10 NOISE

10.1 INTRODUCTION

This chapter of the EIAR assesses the effects of the Proposed Development from noise impacts. The Proposed Development refers to all elements of the application for the proposed Wind Farm, which includes:

- 8 no. wind turbines, site access tracks, Turbine Hardstands, 100 m permanent Met Mast, underground cabling, borrow pit, Temporary Construction Compound, and all site infrastructure on the wind farm site. It also includes the provision of signage at 4 no. locations for existing cultural heritage on the Site and the provision of biodiversity improvements.

This is described in further detail in **Chapter 2: Project Description**. The assessment considers the potential effects at noise sensitive receptors as identified in Section 10.4.2, during the following phases of the Proposed Development:

- Construction of the Development
- Operation of the Development
- Decommissioning of the Development

The Proposed Development refers to all elements of the application for the construction and operation of the wind farm (**Chapter 2: Development Description**).

This chapter of the EIAR is supported by the Figures in **Volume III** and following Appendices documents provided in **Volume IV** of this EIAR:

- **Appendix 10.1:** Photos of noise monitors in-situ
- **Appendix 10.2**: Methodology for calculating wind shear, different hub heights and standardising hub height wind speed
- **Appendix 10.3**: Derived background noise levels, background plus 5 trendline with the predicted noise levels against a noise limit of 43dB(A) at each receptor
- **Appendix 10.4**: SoundPLAN noise outputs
- **Appendix 10.5**: Calibration certificates of noise instruments
- **Appendix 10.6**: Candidate turbine manufacturer's noise emission data

10.1.1 Statement of Authority

Irwin Carr Consulting is based in County Down. The company has a proven track record in noise impact assessments throughout the UK and Ireland, with extensive knowledge of the issues in relation to noise from wind energy developments. Mark Burke carried out the noise modelling in this assessment. Mark is a Consultant in Irwin Carr Consulting, primarily responsible for environmental noise and noise monitoring. He has experience working in both the public and private sectors having previously obtained a BSc (Hons) Degree in Environmental Health. Mark has been responsible for undertaking and reviewing noise impact assessments on numerous large scale wind farms throughout Ireland.

Brendan O'Reilly has a Master's degree in noise and vibration from Liverpool University and has over 40 years' experience in noise and vibration control (and many years' experience in preparation of noise impact statements) and has been a member of a number of professional organisations. Brendan was a co-author and project partner (as a senior noise consultant) in 'Environmental Quality Objectives Noise in Quiet Areas' administered by the EPA. Brendan has considerable experience in the assessment of noise impact and has compiled studies for over 100 wind farm developments throughout Ireland, north and south. Brendan carried out the baseline study.

10.1.2 Acoustic Terminology

Table 10.1 Table of Definitions

Term	Definition
A-weighting	A frequency weighting designed to correlate measured sound levels with subjective human response. The human ear is frequency selective and our ears are most sensitive between 500 Hz to 6 kHz, particularly when compared with lower and higher frequencies. The A-weighting applies a frequency correction which reduces the effect of these low and high frequencies on the overall measured level in order to account for the subjective human response at these frequencies.
LAeq	LAeq is defined as being the A-weighted equivalent continuous steady sound level that has the same sound energy as the real fluctuating sound during the sample period and effectively represents a type of average value.
LA90	LA90, or L90dBA is defined as the noise level equalled or exceeded for 90% of the measurement interval and with wind farm noise the interval used is 10 minutes.
Site	The land required for the Proposed Development
Lden	The average sound level over a 24 hour period, including a penalty for noise at night and in the evening.
dBm-1	The atmospheric absorption coefficient, measured in decibels per milliwatt.
Sound Power Level	The logarithmic measure of sound power in comparison to a referenced sound intensity level of one picowatt (1pW) per m2
Sound Pressure Level	Sound pressure refers to the fluctuations in air pressure caused by the passage of a sound wave. It may be expressed in terms of sound pressure level at a point

Table 10.2 List of Abbreviations

Abbreviation	Description
dB	Decibel
Hz	Hertz
IOA	Institute of Acoustics
2006 Guidelines	Wind Energy Development Guidelines 2006
WHO	World Health Organisation
DRWEDG 2019	Draft Revised Wind Energy Development Guidelines December 2019
ISO 1996	ISO 1996 Acoustics-Description and Measurement of Environmental Noise - Part 1: Basic Quantities and Procedures (ISO 1996)
ISO 9613-2	ISO 9613-2 Acoustics - Attenuation of sound during propagation outdoors, Part 2: General Method of Calculation
IEC 61400	IEC Technical Specification 61400-11-2 Wind energy generation systems – Part 11-2: Acoustic noise measurement techniques – Measurement of wind turbine sound characteristics in receptor position, 2024
ETSU-R-97	ETSU-R-97: The Assessment & Rating of Noise from Wind Farms (ETSU-R-97)
NRA	National Roads Authority
TII	Transport Infrastructure Ireland
ABP	An Bord Pleanála
IOA RM	Institute of Acoustics Reference Method
m/s	Meters per second
STE	Serrated trailing edge
Leq,d 8 hour dBA	The time weighted average of the daily noise exposure level for a normal week of five eight hour working days

Sound is simply the pressure oscillations that reach our ears. These are characterised by their amplitude, measured in decibels (dB), and their frequency, measured in Hertz (Hz). Noise is unwanted or undesirable sound, it does not accumulate in the environment, is transitory, fluctuates, and is normally localised. Environmental noise is normally assessed in terms of A-weighted decibels, dB (A), when the 'A weighted' filter in the measuring device elicits a response which provides a good correlation with the human ear. The criteria for environmental noise control are of annoyance or nuisance rather than damage. In general, a noise level is liable to provoke a complaint whenever its level exceeds by a certain margin, the pre-existing noise level or when it attains an absolute level. A change in noise level of 3 dB (A) is 'barely perceptible', while an increase in noise level of 10 dB (A) is perceived as a twofold increase in loudness[1]. A noise level in excess of 85 dB (A) gives a significant risk of hearing damage. Construction and industrial noise sources are normally assessed and expressed using equivalent continuous levels, LAeq. Wind turbine source noise is generally expressed in Leq dBA and in sound power levels (LWA dB), however it can also be measured using the LA90 descriptor. Sound power level the descriptor of the noise emitted by as source while sound pressure level is a measurement taken at a distance from the noise source carried out with a noise meter.

Operational wind turbine noise is assessed using the LA90 descriptor, which allows reliable measurements to be made without corruption from relatively loud transitory noise events from other sources such as barking dogs, background noise levels generated by wind in the vicinity or local road traffic. The LA90 should be used for assessing both the wind energy development noise and background noise as stated in the Wind Energy Development Guidelines (WEDG)[2] 2006 (the 2006 Guidelines) and the Draft Revised Wind Energy Development Guidelines December 2019 (DRWEDG 2019). As discussed in ETSU-R-97[3] the LA90 is 1.5-2.5dBA less than the LAeq measured over the same period. In this assessment, the difference between LAeq and LA90 is given as 2dBA, in line with the Institute of Acoustics Good Practice Guide which is best practice and the value most commonly applied in wind farm assessments in Ireland. Wind turbine noise levels are given as sound power levels (LWA) dB at integer wind speeds up to maximum LWA levels. The wind turbine noise levels for the Proposed Developed have been detailed in Section 10.2.11. **Table 10.3** gives a comparison of noise levels in our everyday environment, a 10-turbine wind farm at 350m produces approximately 35-45 dB(A)[4].

[1] Department of Environment, Heritage and Local Government: Wind Energy Development Guidelines, Guidelines for Planning Authorities 2006 Energy
[2] Department of Environment, Heritage and Local Government: Wind Energy Development Guidelines, Guidelines for Planning Authorities 2006 Energy
[3] ETSU-R-97, The Assessment & Rating of Noise from Wind Farms, June 1996
[4] Select Committee on Wind Turbines (2014) Wind Energy, Climate and Health: Evidence For The Impacts Of Wind Generated Energy in Australia

A similar figure is presented in Section 3 of "Guidance Note for Noise: License Applications, Surveys and Assessments in Relation to Scheduled Activities (NG4)".

Table 10.3: Comparison of sound pressure level in our Environment[5]

Source/Activity	Indicative noise level dBA
Threshold of hearing	0
Rural night-time background	20-50
Quiet bedroom	35
Wind farm at 350m	35-45
Busy road at 5 km	35-45
Car at 65km/hr at 100m	55
Busy general office	60
Conversation	60
Truck at 50km/hr at 100m	65
Inside a typical shopping centre	70-75
Inside a modern car at around 90km/hr	75-80
Passenger cabin of jet aircraft	85
City Traffic	90
Pneumatic drill at 7m	95
Jet aircraft at 250m	105
Threshold of pain	140

10.1.3 Assessment Structure

This Chapter contains the following sections:

- **Assessment Methodology and Significance Criteria** – a description of the methods used in baseline surveys and in the assessment of the significance of effects.
- **Baseline Description** – a description of the current baseline noise environment of the area surrounding the Proposed Development based on the results of surveys, desk information and consultations, and a summary of any information required for the assessment that could not be obtained.
- **Assessment of Potential Effects** – identifying the ways in which noise receptors within 2.0km of the Proposed Development could be affected by the construction, operational and decommissioning phases of the Proposed Development, including a summary of the measures taken during design of each phase of the Proposed Development to minimise noise effects.
- **Mitigation Measures and Residual Effects** – a description of measures recommended to off-set potential negative effects and a summary of the significance of the effects of the EIA Proposed Development after mitigation measures have been implemented.

