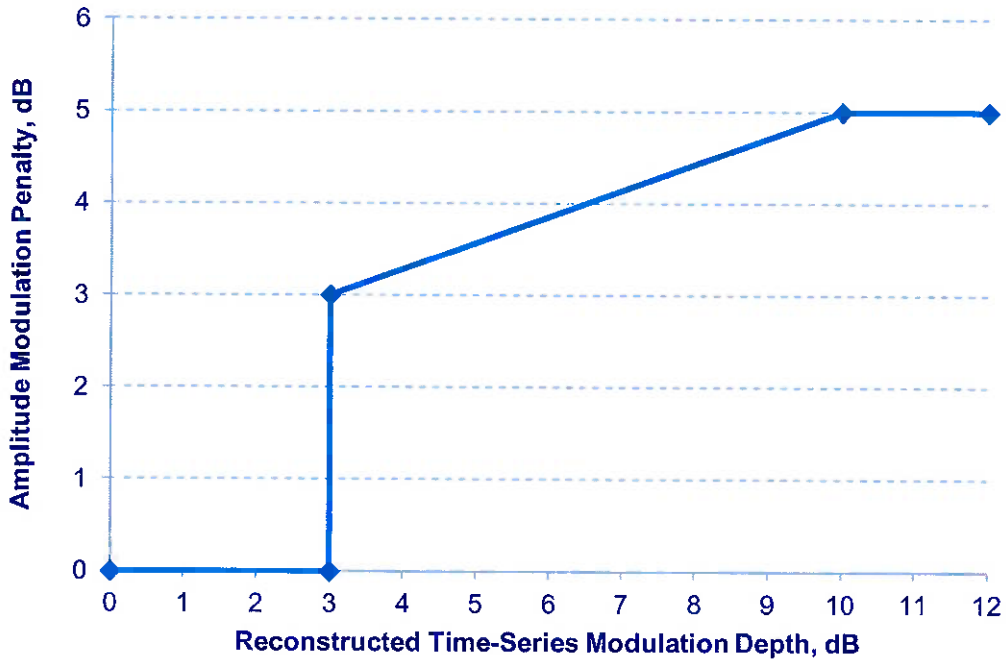


Figure 12: Proposed Level Penalty Regime

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.

[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.

6 REFERENCES

AECOM. (2015). Survey of Noise Attitudes (SoNA) 2013. Prepared for: DEFRA. Report Ref: 47067932.NN1501.R1/02. DEFRA.

Bengtsson, J., Persson Waye, K., & Kjellberg, A. (2004). Sound characteristics in low frequency noise and their relevance for the perception of pleasantness. Acta Acustica united with Acustica, 171-180.

Bockstael, A., Dekoninck, L., Can, A., Oldoni, D., de Coensel, B., & Botteldooren, D. (2012). Reduction of wind turbine noise annoyance: an operational approach. Acta Acustica united with Acustica, 392-401.

Bockstael, A., Dekoninck, L., de Coensel, B., Oldoni, D., Can, A., & Botteldooren, D. (2011). Wind turbine noise: annoyance and alternative exposure indicators. Forum Acusticum (pp. 345-350). Aalborg, Denmark: EAA.

Bradley, J. S. (1994). Annoyance caused by constant-amplitude and amplitude-modulated sounds containing rumble. Noise Control Engineering Journal, 203-208.

BSI. (1997). BS 4142:1997 Method for rating industrial noise affecting mixed residential and industrial areas. London: British Standards Institution.

BSI. (2008). BS 6472-1:2008 Guide to evaluation of human exposure to vibration in buildings. Part 1. Vibration sources other than blasting. London: British Standards Institution.

BSI. (2014). BS 4142:2014 Methods for rating and assessing industrial and commercial sound. London: British Standards Institution.

Bullmore, A., & Cand, M. (2013). Wind turbine amplitude modulation: research to improve understanding as to its cause & effect. Work package C: Collation and analysis of existing acoustic recordings. RenewableUK.