[5] Fact sheet published by the Australian Government (Greenhouse Office) and the Australian Wind Energy Association

- **Cumulative Effects** – identifying and assessing the potential for effects of the EIA Proposed Development to combine with those from other wind farm developments.
- **Summary of Effects** – a summary of the effects of construction, operational and decommissioning noise associated with the Proposed Development.
- **Statement of Significance –** the significance of the potential effects of the Proposed Development during operation, construction and Decommissioning.

10.2 ASSESSMENT METHODOLOGY AND SIGNIFICANCE CRITERIA

10.2.1 Assessment Methodology

This assessment has involved the following elements, further details of which are provided in the following sections:

- Legislation and guidance review
- Desk study, including review of available maps and published information
- Site walkover
- Evaluation of potential effects
- Evaluation of the significance of these effects
- Identification of measures to avoid and mitigate potential effects

10.2.2 Description of Effects

The significance of effects of the Proposed Development is described in accordance with the EPA guidance document '*Guidelines on the information to be contained in the Environmental Impact Assessment Reports (EIAR), EPA May 2022'*. The details of the methodology for describing the significance of effects are provided in Table 3.4: Section 3.7.3 of the aforementioned EPA 2022 document.

10.2.3 Relevant Legislation and Guidance

The noise assessment is carried out in accordance with the guidance contained in the following documents:

- Wind Energy Development Guidelines (WEDG)[6] 2006(the 2006 Guidelines)
- Recent 2023 An Bord Pleanála Decision on Noise Limits
- WHO 2018 Environmental Noise Guidelines for European Region (WHO 2018)
- Draft Revised Wind Energy Development Guidelines December 2019 (DRWEDG 2019).

[6] Department of Environment, Heritage and Local Government: Wind Energy Development Guidelines, Guidelines for Planning Authorities 2006 Energy

- A Good Practice Guide to the Application of ETSU-R-97 for the Assessment and Rating of Wind Turbine Noise including Supplementary Guidance Note 4: Wind Shear'[7] (the IOA Good Practice Guide) 2013
- ISO 1996[8] Acoustics-Description and Measurement of Environmental Noise - Part 1: Basic Quantities and Assessment Procedures Third Edition (ISO 1996)
- ISO 9613-2 Acoustics - Attenuation of sound during propagation outdoors, Part 2: General Method of Calculation
- ETSU-R-97[9]: The Assessment & Rating of Noise from Wind Farms (ETSU-R-97)
- Institute of Acoustics Amplitude Modulation Working Group[10], WSP Turbine AM Review[11] and IEC Technical Specification 61400-11-2 Wind energy generation systems – Part 11-2: Acoustic noise measurement techniques – Measurement of wind turbine sound characteristics in receptor position, 2024[12]
- National Roads Authority (NRA) Guidelines for the Treatment of Noise and Vibration in National Road Schemes, 2004
- Transport Infrastructure Ireland (TII) document Good Practice Guidance for the Treatment of Noise during the planning of National Road Schemes, 2014
- BS 5228:2009-1+A1:2014, *Code of Practice for Noise and Vibration Control on Construction and Open Sites* (two parts)
- Cork County Development Plan 2022-2028

10.2.3.1 Wind Energy Development Guidelines 2006 ("2006 Guidelines")

The following are a number of key extracts from Section 5.6 of the 2006 Guidelines in relation to noise impact:

<u>General Noise Impact</u>

"*Noise impact should be assessed by reference to the nature and character of noise sensitive locations*."

"*Separate noise limits should apply for day-time and for night-time*"

"Noise limits should be applied to external locations and should reflect the variation in both turbine source noise and background noise with wind speed."

[7] Institute of Acoustics (2013) A Good Practice Guide to the Application of ETSU-R-97 for the Assessment and Rating of Wind Turbine Noise

[8] ISO 1996/1- Acoustics-Description and Measurement of Environmental Noise - Part 1: Basic Quantities and Procedures

[9] ETSU-R-97: Acoustics-The Assessment & Rating of Noise from Wind Farms: ETSU for the DTI, UK, 1996

[10] IOA Noise Working Group (Wind Turbine Noise) Amplitude Modulation Working Group, Final Report, A Method for Rating Amplitude Modulation in Wind Turbine Noise, August 2016

[11] Wind Turbine AM Review, Phase 2 Report, Department of Energy & Climate Change, WSP/Parsons Brinckerhoff, August 2016

[12] IEC Technical Specification 61400-11-2 Wind energy generation systems – Part 11-2: Acoustic noise measurement techniques – Measurement of wind turbine sound characteristics in receptor position, 2024

Measurement Units

"The descriptor [LA90 10min] which allows reliable measurements to be made without corruption from relatively loud transitory noise events from other sources, should be used for assessing both wind energy development noise and background noise."

Specific Noise Limits

"Noise limits should be applied to external locations and should reflect the variation in both turbine source noise and background noise with wind speed."

"In general, a lower fixed limit of 45 dB(A) or a maximum increase of 5 dB(A) above background noise at nearby noise sensitive locations is considered appropriate to provide protection to wind energy development neighbours.

However, in very quiet areas, the use of the margin of 5 dB(A) above the background noise at nearby noise sensitive properties is not necessary to offer a reasonable degree of protection and may unduly restrict wind energy developments. Instead in low noise environments where background noise is less than 30 dB(A), it is recommended that the daytime level of LA90,10min of the wind energy development noise should be limited to an absolute level within the range 35-40 dB(A)".

"During the night the protection of external amenity becomes less important and the emphasis should be on preventing sleep disturbance. A fixed limit of 43 dB(A) will protect sleep inside properties during the night"

The 2006 Guidelines do not specify daytime or night-time hours. However, it is considered good practice to follow the framework given in ETSU-R-97 and IOA Good Practice Guide where daytime and night-time hours are specified. The limits are based on the prevailing background noise level for 'quiet daytime' periods, defined in ETSU-R-97 as:

- Quiet waking hours or quiet day-time periods are defined as:
  - All evenings from 18:00 to 23:00 hrs
  - Saturday afternoon from 13:00 to 18.00 hrs and all-day Sunday 07:00 to 18:00 hrs
- Night-time is defined as 23:00 to 07:00 hrs

The consideration of only the Quiet Daytime hours ensures that a conservative noise limit is applied to all daytime hours.

10.2.3.2 An Bord Pleanála

2023 An Bord Pleanála Decisions

A recent decision by ABP gave limits (ABP-313750-22, dated 23rd November 2023) in accordance with the 2006 Guidelines and were as follows:

(a) between 7am and 11pm:

(i) the greater of 5 dB(A) L90,10min above background noise levels, or 45 dB(A) L90, 10min, at wind speeds of 7m/s or greater,

(ii) 40 dB(A) L90, 10min, at all other wind speeds.

(b) 43 dB(A) L90,10min at all other times

where wind speeds are measured at 10 metres above ground level.

10.2.3.3 World Health Guidelines (WHO) 2018

The most recent WHO 2018 Guidelines: 'Environmental Noise Guidelines for the European Region' gives a recommendation limit of 45 dB Lden . This is an annual average noise level, based on wind speed and direction in the vicinity of the site with no specific limits for night.

10.2.3.4 Draft Revised Wind Energy Development Guidelines 2019 (DRWEDG 2019)

There have been a number of draft guidelines over the years with the latest one being in December 2019. The DRWEDG 2019 guidelines, currently in draft format are subject to significant public and stakeholder consultation and liable to change, in line with best practice.

A tender has been issued by the Department of Environment, Climate and Communications to review and re-draft the Wind Energy Development Guidelines. This process has yet to be completed.

This assessment is based on the current guidance outlined in Section 10.2.3.1.

10.2.3.5 Cork County Development Plan 2022

The Cork County Development Plan 2022 has a new of key extracts, in particular Section BE 15-13 : Noise and Light Emissions, in relation to noise impact:

(a) Seek the minimisation and control of noise pollution associated with activities or development, having regard to relevant standards, published guidance and the receiving environment

The relevant standards and guidelines identified above are considered applicable in line with this requirement of the County Development Plan.

10.2.4 Desk Study

The locations for noise monitoring were selected by inspection of Site layout maps produced at design freeze and by identifying the nearest noise sensitive receptors surrounding the wind turbines. The Noise Study Area has been defined such that the predicted results have been included for all residential receptors within 2.0km of the wind farm.

The six noise monitoring locations are considered representative of the local noise environment.

10.2.5 Acquisition and Analysis of Background Noise Data

The 2006 Guidelines, ETSU-R-97 and the IOA Good Practice Guide recommend the measurement and use of wind speed data, against which background noise measurements are correlated. The IOA Good Practice Guide Supplementary Guidance Note 4[13] (**Appendix 10.2)** gives the methodology to account for wind shear, calculation to hub height and to standardise 10m height wind speed.

A LiDAR positioned within the Site during the noise survey was used for wind data measurements over 10-minute intervals.

The 100 m hub height wind speed was then standardised to 10 m height wind speed with the wind speed plotted against the 10-minute background noise data to derive a best fit polynomial curve.

10.2.6 Prediction of Wind Turbine Noise Levels

The predicted noise levels are based on the methodology given in the IOA Good Practice Guide. Noise level calculations are based on ISO 9613-2[14] which provides a prediction of noise levels likely to occur under worst-case down-wind conditions.

There are numerous models for predicting noise from a point source and some of these models are specifically used for the prediction of noise from wind farms. SoundPLAN software package was used to calculate the noise level at the receptors. The propagation model calculates the predicted sound pressure levels by taking the source sound power level for each turbine in their respective octave bands and subtracting a number of attenuation factors according to the following formula:

Predicted Octave Band Noise level = $LW + D - (A_{geo} + A_{atm} + A_{gr} + A_{br} + A_{mis})$

[13] IOA, A Good Practice Guide to the Application of ETSU-R-97 for the Assessment and Rating of Wind Turbine Noise- Supplementary Guidance Note 4: Wind Shear

[14] ISO 9613-2 Acoustics -Attenuation of sound during propagation outdoors, Part 2: General Method of Calculation

Each attenuation factor is considered in more detail below.
The predicted octaves from each of the turbines are summed to give the predicted noise level expressed as dBA.

No allowance has been made for the character of noise emitted by the turbines, however in general the emissions from wind turbines are broadband (non-tonal) in nature. In the unlikely event of a turbine exhibiting clearly tonal components at any receptor, the turbine would be turned down or stopped until such tonality is ameliorated. A guarantee will be required in the procurements of the turbine to be used onsite, stating that there should be no clearly tonal or impulsive components audible at any noise sensitive receptor location.

A_{geo} –Geometric Spreading

Geometric (spherical) spreading from a simple free-field point source results in attenuation over distance according to:

$$Lp = Lw – (20 \log R + 11)$$

Where:

Lp = sound pressure level

Lw = sound power level

R = distance from the turbine to receiver

D – Directivity Factor

The directivity factor allows for adjustment where the sound radiated in the direction of the receptor is higher than that for which the sound power level is specified. In this case, the sound power levels are predicted as worst-case propagation conditions, i.e. all receptors are assumed to be in downwind conditions.

A_{gr} - Ground Effects

Ground effect is the result of sound reflected by the ground interfering with the sound propagating directly from the turbine to receiver. The prediction of ground effects is complex and depends on the source height, receiver height, propagation height between the source and receiver and the intervening ground conditions.

Ground conditions are described according to a variable defined as G, which varies between 0 for hard ground and 1 for soft ground. Although in reality the ground is predominately porous, it has been modelled as mixed 50% hard and 50% porous corresponding to a ground absorption coefficient of 0.5. Our predictions have been carried out using a source height corresponding to the proposed height of the turbine nacelle, a receiver height of 4m and an assumed ground factor of G=0.5 as recommended in the IOA Good Practice Guide.

A_{bar}- Barrier Attenuation

The effect of a barrier (including a natural barrier) between a noise source and receptor is that noise will be reduced according to the path difference (difference between the direct distance between source to receptor and distance between source and receptor over the barrier). The reduction is relative to the frequency spectrum of the sound and may be predicted according to the method given in ISO 9613. In practice, barriers can become less effective in downwind conditions. A barrier can be very effective when it lies within a few metres of the receptor. In the prediction model, zero attenuation is given for barrier effects, which is a worst-case scenario setting.

A_{atm} - Atmospheric Absorption

Sound emergence through the atmosphere is attenuated by conversion of sound energy to heat. This energy is dependent on the temperature and relative humidity of the air, but only weakly on ambient pressure through which the sound is travelling and is frequency dependent, with increasing attenuation towards higher frequencies. The attenuation by atmospheric absorption A_{atm} in decibels during propagation through distance in metres is given by:

$A_{atm} = d \times \alpha$,

α = atmospheric absorption coefficient in dBm^{-1}

d = distance from turbine (m)

Values of α from ISO 9613 Part 1, corresponding to a temperature of $10^{0}C$ and a relative humidity of 70% has been used for these predictions and are given in **Table 10.4** below. These values are recommended in the IOA Good Practice Guide.

Table 10.4: Frequency dependent atmospheric attenuation coefficients (dB/m)

Octave Band Centre Frequency (Hz)	63	125	250	500	1k	2k	4k	8k
Atmospheric Absorption Coefficient (dB/m^{-1})	0.0001	0.0004	0.001	0.0019	0.0037	0.0097	0.0328	0.117

A_{misc} – Miscellaneous Other Effects

ISO 9613 includes effects of propagation through foliage, industrial plants and housing as additional attenuation effects. These have not been included here and any such effects are unlikely to significantly reduce noise levels below those predicted.

The ISO 9613-2 standard calculates under downwind propagation conditions and therefore predicts the average downwind sound pressure level at each dwelling. The model assumes that the wind is directly downwind from each turbine to each dwelling. The prediction model is calculated as a worst-case scenario.

The predicted noise levels $L_{Aeq\ 10min}$ are converted to the required $L_{A90,10min}$ by subtracting 2 dBA.

10.2.7 Aerodynamic Modulation or Aerodynamic Noise

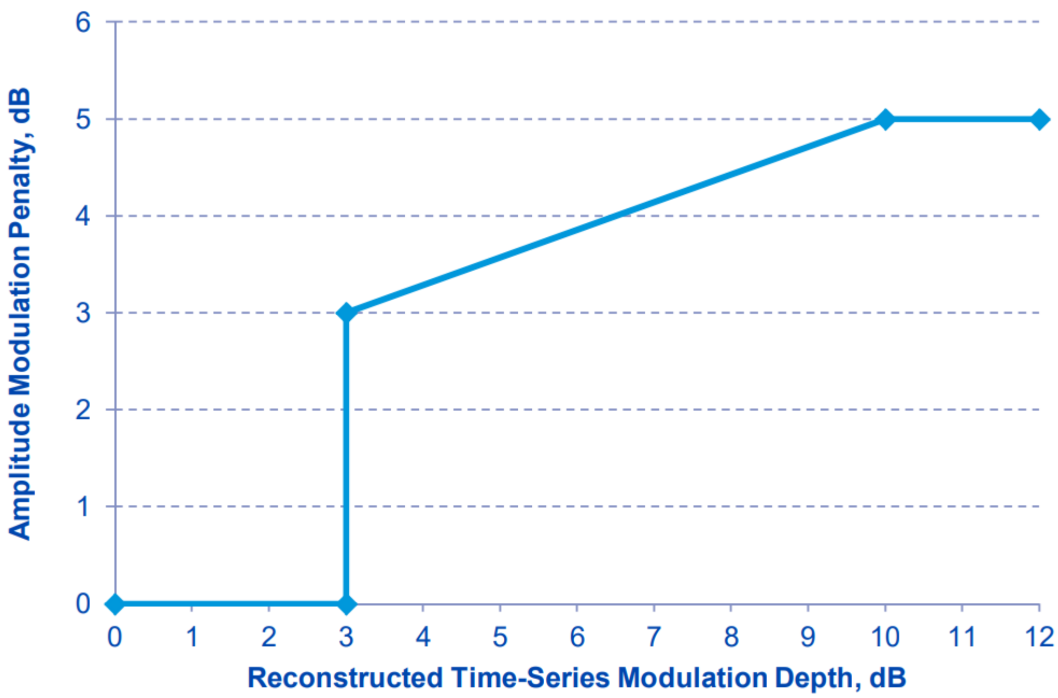
Aerodynamic noise originates from the flow of air over, under and around the blades and is generally broadband in character. It is directly linked to the movement of the rotors through the air and will occur to varying degrees whenever the turbine blades move. Aerodynamic noise is generally both broadband i.e. it does not contain a distinguishable note or tone, and of random character, although the level is not constant and fluctuates in time with the movement of the blades. The dominant character of such aerodynamic noise is therefore normally a 'swish' type of sound, which is familiar to most people who have stood near to a large wind turbine.

The sound level of aerodynamic noise from wind turbine blades is not completely steady but is modulated (fluctuates) in a cycle of increased and then reduced level, sometimes called "*blade swish*", typically occurring in step with the angle of rotation of the blades and so being periodic at the rotor's rotational speed – for typical commercial turbines, this is at a rate of around once or twice per second. This phenomenon is known as Amplitude Modulation of Aerodynamic Noise or more succinctly by the acronym AM. In some situations, however, the modulation characteristics can change in character to the point where it can potentially give rise to increased annoyance.