Bullmore, A., Jiggins, M., Cand, M., Smith, M., von Hünerbein, S., & Davis, R. (2011). Wind turbine amplitude modulation: research to improve understanding as to its cause & effect. 4th International Meeting on Wind Turbine Noise. Rome, Italy: INCE Europe.

Cand, M., & Bullmore, A. (2015a). Understanding amplitude modulation of noise from wind turbines: causes and mitigation. Acoustics in Practice, 45-52.

Cand, M., & Bullmore, A. (2015b). Measurements demonstrating mitigation of far-field AM from wind turbines. 6th International Meeting on Wind Turbine Noise. Glasgow, UK: INCE Europe.

Council of Canadian Academies. (2015). Understanding the evidence: wind turbine noise. Ottawa: The Expert Panel on Wind Turbine Noise and Human Health, Council of Canadian Academies.

Cowen, R. (2015). Wind turbine amplitude modulation & planning control study – Work Package 6.1: Legal issues: the control of excessive amplitude modulation from wind turbines . Retrieved 2015, from www.heatonharris.com.

Cox, R. (2015). Wind turbine amplitude modulation & planning control study - Work Package 2.1: Review of reference literature. Retrieved 2015, from www.heatonharris.com.

Cox, R. (2015). Wind turbine amplitude modulation & planning control study – Work Package 8: Review of Institute of Acoustics amplitude modulation study and methodology. Retrieved 2015, from www.heatonharris.com.

DCLG. (2012). National planning policy framework. London: Department for Communities and Local Government.

DEFRA. (2010). Noise policy statement for England. London: Department for Environment, Food and Rural Affairs.

Di Napoli, C. (2009). Case study: wind turbine noise in a small and quiet community in Finland. 3rd International Meeting on Wind Turbine Noise. Aalborg, Denmark: INCE Europe.

Di Napoli, C. (2011). Wind turbine noise assessment in a small and quiet community in Finland. Noise Control Engineering Journal, 30-37.

Dittrich, K., & Oberfeld, D. (2009). A comparison of the temporal weighting of annoyance and loudness. Journal of the Acoustical Society of America, 3168-3178.

Energy Technology Support Unit Working Group on Noise from Wind Turbines. (1996). ETSU-R-97 The assessment and rating of noise from wind farms. DTI.

Fastl, H., & Menzel, D. (2013). Psychoacoustic aspects of noise from wind turbines . Inter-noise. Innsbruck, Austria: I-INCE.

Fastl, H., & Zwicker, E. (2007). Psychoacoustics: facts and models. Berlin: Springer-Verlag.

Gabriel, J., Vogl, S., Neumann, T., Hübner, G., & Pohl, J. (2013). Amplitude modulation and complaints about wind turbine noise. 5th International Conference on Wind Turbine Noise. Denver, USA: I-INCE.

Gray, B. (2015). Wind turbine amplitude modulation & planning control study – Work Package 6.2: Control of AM noise without an AM planning condition using statutory nuisance. Retrieved 2015, from www.heatonharris.com.

Gray, B., & Tossell, J. (2015). Wind turbine amplitude modulation & planning control study – Work Package 9: The Cotton Farm monitor experience. Retrieved 2015, from www.heatonharris.com.

Hanning, C. D. (2015). Wind turbine amplitude modulation & planning control study – Work Package 3.2: Excessive amplitude modulation, wind turbine noise, sleep and health. Retrieved 2015, from www.heatonharris.com.

Hansen, K. L., Zajamšek, B., & Hansen, C. H. (2015). Quantifying the character of wind farm noise. 22nd International Congress on Sound and Vibration. Florence, Italy: IIAV.

Health Canada. (2014a). Environmental and workplace health. Wind turbine noise and health study: summary of results. Retrieved 2015, from www.hc-sc.gc.ca: http://www.hc-sc.gc.ca/ewh-semt/noise-bruit/turbine-eoliennes/summary-resume-eng.php

Health Canada. (2014b). Environmental and workplace health. Health impacts and exposure to sound from wind turbines: updated research design and sound exposure assessment. Retrieved 2015, from www.hc-sc.gc.ca: http://www.hc-sc.gc.ca/ewh-semt/consult/_2013/wind_turbine-eoliennes/research_recherche-eng.php

Hulme, M. W. (2015). Wind turbine amplitude modulation & planning control study – Work Package 4: Den Brook. Retrieved 2015, from www.heatonharris.com.