In early wind turbine designs, where the rotor was positioned downwind of the tower, a pronounced 'beat' was audible as each blade passed through the turbulent wake shed from the tower. However, this effect does not exist for the upwind rotor designs found on the majority of modern wind farms where the air flow to the blades is not interrupted by the tower structure. Instead, it seems that aerodynamic modulation is due to fluctuation of the primary mechanisms of aerodynamic noise generation.

The most recent information in relation assessing AM comes in the IEC TS 61400-11. The scope of this document includes an assessment of the sound characteristics of the noise and relies on the Institute of Acoustics Reference Method (IOA RM) to quantify the AM level along with the WSP Phase 2 Report which identified a penalty scheme as shown Figure 1 below.

Figure 1: Proposed Penalty Scheme



Current scientific knowledge is such that AM cannot be predicted at the planning stage but can only be measured once the wind farm becomes operational.

The methodology contained within the IOA RM and IEC 61400 allows quantification of all aspects of AM and the penalty scheme identified above allows quantification of the mitigation required, if any. An appropriate penalty based on the Reconstructed Time-Series Modulation Depth as defined by the IOA RM and the IEC 61400 documentation and shown in Figure 1 above can be added onto the measured LA90 noise level, to ensure overall noise levels comply with the applicable noise limit.

10.2.8 Infrasound and Low Frequency Noise and Vibration

There is always low frequency (or infrasound) noise present in the ambient quiet background. It is generated by natural sources such as road traffic, wind effects through air and vegetation, wave motion, water flow in streams and rivers. Low frequency emissions are also present from many sources found in modern life, such as household appliances (e.g., washing machines, air conditioners, fridges, heating systems, boilers, burners, heat pumps, extraction systems, electric or battery clocks, sky box, etc.), Other sources include water flowing through pipes within your home and in water flow from municipal water supply. Vibration of elements of structures (low frequency, less than 20Hz)) can be generated by local activity in one's home by way of normal routine activity, like climbing stairs, walking on the floor, closing doors etc. When sitting in a moving vehicle very high levels of low frequency vibration/sound is experienced.

The frequency range of audible noise is in the range of 20 to 20,000Hz and low frequency noise is generally from about 2 to 200Hz with infrasound typically of frequencies below 20Hz. There appears to be little or no agreement about the biological effects of low frequency noise on human health and there is evidence to suggest that there are no serious consequences to people's health from infrasound exposure.

A study of low frequency noise (infrasound) and vibration around a modern wind farm was carried out for ETSU and reported in ETSU W/13/00392/REP – '*Low Frequency Noise and Vibration Measurements at a Modern Wind Farm*'[15]. The results showed levels of infrasound to be below accepted thresholds of perception even on the Site. Furthermore, a document prepared for the World Health Organisation[16]. , states that *"there is no reliable evidence that infrasound below the hearing threshold produce physiological or psychological effects".*

Significant research carried out on low frequency noise has been in the area of blasting (air overpressure) which falls into a very low frequency range (2-20 Hz), although with a considerably higher magnitude. Most microphones recording air-overpressure (low frequency sound) is linear down to 2 Hz with a range that does not go below a level of 88dB, as below that value trigger can occur from relatively low wind speeds (a gust of wind at 9m/s equates to an air overpressure of 133dB).

The level of ground vibration from the operation of the wind farms is below human threshold of 0.2mm/s[17] at the base of a turbine.

South Australian Environment Protection Authority (EPA) Infrasound Study

A report released in January 2013 by the South Australian EPA[18] entitled "Infrasound levels near windfarms and in other environments", found that the level of infrasound from wind turbines is insignificant and no different to any other sources of noise, and that the worst contributors to household infrasound are air-conditioners, traffic and noise generated by

[15] ETSU W/13/00392/REP – '*Low Frequency Noise and Vibration Measurements at a Modern Wind Farm'.*
[16] Community Noise – Document Prepared for the World Health Organisation, Eds. Bergland B. & Lindvall T., Archives of the Centre for Sensory Research Vol. 2(1) 1995
[17] Wiss, J. F., and Parmelee, R. A. (1974) Human Perception of Transient Vibrations, "*Journal of Structural Division"*, ASCE, Vol 100, No. S74, PP. 773-787
[18] Infrasound levels near windfarms and in other environments, Environment Protection Authority, 2013, http://www.epa.sa.gov.au/environmental_info/noise/wind_farms

people. The study included several houses in rural and urban areas, houses both adjacent to a wind farm and away from turbines and measured the levels of infrasound with the wind farms operating and also switched off. There were no noticeable differences in the level of infrasound under all these different conditions. In fact, the lowest levels of infrasound were recorded at one of the houses closest to a wind farm, whereas the highest levels were found in an urban office building. The South Australian study found: '*the contribution of wind turbines to the measured infrasound levels is insignificant in comparison with the background level of infrasound in the environment'*.

Massachusetts Institute of Technology (MIT)

A report by an Independent Expert Panel prepared for Massachusetts Department of Health (2012)[19] entitled "Wind Turbine Health Impact Study: Report of Independent Expert Panel" consisted of a panel that included seven individuals with backgrounds in public health, epidemiology, toxicology, neurology and sleep medicine, neuroscience, and mechanical engineering, all of which were considered independent experts from academic institutions. The report found that *"there is insufficient evidence that the noise from wind turbines is directly (i.e., independent from an effect on annoyance or sleep) causing health problems or disease'* and '*available evidence shows that infrasound levels near wind turbines cannot impact the vestibular system"*.

Technical Research Centre of Finland

A long-term study into so-called "wind turbine syndrome"[20] health problems supposedly caused by low-frequency sound from spinning blades has concluded that this "infrasound" has absolutely no physical impact on the human body.

The study entitled "Infrasound Does Not Explain Symptoms Related to Wind Turbines", conducted by the Technical Research Centre of Finland (VTT)[21] and others, commissioned by the Finnish government, found that infrasound sound waves with frequencies below the range of human hearing cause no measurable changes in the human body, and cannot in any way be detected by the human ear.

Infrasound measurements were taken inside and outside local dwellings near two Finnish wind farms, as well as inside the facilities and beyond them, for 308 days.

[19] Ellenbogen, J.M., Grace, S., Heiger-Bernays, W.J., Manwell, J.F., Mills, D.A., Sullivan, K.A., Weisskopf, M.G., and Santos, S.L, Wind Turbine Health Impact Study: Report of Independent Expert Panel, January 2012
[20] Report by Leigh Collins, 21st April 2020 on a study commissioned by the Finnish Government into infrasound and wind turbine syndrome
[21] Infrasound Does Not Explain Symptoms Related to Wind Turbines, Finnish Government, June 2020, https://www.vttresearch.com/en/news-and-ideas/vtt-studied-health-effects-infrasound-wind-turbine-noise-multidisciplinary

Measurements showed that the infrasound levels in rural areas with wind farms were about the same as levels in a regular urban environment.

"Infrasound samples representing the worst-case scenarios were picked out from the measurement data and used in the listening tests," said VTT.

"The participants in the listening tests were divided into two groups based on how they reported wind turbine infrasound related symptoms: people who suffered from those and people who never had symptoms."

"The participants were unable to make out infrasonic frequencies in wind turbine noise, and the presence of infrasound made no difference to how annoying the participants perceived the noise, and their autonomous nervous system did not respond to it. There were no differences between the results of the two groups."

10.2.9 Field Work

Baseline noise monitoring was undertaken between 21st February and 21st March 2022 at the locations shown in **Appendix 10.1**. The continuous monitoring period coincided with the wind speed monitoring over the same period at the same 10-minute intervals using a LiDAR located on site. Noise data was recorded for a representative range of wind speeds during the monitoring period.

10.2.10 Consultation

Consultation was carried out with landowners who were familiar with the Site. Access to the nearest dwellings was carried out with permission from the householders / landowners.

10.2.11 Noise Assessment Methodology

In summary, the assessment process comprised:

- Identification of potential receptors, i.e., houses and other potentially noise-sensitive locations;
- Measurement of existing background noise levels at representative locations close to the Site;
- Prediction of the noise levels from wind turbines received at each receptor; and
- Comparison of the predicted noise levels with noise limits.

Potential receptors in the area around the Proposed Development were initially identified from Ordnance Survey maps, google maps, EPA maps and Site visits. Background measurements were carried out at the locations shown in **Appendix 10.1**.

The method of measuring background noise is described in ISO 1996 and ETSU-R-97. In practice, it means carrying out continuous monitoring of background noise levels at receptors for a period that includes a range of wind speeds which correspond to the maximum sound power of the candidate turbines being proposed which is usually 3 to 4 weeks duration. The candidate turbine assessed reaches maximum sound power level at a mean wind speed of 8 m/s at 10 m height and generates the highest noise level for that turbine specification.