Independent Noise Working Group. (2015). Wind turbine amplitude modulation & planning control study - Terms of reference. Retrieved 2015, from www.heatonharris.com.

IOA. (2013). A good practice guide to the application of ETSU-R-97 for the assessment and rating of wind turbine noise. St Albans: Institute of Acoustics.

IOA AMWG. (2015a). IOA Noise Working Group (Wind Turbine Noise) Amplitude Modulation Working Group Discussion Document: Methods for rating amplitude modulation in wind turbine noise. St Albans: Institute of Acoustics.

IOA AMWG. (2015b). IOA Consultation Questionnaire for "Methods for rating amplitude modulation in wind turbine noise". St Albans: Institute of Acoustics.

IOA AMWG. (2016). IOA Noise Working Group (Wind Turbine Noise) Amplitude Modulation Working Group Final Report: A method for rating amplitude modulation in wind turbine noise. St Albans: Institute of Acoustics.

ISO. (2003). ISO/TS 15666:2003 Acoustics - Assessment of noise annoyance by means of social and socio-acoustic surveys. Geneva: International Standards Organization.

Kaczmarek, T., & Preis, A. (2010). Annoyance of time-varying road traffic noise. Archives of Acoustics, 383-393.

Kageyama, T., Yano, T., Kuwano, S., Sueoka, S., & Tachibana, H. (2014). ◊ Exposure-response relationship of wind turbine noise with subjective symptoms on sleep and health: a nationwide socio-acoustic survey in Japan. 11th International Congress on Noise as a Public Health Problem. Nara, Japan: ICBEN.

Kantarelis, C., & Walker, J. G. (1988). The identification and subjective effect of amplitude modulation in diesel engine exhaust noise. Journal of Sound and Vibration, 297-302.

Kelley, N. D., McKenna, H. E., Hemphill, H. E., Etter, C. L., Garrelts, R. L., & Linn, N. C. (1985). Acoustic noise associated with the MOD-1 wind turbine: its source, impact and control. Colorado, USA: Solar Energy Research Institute.

Klein, A., Marquis-Favre, C., & Weber, R. T. (2015). Spectral and modulation indices for annoyance-relevant features of urban road single-vehicle pass-by noises. Journal of the Acoustical Society of America, 1238-1250.

Knopper, L. D., Ollson, C. A., McCallum, L. C., Whitfield Aslund, M. L., Berger, R. G., Souweine, K., et al. (2014). Wind turbines and human health. Frontiers in Public Health, 2(63).

Krogh, C. M., Gillis, L., Kouwen, N., & Aramini, J. (2011). WindVOiCe, a self-reporting survey: adverse health effects, industrial wind turbines, and the need for vigiliance monitoring. Bulletin of Science, Technology and Society, 334-345.

Kurpas, D., Mroczek, B., Karakiewicz, B., Kassolik, K., & Andrzejewski, W. (2013). Health impact of wind farms. Annals of Agricultural and Environmental Medicine, 595-605.

Kuwano, S., Yano, T., Kageyama, T., Sueoka, S., & Tachibana, H. (2014). Social survey on wind turbine noise in Japan. Noise Control Engineering, 503-520.

Large, S. (2015). Wind turbine amplitude modulation & planning control study - Work Package 2.2: AM evidence review. Retrieved 2015, from www.heatonharris.com.

Large, S., & Stigwood, M. (2014). Noise characteristics of 'compliant' wind farms that adversely affect its neighbours. Inter-noise. Melbourne, Australia: I-INCE.

Large, S., Stigwood, D., & Bingham, D. (2015). Wind turbine amplitude modulation & planning control study - Work Package 5: Towards a draft AM condition. Retrieved 2015, from www.heatonharris.com.

Lee, S., Kim, K., Choi, W., & Lee, S. (2011). Annoyance caused by amplitude modulation of wind turbine noise. Noise Control Engineering Journal, 38-46.

Lee, S., Kim, K., Lee, S., Kim, H., & Lee, S. (2009). An estimation method of the amplitude modulation in wind turbine noise for community response assessment. Third International Meeting on Wind Turbine Noise. Aalborg, Denmark: INCE Europe.

Lee, S., Lee, S., & Lee, S. (2013). Numerical modeling of wind turbine aerodynamic noise in the time domain. Journal of the Acoustical Society of America, JASA Express Letters.

Legarth, D. V. (2007). Auralization and assessments of annoyance from wind turbines. Second International Meeting on Wind Turbine Noise. Lyon, France: INCE Europe.

Makarewicz, R., & Gołębiewski, R. (2015). Influence of blade pitch on amplitude modulation of wind turbine noise. Noise Control Engineering Journal, 195-201.

McCunney, R. J., Mundt, K. A., Colby, W. D., Dobie, R., Kaliski, K., & Blais, M. (2014). Wind turbines and health: a critical review of the scientific literature. Journal of Occupational and Environmental Medicine, 108-130.

Merlin, T., Newton, S., Ellery, B., Milverton, J., & Farah, C. (2013). Systematic review of the human health effects of wind farms. Canberra, Australia: National Health and Medical Research Council.

Michaud, D. S., Feder, K., Keith, S. E., Voicescu, S. A., Marro, L., Than, J., et al. (2016). Effects of wind turbine noise on self-reported and objective measures of sleep. Sleep, 97-107.

Michaud, D. S., Keith, S. E., Feder, K., Soukhovtsev, V., Marro, L., Denning, A., 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, 14-23.

Moorhouse, A. T., Waddington, D. C., & Adams, M. (2013). Erratum: a procedure for the assessment of low frequency noise complaints [J. Acoust. Soc. Am. 126, 1131-1141 (2009]. Jorunal of the Acoustical Society of America, 2336.

Moorhouse, A. T., Waddington, D. C., & Adams, M. D. (2007). The effect of fluctuations on the perception of low frequency sound. Journal of Low Frequency Noise, Vibration and Active Control, 81-89.

Moorhouse, A. T., Waddington, D. C., & Adams, M. D. (2009). A procedure for the assessment of low frequency noise complaints. Journal of the Acoustical Society of America, 1131-1141.

Nissenbaum, M. A., Aramini, J. J., & Hanning, C. D. (2012). Effects of industrial wind turbine noise on sleep and health. Noise and Health, 237-243.

Nobbs, B., Doolan, C. J., & and Moreau, D. J. (2012). Characterisation of noise in homes affected by wind turbine noise. Proceedings of Acoustics 2012. Freemantle, Australia: Australian Acoustics Society.

Oerlemans, S. (2015). Effect of wind shear in amplitude modulation of wind turbine noise. International Journal of Aeroacoustics, 715-728.

Ollson, C. A., Knopper, L. D., McCallum, L. C., & L, W.-A. M. (2013). Letter to Editor: Are the findings of "Effects of industrial wind turbine noise on sleep and health" supported? Noise and Health, 148-150.

Onakpoya, I. J., O'Sullivan, J., Thompson, M. J., & Heneghan, C. J. (2015). The effect of wind turbine noise on sleep and quality of life: a systematic review and meta-analysis of observational studies. Environmental International, 1-9.

Pedersen, E., & Persson Waye, K. (2004). Perception and annoyance due to wind turbine noise – a dose-response relationship. Journal of the Acoustical Society of America, 3460-3470.

Pedersen, E., van den Berg, F., Bakker, R., & Bouma, J. (2009). Response to noise from modern wind farms in The Netherlands. Journal of the Acoustical Society of America, 634-643.

Persson Waye, K., & Öhrström, E. (2002). Psycho-acoustic characters of relevance for annoyance of wind turbine noise. Journal of Sound and Vibration, 65-73.

RenewableUK. (2013). The development of a penalty scheme for amplitude modulated wind farm noise. London: RenewableUK.