The method of predicting noise levels of wind turbines at receptors is discussed in Section 10.2.6. This method was applied to the calculations for both contour plots and individual receptor predictions.

It is standard practice to predict noise levels for a reference wind speed and to adjust these for other wind speeds, according to the variation in sound power level with wind speed.
For EIA purposes one candidate turbine, the Vestas V150-6.0 megawatts (MW) operating in unrestricted mode PO6000, with serrated trailing edge (STE) has been selected with a hub height of 105 m for the EIA technical assessment. The turbine used in this assessment is the Vestas V150-6.0 MW operating in unrestricted mode PO6000, with STE and a hub height of 105 m. This is a conservative assessment as the 105 m hub height shall have a higher sound power level than the 100m hub height turbine to be installed as part of the Proposed Development. The tip of the blades with STE lowers noise emissions without reducing energy output, and the selected turbine will have STE as standard. The worst-case sound power level at each wind speed from 4 m/s to 12 m/s was input into the noise model. A copy of the manufacturers performance specification for the turbines used in the assessment when operating in unrestricted mode PO6000 with STE is given in the **Appendix 10.6**.

The prediction modelling is based on the turbines operating at full power and all turbines fitted with STE which reduces noise emissions of each turbine. The IOA Good Practice Guide recommends that an uncertainty value is required to be added to the turbine emission data prior to modelling. Depending on the type of manufacturer's data, the uncertainty value will range from 0 to 2dBA. However, as no uncertainty is given in the manufacturer's data sheet, an uncertainty value of 2dBA is applied in line with the IOA GPG. **Table 10.5** presents the noise emission data for the turbine up to maximum sound power output at varying wind speed at 105m hub height. **Table 10.6** presents the maximum sound power output at varying wind speed (presented at standardised 10m height) for the turbine with a hub height of 105 m. A value of 2dBA is subtracted to account for conversion from LAeq to LA90 which is best practice.

Table 10.5: Noise Emission Data, Vestas V150-6.0MW, STE at Maximum Sound Power (LWA dB) at Hub Height (105m) at varying wind speeds

Hub Height Wind Speed, ms^{-1}	4	5	6	7	8	9	10	11	12
Sound Power Level, dB LWA at Varying Wind Speeds	92.2	94	96.9	99.9	102.7	104.6	104.8	104.9	104.9
Uncertainty added and conversion of LAeq to LA90	92.2	94	96.9	99.9	102.7	104.6	104.8	104.9	104.9

Table 10.6: Noise Emission Data, Vestas V150-6.0MW, STE at Maximum Sound Power (LWA dB) at Standardised 10m Height wind Speed

Standardised 10m Height Wind Speed ms^{-1}	4	5	6	7	8	9	10	11	12
Sound Power Level dB LWA derived from 105m hub height	95.4	99.5	103.2	104.7	104.9	104.9	104.9	104.9	104.9
Uncertainty added and Conversion of LAeq to LA90	95.4	99.5	103.2	104.7	104.9	104.9	104.9	104.9	104.9

The octave band values are given in **Table 10.7** for the V150–6.0MW with uncertainty values and conversion for LAeq to LA90 added as input to the prediction model.

Table 10.7: Octave Band Spectrum of Vestas V150-6.0MW, STE at Maximum Sound Power (LWA dB) at 12m/s wind speed

Octave Band Frequency (Hz)	63	125	250	500	1k	2k	4k	8k	L_{WA}
Sound Power Level, dB LWA at max sound power level	85.5	93.3	98.2	100.1	99.0	94.8	87.7	77.6	**104.9**
Uncertainty added to octaves and conversion of LAeq to LA90	85.5	93.3	98.2	100.1	99.0	94.8	87.7	77.6	

10.2.11.1 Noise Limits

The method of deriving operational noise limits, described in Section 10.2.3.1**,** is based on the 2006 Guidelines Wind Energy Development Guidelines 2006 and lower limits specified in a recent An Bord Pleanála decision (ABP-313750-22). The noise limits for the Gortloughra Wind Farm are designed to meet:

'Wind turbine noise arising from the proposed development, by itself or in combination with other existing or permitted wind energy development in the vicinity, shall not exceed the greater of:

43dB(A) L90,10min for day and night at wind speeds of 7m/s or greater, and

40 dB(A) L90, 10min at all other wind speeds

where wind speeds are measured at 10 metres above ground level. Where properties are financially involved, a 45dB(A) L90,10min limit can be applied.'

10.2.12 Construction Assessment Methodology

10.2.12.1 Relevant Guidance

There is no published national guidance relating to the maximum permissible noise level that may be generated during the construction phase of a project. However National Roads Authority (NRA) give limit values which are acceptable (the NRA Guidelines 2004)[22]. Guidance to predict and control noise is also given in BS 5228:2009-1+A1:2014, *Code of Practice for Noise and Vibration Control on Construction and Open Sites* (two parts) where Part 1 deals with Noise[23].

10.2.12.1.1 NRA Guidelines for the Treatment of Noise and Vibration in National Road Schemes

The NRA Guidelines provide noise limits which are acceptable and states, where it is deemed necessary to predict noise levels associated with construction noise, that this should be done in accordance with BS 5228.

10.2.12.1.2 BS 5228: 2009-1A; 2014 Code of Practice for Noise and Vibration Control on Construction and Open Sites

Part 1 of BS 5228 deals with noise prediction and control. It recommends procedures for noise control in respect of construction operations. The standard stresses the importance of community relations, and states that early establishment and maintenance of the relations throughout the carrying out of Site operations will go some way towards allaying people's concerns. Some of the more relevant factors that are likely to affect the acceptability of construction noise are:

- The attitude of local residents to the Development
- Site location relevant to noise sensitive receptors
- Duration of Site operations
- Hours of work
- The characteristics of the noise produced.

Recommendations are made regarding the supervision, planning, preparation and execution of works, emphasising the need to consider noise at every stage of the activity. Measures to control noise are described including:

[22] National Roads Authority, *Guidelines for Noise and Vibration in National Road Schemes.*
[23] BS 5228-1: 2009-1+A1:2014, Code of Practice for Noise and Vibration Control on Construction and Open Sites: *Code of Practice for Basic Information and Procedures for Noise Control*.

Control of noise at source by, for example:

- Substitution of plant or activities for less noisy ones
- Modification of plant or equipment by less noisy ones
- Using noise control enclosures
- Siting of equipment and its method of use
- Maintenance of equipment
- Controlling the spread of noise by increasing distance between plant and receptors, or by the provision of acoustic screening

Example criteria for the assessment of the significance of noise effects are also given, although these are not mandatory.

Methods of calculating the levels of noise resulting from construction activities are provided, as are updated source levels for various plant, equipment and construction activities.

10.2.12.2 Construction and Decommissioning Noise Assessment Methodology

The NRA guidelines for construction noise which are considered acceptable are given in **Table 10.8**.

Table 10.8: Noise levels that are considered acceptable based on the NRA guidelines

Day / Times	Guideline Limits
Monday to Friday 07:00 – 19:00hrs 19:00 – 22:00hrs	 70dB LAeq, (1h) and LAmax 80dB *60dB LAeq, (1h) and LAmax 65dB*
Saturday 08:00 – 16:30hrs	 65dB LAeq,1h and LAmax75dB
Sunday and Bank Holidays 08:00 – 16:00hrs	 *60dB LAeq,1h and LAmax 65dB*

*Construction at these times, other than required by an emergency works, will normally require explicit permission from the relevant local authority, in this case Cork County Council.

<u>Construction Times for The Development</u>

The construction times for this Development are:

Monday to Friday: 07.00 to 19.00hrs, Saturday 08.00 to 13.00hrs with no work on Sunday, or Bank Holidays.

Part 1 of BS 5228 provides several example criteria for the assessment of the significance of noise effects from construction activities. Noise levels generated by construction activities are considered significant if:

- The LAeq, period level of construction noise exceeds lower threshold values of 65dB during daytime, 55dB during evenings and weekends or 45dB at night.
- The total noise level (pre-construction ambient noise plus construction noise) exceeds the pre-construction noise level by 5dB or more for a period of one month or more.

Construction noise from wind farm development, or decommissioning is not considered an intensive activity. The main noise sources will be associated with the construction of the Turbine Foundations and Turbine Hardstands. Lesser noise source activity will be construction of site access tracks, temporary construction compound, turbine erection and the construction of an Onsite Control Building and Substation.

Decommissioning will involve the remediation of Turbine Hardstand Areas and Turbine Foundations, where they will be covered in topsoil and allowed to revegetate. site access tracks will be left in-situ for use by the landowners. Underground Internal Wind Farm Cables will be removed, and the ducting left in-situ. Therefore, the decommissioning phase is to be shorter and less intrusive than the construction phase with the resultant effects being less. All workers associated with the Proposed Development will be subject to the Health and Safety Authority Guidance[24] which states that for noise exposure noise levels likely to exceed 80 dBA (expressed as Leq,d 8 hour dBA) there is the potential of risk of damage to hearing. All workers on site will be given guidance on how to comply with the 'First Action Level'.