RSG et al. (2016). Massachusetts study on wind turbine acoustics. Massachusetts: Massachusetts Clean Energy Centre and Massachusetts Department of Environmental Protection.

Schmidt, J. H., & Klokker, M. (2014). Health effects related to wind turbine noise exposure: a systematic review. PLoS ONE, 9(12).

Seong, Y., Lee, S., Gwak, D., Cho, Y., Hong, J., & Lee, S. (2013a). An experimental study on annoyance scale for assessment of wind turbine noise. Journal of Renewable and Sustainable Energy.

Seong, Y., Lee, S., Gwak, D., Cho, Y., Hong, J., & Lee, S. (2013b). An experimental study on rating scale for annoyance due to wind turbine noise. Inter-noise. Innsbruck, Austria: I-INCE.

Sherman, T. (2015). 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. Retrieved 2015, from www.heatonharris.com.

SLR & Hoare Lea. (2015). Wind farm impacts study - Final report. Edinburgh: ClimateXChange.

Smith, M. G. (2013). Wind turbine amplitude modulation: research to improve understanding as to its cause & effect. Work package A(2): Fundamental research into possible causes of amplitude modulation. RenewableUK.

South Australia Environmental Protection Agency. (2015). Waterloo Wind Farm Environmental Noise Study. Retrieved 2015, from www.epa.sa.gov.au: http://www.epa.sa.gov.au/environmental_info/noise/types_of_noise/wind_farms/waterloo_wind_farm_environmental_noise_study

Stigwood, M., Large, S., & Stigwood, D. (2013). Audible amplitude modulation - results of field measurements and investigations compared to psychoacoustical assessment and theoretical research. 5th International Conference on Wind Turbine Noise. Denver: USA.

Stigwood, M., Stigwood, D., & Large, S. (2014). Initial findings of the UK Cotton Farm Wind Farm long term long term community noise monitoring project. Inter-noise. Melbourne, Australia: I-INCE.

Tachibana, H. (2014). Outcome of systematic research on wind turbine noise in Japan. Inter-noise. Melbourne, Australia: I-INCE.

Tachibana, H., Yano, H., Fukushima, A., & Sueoka, S. (2014). Nationwide field measurements of wind turbine noise in Japan. Noise Control Engineering Journal, 90-101.

The Senate Community Affairs Reference Committee. (2011). The social and economic impact of rural wind farms. Commonwealth of Australia.

Thorne, R. (2014). Perception and effect of wind farm noise at two Victorian wind farms. Brisbane, Australia: Noise Measurement Services.

van den Berg, F. (2009). Why is wind turbine noise noisier than other noise? Euronoise. Edinburgh, Scotland: INCE Europe.

van den Berg, F. (2011). Effects of sound on people. In G. Leventhall, & D. Bowdler, Wind turbine noise. Brentwood: Multi-Science Publishing.

van den Berg, F. (2013). Wind turbine noise: an overview of acoustical performance and effects on residents. Proceedings of Acoustics. Victor Harbour, Australia: Australian Acoustical Society.

van den Berg, F., & Bowdler, D. (2011). Amplitude modulation. In G. Leventhall, & D. Bowdler (Eds.), Wind turbine noise. Multi-Science Publishing.

van den Berg, G. P. (2004). Effects of the wind profile at night on wind turbine sound. Journal of Sound and Vibration, 955-970.

van den Berg, G. P. (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, 1-24.

von Hünerbein, S., & Piper, B. (2015). Affective response to amplitude modulated wind turbine noise. 6th International Meeting on Wind Turbine Noise. Glasgow, UK: INCE Europe.

von Hünerbein, S., King, A., Piper, B., & Cand, M. (2013). Wind turbine amplitude modulation: research to improve understanding as to its cause & effect. Work package B(2): development of an AM dose-response relationship. RenewableUK.

Vos, J., & Houben, M. M. (2010a). Analysis of wind turbine sound recordings. TNO.

Vos, J., Houben, M. M., van der Ploeg, F., & Buikema, E. (2010b). Annoyance caused by low frequency sounds: spectral and temporal effects. Inter-noise. Lisbon: I-INCE.

Wells, G. A., Shea, B., O'Connell, D., Peterson, J., Welch, V., Losos, M., et al. (n.d.). The Newcastle-Ottawa Scale (NOS) for assessing the quality of nonrandomised studies in meta-analyses. Retrieved 2015, from www.ohri.ca/.

WHO. (2009). Night noise guidelines for Europe. Geneva: World Health Organization.

WHO. (2011). Burden of disease from environmental noise: quantification of healthy life years lost in Europe. Geneva: World Health Organization.

Yano, T., Kuwano, S., Kageyama, T., Sueoka, S., & Tachibana, H. (2013). Dose-response relationships for wind turbine noise in Japan. Inter-noise. Innsbruck, Austria: I-INCE.

Yelland, J. V. (2015). Wind turbine amplitude modulation & planning control study - Work Package 1: The fundamentals of amplitude modulation of wind turbine noise. Retrieved 2015, from www.heatonharris.com.

Yokoyama, S., Koboyashi, T., Sakamoto, S., & Tachibana, H. (2015). Subjective experiments on the auditory impression of the amplitude modulation sound contained in wind turbine noise. 6th International Meeting on Wind Turbine Noise. Glasgow: INCE Europe.

Yokoyama, S., Sakamoto, S., & Tachibana, H. (2013). Study on the amplitude modulation of wind turbine noise: part 2 – auditory experiments. Inter-noise. Innsbruck, Austria: I-INCE.

Yokoyama, S., Sakamoto, S., & Tachibana, H. (2014a). Audibility of low frequency components in wind turbine noise. Forum Acusticum. Kraków, Poland: EAA.

Yokoyama, S., Sakamoto, S., & Tachibana, H. (2014b). Perception of low frequency components in wind turbine noise. Noise Control Engineering Journal, 295-305.

Zeng, X., Zhang, Y., Kwong, J. S., Zhang, C., Li, S., Sun, F., et al. (2014). The methodological quality assessment tools for preclinical and clinical studies, systematic review and meta-analysis, and clinical practice guideline: a systematic review. Journal of Evidence-based Medicine, 2-10.

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.

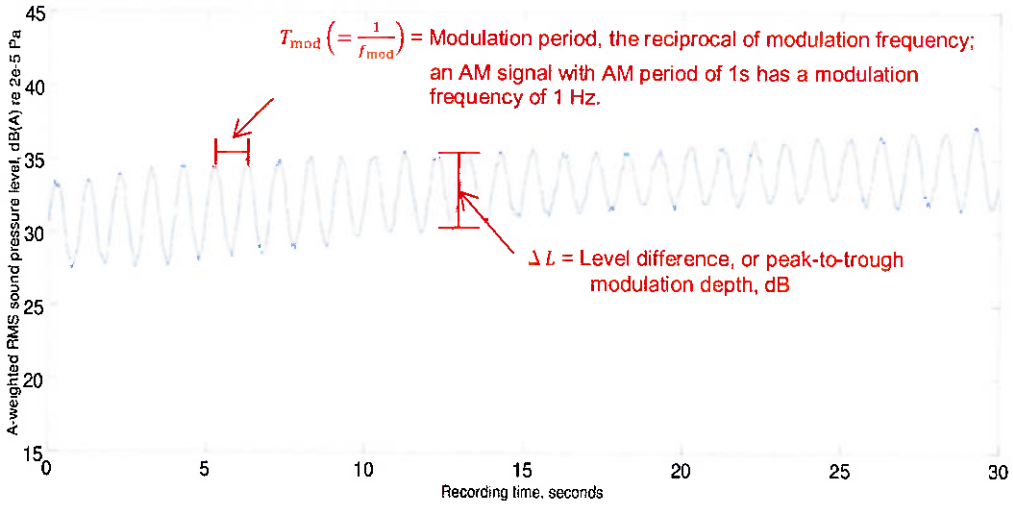
GLOSSARY

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.