10.2.13 Evaluation of Potential Effects

The potential impacts of construction are evaluated by comparing the predicted noise levels against the guideline limits given in **Table 10.8:** Noise levels that are considered acceptable based on the NRA guidelines**,** and sample criteria in Part 1 of BS 5228 in Section 10.2.12.1.2.

The potential operational impacts are evaluated by comparing the predicted noise levels against the day and night-time noise limits given in Section 10.3.6. The predicted noise levels are calculated according to the IOA Good Practice Guide as detailed in Section 10.2.6 and potential impacts are assessed against the noise limits at the nearest receptors.

[24] Noise - Frequently Asked Questions - Health and Safety Authority (hsa.ie)

10.2.13.1 Sensitivity

The sensitivity of the Proposed Development during construction is based on the guideline values in **Table 10.8:** Noise levels that are considered acceptable based on the NRA guidelines**,** and sample criteria in Part 1 of BS 5228. The sensitivity of the Proposed Development during operation is based on the values in Section 10.3.4 and Section 10.4.2.

10.2.13.2 Magnitude

The magnitude of potential impacts of construction is based on the values in **Table 10.11**. The magnitude of the Development during operation is based on the values in **Table 10.14**.

10.2.13.3 Significance Criteria

The significance of construction is based on the potential impacts based on the predicted values and compliance with the guideline limits in **Table 10.8** and sample criteria in Part 1 of BS 5228.

The significance of the potential impacts of the Proposed Development have been assessed by taking into account the noise limits at receptors and the degree to which compliance has been met.

10.3 BASELINE DESCRIPTION

10.3.1 Identification of Potential Receptors

A number of predictions were prepared for the layout of the Proposed Development. Based on the initial layout, potential noise-sensitive receptors within 2.0 km of the Proposed Development, including occupied and un-occupied dwellings, were identified from maps. Receptor locations were verified through visits to the area surrounding the Development.

10.3.2 Selection of Baseline Noise Survey Locations

Six baseline noise survey locations were selected on the basis of their locations relative to the turbine layout. The six locations selected also ensure that the distance was sufficient to ensure no noise contribution from any other operating wind turbines (see **Appendix 10.1**).

10.3.3 Baseline Noise Survey

Baseline noise measurements were carried out continuously between 21st February and 21st March 2022 at the receptor locations given in **Table 10.9** (Photos of monitors in-situ in **Appendix 10.1**).

Table 10.9: Baseline Noise Survey

Location	ITM Reference	Description of Location
NML 1 – H5	513258E, 560218N	Monitor located in front of the house. Main noise source was sounds from a river in the valley.
NML 2 – H39	513035E, 558529N	Monitor located approximately 40 m from the house. Main noise sources were from streams and wind interaction on conifers.
NML 3 – H67	514062E, 558379N	Monitor located approximately 20 m from the house. Main noise sources were a waterfall close to back garden and a second waterfall in the distance.
NML 4 – H20	516995E, 559974N	Monitor located approximately 30 m from the house. Noise levels controlled by nearby streams and sheep farming activity.
NML 5 – H15	516742E, 559597N	Monitor located approximately 20 m from the west of the house. Rural setting on mountainous setting with streams in the distance.
NML 6 – H36	516258E, 557871N	Monitor located approximately 12 m directly in front of the house. Some road traffic and low level background noise from distant streams.

The survey was carried out in accordance with ISO 1996, ETSU-R-97 and the IOA Good Practice Guide with the following implemented:

- Measurement of background noise levels at 10-minute intervals was undertaken using Type 1 instruments.
- Concurrent measurements of noise and mean wind were made at 10-minute intervals with the mean wind speed recorded from a LiDAR on the Development Site. The methodology is given in Section 10.2.5.
- The background noise measurement recorded continuously included 10-minute intervals, as LA90, 10min along with a series of other parameters including LAeq,10min.
- Noise measurements were recorded at a height of 1.2-1.5m above ground level and more than 5 m from any reflective surface, other than the porous ground.
- An electronic rain gauge was installed onsite at NML 8 - H104 to monitor rainfall at 10-minute intervals over the duration of the noise survey.
- The standardised 10 m wind speed was plotted against the time synchronised background noise levels using a best-fit polynomial line.

10.3.3.1 Instrumentation Used

The following instrumentation was used in the baseline survey measurements:

- Larson Davis Precision Integrating Sound Level Analyser/Data logger with 1/2" Condenser Microphones. Microphone was fitted with double skin windscreens based on that specified in W/31/00386/REP 'Noise Measurements in Windy Conditions[25]'.
- Calibration Type: Larson Davis Precision Acoustic Calibrator.
- Rain Gauge Type: TR-525met tipping bucket rain gauge, 0.2 mm pulse with LOGBOX datalogger.

All acoustic instrumentation was calibrated before and after the survey and the drift of calibration was less than 0.3 dB, which is within accepted guidelines. Calibration certificates of the acoustic instruments are included in **Appendix 10.5**.

10.3.4 Prevailing Background Noise Levels

Table 10.10 gives the background noise levels obtained from quiet daytime and night-time measurement periods at the baseline measurement locations completed during the monitoring period in Section 10.3.3. Within the vicinity of the noise monitoring locations, there were many small streams flowing down the mountain side. This area has a high rainfall level. Stream flow or distant river flow generate very steady noise levels which can be difficult to clarify with audibility as it is a very low frequency sound source. The distance of the six monitoring locations selected to ensure all sides of the wind farm were measured and the lowest background noise level was relied upon as being the prevailing background noise level to ensure conservatism.

The 2006 Guidelines define a low noise environment as an environment where the background noise is less than 30 dB(A). The area surrounding the Proposed Development is not defined as a low noise environment as the background is above 30 dB LA90 for most locations at all wind speeds, with the exception of some levels below 30 dB at low wind speeds.

[25] W/31/00386/REP 'Noise Measurements in Windy Conditions', ISVR, Davis and Lower 1996.

Table 10.10: Prevailing Background Noise Levels

Monitoring Location		Prevailing Background (B/G) noise levels LA90dB, 10min Standardised Mean 10 m Height Wind Speed, (m/s)								
		4	5	6	7	8	9	10	11	12
NML 1 – H5	Day	35.7	35.9	36.2	36.7	37.3	38.1	39.0	40.0	41.1
	B/G+5	40.7	40.9	41.2	41.7	42.3	43.1	44.0	45.0	46.1
NML 1 – H5	Night	36.4	36.3	36.3	36.5	36.8	37.3	38.0	39.0	40.3
	B/G+5	41.4	41.3	41.3	41.5	41.8	42.3	43.0	44.0	45.3
NML 2 – H39	Day	31.8	33.0	34.6	36.6	38.7	40.9	42.9	44.5	45.7
	B/G+5	36.8	38.0	39.6	41.6	43.7	45.9	47.9	49.5	50.7
NML 2 – H39	Night	32.6	33.2	34.1	35.2	36.7	38.4	40.3	42.5	44.8
	B/G+5	37.6	38.2	39.1	40.2	41.7	43.4	45.3	47.5	49.8
NML 3 – H67	Day	42.1	42.1	42.3	42.6	43.2	43.9	44.9	46.0	47.4
	B/G+5	47.1	47.1	47.3	47.6	48.2	48.9	49.9	51.0	52.4
NML 3 – H67	Night	44.3	44.0	43.7	43.6	43.6	43.7	44.0	44.4	44.9
	B/G+5	49.3	49.0	48.7	48.6	48.6	48.7	49.0	49.4	49.9
NML 4 – H20	Day	39.6	39.6	39.8	40.2	40.7	41.5	42.5	43.9	45.7
	B/G+5	44.6	44.6	44.8	45.2	45.7	46.5	47.5	48.9	50.7
NML 4 – H20	Night	40.1	40.0	40.0	40.0	40.2	40.6	41.3	42.4	43.9
	B/G+5	45.1	45.0	45.0	45.0	45.2	45.6	46.3	47.4	48.9
NML 5 – H15	Day	34.6	34.9	35.6	36.6	37.8	39.0	40.2	41.2	41.8
	B/G+5	39.6	39.9	40.6	41.6	42.8	44.0	45.2	46.2	46.8
NML 5 – H15	Night	34.5	34.2	34.4	35.0	36.1	37.4	39.1	40.9	42.8
	B/G+5	39.5	39.2	39.4	40.0	41.1	42.4	44.1	45.9	47.8
NML 6 – H36	Day	32.1	33.6	35.5	37.7	40.1	42.4	44.5	46.2	47.2
	B/G+5	37.1	38.6	40.5	42.7	45.1	47.4	49.5	51.2	52.2
NML 6 – H36	Night	32.2	32.8	34.0	35.8	37.8	40.2	42.6	45.0	47.2
	B/G+5	37.2	37.8	39.0	40.8	42.8	45.2	47.6	50.0	52.2

Appendix 10.3 of this chapter plots the derived background noise levels, background plus 5 trendline with the predicted noise levels against a noise limit of 43dB(A) at each receptor.

10.3.5 Noise Assessment Locations

The monitoring locations were chosen so that the distance was sufficient to ensure no noise contribution from any other operating wind turbines.

10.3.6 Noise Limits

The noise limits for the Proposed Development are based on the limits contained within the Wind Energy Development Guidelines 2006 and on the background levels obtained in **Table 10.11**. A lower fixed limit of 45 dBA for daytime could be applied, however a more stringent limit is applied with the lowest background noise levels obtained at the location of NML 1 – H5 used as the basis for the assessment at all receptors with a limit of 43dBA being applied for day and night. Where receptors are financially involved, a 45 dBA limit can be applied as per the WEDG 2006 Guidelines.

Table 10.11: Derived Background Day and Night Noise Levels used in Assessment

Monitoring Location		Prevailing Background (B/G) noise levels LA90dB, 10min Standardised Mean 10 m Height Wind Speed, (m/s)								
		4	5	6	7	8	9	10	11	12
NML 1 – H5	Day	35.7	35.9	36.2	36.7	37.3	38.1	39.0	40.0	41.1
	B/G+5	40.7	40.9	41.2	41.7	42.3	43.1	44.0	45.0	46.1
Noise Limit		43	43	43	43	43	43.1	44.0	45.0	46.1
NML 1 – H5	Night	36.4	36.3	36.3	36.5	36.8	37.3	38.0	39.0	40.3
	B/G+5	41.4	41.3	41.3	41.5	41.8	42.3	43.0	44.0	45.3
Noise Limit		43	43	43	43	43	43	43	44.0	45.3

10.3.7 Development Design Mitigation

The preferred turbine model, the V150 will be fitted with STE as standard which is best practice. A serrated extension of the trailing edge to the rotor blades mitigates noise emissions by effectively breaking up the turbulence on the tooth flanks into smaller eddies. The intensity of the pressure fluctuations is reduced which mitigates the noise emissions. Since the intensity of the noise emissions is largely dependent on the flow speed, STE are only installed on the outer rotor blade area where the rotary speed is the highest. Typically, STE reduces the noise levels by 2 to 3 dBA depending on specific turbine used.

10.4 ASSESSMENT OF POTENTIAL EFFECTS

10.4.1 Construction Noise

10.4.1.1 Construction and Decommissioning Noise Levels

As has been previously stated, the construction process associated with wind farms is not considered intensive and is temporary works most of which is carried out a considerable distance from receptors. The main noise sources will be associated with the construction of the Turbine Foundations, Turbine Hardstands, Grid Connection Route Options and Temporary Construction Compound, with lesser sources being the construction of the Onsite Substation and Control Building. The main construction traffic to the Site will be during a very short period where ready-mix trucks deliver concrete for the turbine bases. While delivery of material from local quarries for upgrade of site access tracks, Turbine Hardstands, Temporary Construction Compound and Onsite Substation and Control Building will be for longer periods but will be of less intensity, generating lower levels of noise along the routes. During delivery of materials, trucks will access the Site from a different route than leaving the Site, thereby reducing traffic noise at receptors along the local road network. The delivery of turbines by large trucks travelling at very low speed will generate very low levels of noise at receptors along the Turbine Delivery Route.

It is not possible to specify the precise noise levels of emissions from the construction equipment until such time as a contractor is chosen and construction plant has been selected. However, **Table 10.12** indicates typical construction range of noise levels for this type of activity (levels from author's database and BS 5228[26]). Predictions are made for receptors nearest to the turbine bases / hardstands activity, compound development and for receptors at varying distance from the Grid Connection route.

[26] BS 5288-1: 2009-1+A1:2014, Code of Practice for Noise and Vibration Control on Construction and Open Sites: *Code of Practice for Basic Information and Procedures for Noise Control*

Table10.12: Typical Noise Levels from Construction Works

Activity	L_{Aeq} at 10m
General Construction (ready-mix trucks pouring concrete)	70-84 dBA
Tracked excavator removing topsoil, subsoil for foundation	80- 87 dBA
Rock breaker and excavator loading	82-89 dBA
Vibrating rollers including tipping material	76-86 dBA
Grid Connection: Trenching Tracked excavator 14t, pneumatic breaker, vibratory roller 71t, tractor	71-74 dBA
Excavator loading / tipping, excavator and Vibratory roller	80- 87 dBA

The difference in noise levels between two locations can be calculated as:

$$\mathbf{L}_{p2} - \mathbf{L}_{p1} = 10 \log (R_2 / R_1)^2 - (A_{atm} + A_{gr} + A_{br} + A_{mis})$$

$$= 20 \log (R_2 / R_1) - (A_{atm} + A_{gr} + A_{br} + A_{mis})$$

where:

L_{p1} = sound pressure level at location 1

L_{p2} = sound pressure level at location 2

R_1 = distance from source to location 1

R_2 = distance from source to location 2

and where:

A_{atm} = Attenuation due to air absorption

A_{gr} = Attenuation due to ground absorption

A_{br} = Attenuation provided by a barrier

A_{mis} = Attenuation provided by miscellaneous other effects

In the calculations attenuation by A_{atm}, A_{gr} and A_{mis} is taken as 3 dBA where distances are more than 200 m from a source and as zero within 200 m - amelioration by barriers is not accounted for.

Table 10.13 gives the noise levels predicted from construction activity at varying distances. The main noise sources are assumed to be the construction of the Turbine Foundations, Turbine Hardstands and Grid connection. The development of the site access tracks, construction of the Onsite Substation and Control Building will also take place, however the noise levels associated with this activity will be lower and of shorter duration than other works. The main road traffic noise will be associated with the delivery of ready-mix concrete for Turbine Foundations.

Road traffic is dealt with under a sub-heading **'Traffic and Transport'** in **Chapter 14**.
The maximum construction noise levels associated with the Development and Grid Connection are listed in **Table 10.13.** At receptor locations further away, noise levels will be less than that predicted. Works associated with Decommissioning will be no more than the levels predicted in **Table 10.13**.

Table 10.13: Predicted Construction Noise Levels

Activity taken as 100% per hour	Distance of Activity (m)	LAeq dB 1hr range
General Construction (ready-mix trucks pouring concrete)	486m to H67	33.4-47.4dBA
Tracked excavator removing topsoil, subsoil for foundation	486m to H67	43.4-50.4dBA
Rock breaker and excavator loading at nearest turbine T2	486m to H67	45.4-52.4dBA
Vibrating rollers including tipping material set down area close to T2	486m to H67	39.4-49.4dBA
Grid Connection: Trenching Tracked excavator 14t, pneumatic breaker, vibratory roller 71t, tractor	At varying distances along route: 15m 20m 40m 80m	67.5-70.5dBA 65-68dBA 59-62dBA 53-56dBA
Construction of compound (loading / tipping, excavator and Vibratory roller)	486m to H67	43.4-50.4dBA

Construction Traffic

The delivery of turbines to the Site will generate low level traffic noise as the vehicles carrying the turbines will move slowly along the local roads where impact is expected to be greatest. The main construction noise generated by traffic to and from the Site will be due to ready-mix trucks delivering concrete with trucking of spoil being carried out at the same time. The concrete pour for each individual turbine will be required to be completed in a short a period as possible (usually within 10 hours).

Each turbine will require approximately 950 m^3 of concrete while each ready-mix truck has a capacity of 8 m^3. This results in 118.75 loads of concrete and 238 truck movements for each turbine. For delivery of concrete the timeframe envisaged for each turbine concrete pour is taken as 10 hrs. This equates to an average of 23.8 movements per hour, or 24 movements per hour.

The general expression for predicting the 1 hr LAeq alongside a haul road used by single engine items of mobile plant is:

$L_{Aeq} = L_{WA} - 33 + 10\log_{10}Q - 10\log_{10}V - 10\log_{10}d$

where:

L_{WA} = the sound power level of the truck, in decibels (dB);

Q = 24, the number of vehicles per hour;

V = 60, the average vehicle speed, in kilometres per hour (km/h);

d = the distance of receiving position from the centre of haul road, in metres (m).

LAeq = 105-33 +10log24 – 10log60 – 10log20 = 54 LAeq 1hr.

At 10 m from the roadside the noise levels equate to 57 LAeq 1hr. The trucking for the concrete pour will extend for a total of 8 days (1 day for each turbine). In practice the levels generated by truck movement should be lower than predicted due to the smooth surface on the local roads.

Grid Connection-Cable laying along road by trenching

Cable laying and trenching will occur along the Grid Connection route from the On-site Substation and Control Building to either Dunmanway 110kV Substation (Option A) or Carrigdangan 110kV Substation (Option B) which means maximum levels will pertain no more than 0.5 days equivalent (4 hours) at any single receptor.

Construction noise levels are based on continuous operation. In practice, most plant will operate at a maximum level for short intervals.