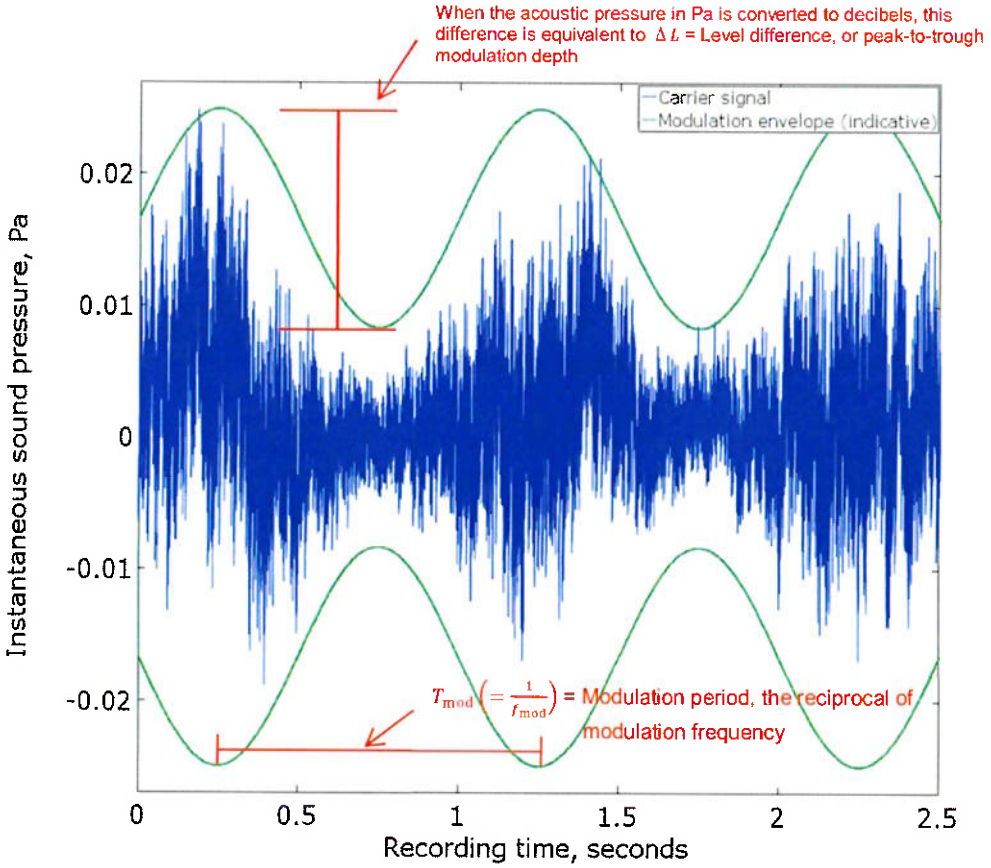
GLOSSARY

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) = $10\ Log_{10}(P/P_{ref})^2$ Where P = root-mean-square (see '*RMS*') sound pressure (in Pa) P_{ref} = Reference pressure $2x10^{-5}$ 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'.

CONCEPT DIAGRAMS



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,MLW et al	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,A et 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 containing rumble	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 stationary sources	Euronoise	[grey]	2d
Jeffery,RD et al	2014	Industrial wind turbines and adverse health effects.	Canadian Journal of Rural Medicine	[black]	2d
Kaczmarek,T et al	2010	Annoyance of time-varying road-traffic noise	Archives of 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 survey in Japan	International Congress on Noise as a Public Health Problem	[grey]	2d
Kantarelis,C et al	1988	Identification+subjective effect of AM in diesel engine exhaust noise	Journal of Sound and Vibration	[black]	2c
Kelley,ND et al	1985	Acoustic noise associated with the MOD-1 wind turbine- its source, impact and control	Independent report	[grey]	2a
Klein, A et al	2015	Spectral + modulation indices for annoyance-relevant features of urban road single-vehicle pass-by noises	Journal of the Acoustical Society of America	[black]	2c
Knopper, 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 of Agricultural 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 effect of 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	Affective Response 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 Relationship	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 + temporal 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
Yelland,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]