10.4.1.2 Assessment of Construction Noise

The higher levels predicted are from the Grid Connection Routes and delivery of concrete for Turbine Foundations. These maximum noise levels will persist for no more than 4 hours at any receptor. All predicted noise levels are well within NRA/TII guidelines[27] given as acceptable and are considered slight. Construction noise is a temporary activity.

27 Transport Infrastructure Ireland (TII) document Good Practice Guidance for the Treatment of Noise during the planning of National Road Schemes, 2014

All activity is predicted without additional mufflers, or without topographic screening. The maximum road traffic noise which is generated by ready-mix trucks delivering concrete for Turbine Foundations will be short term and of 8 days' duration. The predicted noise levels are well within the NRA guidelines given as acceptable and are therefore considered as not significant.

Ground vibration from rock breaking will be below the threshold of sensitivity to humans of 0.2mm/s peak particle velocity at all receptors[28]. The effects of noise and vibration from onsite construction activities are therefore considered not significant.

10.4.1.3 Description of Effects - Construction

The criteria for description of effects for all construction noise activity and the potential worst-case effects, at the nearest receptors is given below.

Table 10.14: Description of Effects – Construction

Quality	Significance	Duration
Negative	Not Significant	Temporary

10.4.1.4 Decommissioning

Noise effects during the Decommissioning phase of the Proposed Development are likely to be of a similar nature to that during construction but of shorter duration. It is likely that site access tracks and Turbine Foundations (excluding plinths) will be left in place and covered over with topsoil unless there are environmental reasons to remove. It is likely that the duration of the Decommissioning phase will be of shorter duration than that during construction. Any legislation, guidance, or best practice relevant at the time of decommissioning will be complied with.

10.4.1.5 Description of Effects - Decommissioning

The criteria for description of effects for all decommissioning noise activity and the potential worst-case effects, at the nearest receptors is given below.

Table 10.15: Description of Effects – Decommissioning

Quality	Significance	Duration
Negative	Not Significant	Temporary

[28] Wiss, J. F., and Parmelee, R. A. (1974) Human Perception of Transient Vibrations, "*Journal of Structural Division*", ASCE, Vol 100, No. S74, PP. 773-787

10.4.1.6 Predicted Operational Noise Levels

Table 10.16 gives the predicted noise levels at the nearest receptors to the Proposed Development at varying wind speeds for each receptor location. A noise contour map of the 8 no. turbine Development at maximum sound power output at a wind speed of 12ms-1 at 10m height is presented in **Appendix 10.4**. The contour map in **Appendix 10.4** assumes that all turbines are simultaneously downwind to each location all of the time (continuously) which results in an overprediction of the noise levels.

Table 10.16: Predicted Noise Levels as LA90 at Varying Wind Speeds from the Development

	ING	ING	4m/s	5m/s	6m/s	7m/s	8m/s	9+m/s
House ID	Easting	Northing	dBA	dBA	dBA	dBA	dBA	dBA
H1	512574	560249	24.8	28.9	32.6	34.1	34.3	34.3
H2	512548	560240	24.6	28.7	32.4	33.9	34.1	34.1
H3	512576	560296	24.7	28.8	32.5	34	34.2	34.2
H4	512607	560021	23.2	27.3	31	32.5	32.7	32.7
H5	513258	560218	27.8	31.9	35.6	37.1	37.3	37.3
H6	513280	560045	28.5	32.6	36.3	37.8	38	38
H7	514664	561741	22.2	26.3	30	31.5	31.7	31.7
H8	517491	561675	17.5	21.6	25.3	26.8	27	27
H9	517560	561620	17.1	21.2	24.9	26.4	26.6	26.6
H10	516223	559500	30.2	34.3	38	39.5	39.7	39.7
H11	516345	559495	29.1	33.2	36.9	38.4	38.6	38.6
H12	516426	559436	28.2	32.3	36	37.5	37.7	37.7
H13	516455	559391	27.8	31.9	35.6	37.1	37.3	37.3
H14	516453	559491	28.2	32.3	36	37.5	37.7	37.7
H15	516742	559597	26.2	30.3	34	35.5	35.7	35.7
H16	516913	559519	24.8	28.9	32.6	34.1	34.3	34.3
H17	517205	559763	23.1	27.2	30.9	32.4	32.6	32.6
H18	517186	559907	23	27.1	30.8	32.3	32.5	32.5
H19	516995	559974	24.3	28.4	32.1	33.6	33.8	33.8
H20	517058	560064	23.8	27.9	31.6	33.1	33.3	33.3
H21	517237	560043	22.7	26.8	30.5	32	32.2	32.2
H22	517355	560026	22	26.1	29.8	31.3	31.5	31.5
H23	517505	560096	21.2	25.3	29	30.5	30.7	30.7
H24	517525	560068	21.1	25.2	28.9	30.4	30.6	30.6
H25	517602	560034	20.8	24.9	28.6	30.1	30.3	30.3
H26	517766	560044	19.9	24	27.7	29.2	29.4	29.4
H27	517833	560174	19.5	23.6	27.3	28.8	29	29
H28	517746	560332	19.7	23.8	27.5	29	29.2	29.2

	ING	ING	4m/s	5m/s	6m/s	7m/s	8m/s	9+m/s
House ID	Easting	Northing	dBA	dBA	dBA	dBA	dBA	dBA
H29	515967	558698	28.9	33	36.7	38.2	38.4	38.4
H30	516071	558608	27.8	31.9	35.6	37.1	37.3	37.3
H31	516831	558505	25.3	29.4	33.1	34.6	34.8	34.8
H32	516331	558002	25.8	29.9	33.6	35.1	35.3	35.3
H33	516489	557893	25.3	29.4	33.1	34.6	34.8	34.8
H34	516258	557871	25.5	29.6	33.3	34.8	35	35
H35	515815	557831	26.7	30.8	34.5	36	36.2	36.2
H36	512706	558535	22.3	26.4	30.1	31.6	31.8	31.8
H37	513035	558529	24.3	28.4	32.1	33.6	33.8	33.8
H38	512590	558155	21.5	25.6	29.3	30.8	31	31
H39	514019	558165	29.3	33.4	37.1	38.6	38.8	38.8
H40	514606	558023	28.7	32.8	36.5	38	38.2	38.2
H41	514826	557698	27.3	31.4	35.1	36.6	36.8	36.8
H42	514556	557258	24.9	29	32.7	34.2	34.4	34.4
H43	514715	557154	25.6	29.7	33.4	34.9	35.1	35.1
H44	514833	557430	25.9	30	33.7	35.2	35.4	35.4
H45	514870	557636	26.8	30.9	34.6	36.1	36.3	36.3
H46	515012	557597	27	31.1	34.8	36.3	36.5	36.5
H47	516168	557781	26.1	30.2	33.9	35.4	35.6	35.6
H48	512339	560424	23.1	27.2	30.9	32.4	32.6	32.6
H49	512089	560001	22.1	26.2	29.9	31.4	31.6	31.6
H50	511856	559964	21.2	25.3	29	30.5	30.7	30.7
H51	515138	562209	19.8	23.9	27.6	29.1	29.3	29.3
H52	511651	559779	20.4	24.5	28.2	29.7	29.9	29.9
H53	514062	558379	31.8	35.9	39.6	41.1	41.3	41.3
H54	517177	559907	23.1	27.2	30.9	32.4	32.6	32.6
H55	517375	560081	21.9	26	29.7	31.2	31.4	31.4
H56	517485	560120	21.3	25.4	29.1	30.6	30.8	30.8
H57	517582	560131	20.8	24.9	28.6	30.1	30.3	30.3
H58	517565	560150	20.9	25	28.7	30.2	30.4	30.4

	ING	ING	4m/s	5m/s	6m/s	7m/s	8m/s	9+m/s
House ID	Easting	Northing	dBA	dBA	dBA	dBA	dBA	dBA
H59	517665	560186	20.3	24.4	28.1	29.6	29.8	29.8
H60	517712	560152	20.1	24.2	27.9	29.4	29.6	29.6
H61	517770	560146	19.8	23.9	27.6	29.1	29.3	29.3
H62	517793	560211	19.8	23.9	27.6	29.1	29.3	29.3
H63	517724	560209	20.2	24.3	28	29.5	29.7	29.7
H64	516185	558817	28	32.1	35.8	37.3	37.5	37.5
H65	516326	559301	28.7	32.8	36.5	38	38.2	38.2
H66	517061	559769	23.8	27.9	31.6	33.1	33.3	33.3
H67	516482	559447	27.8	31.9	35.6	37.1	37.3	37.3
H68	517190	559916	23	27.1	30.8	32.3	32.5	32.5
H69	517202	560097	22.9	27	30.7	32.2	32.4	32.4
H70	517121	559978	23.4	27.5	31.2	32.7	32.9	32.9
H71	517638	560049	20.6	24.7	28.4	29.9	30.1	30.1
H72	517727	560072	20.1	24.2	27.9	29.4	29.6	29.6
H73	517677	560204	20.3	24.4	28.1	29.6	29.8	29.8

10.4.2 Operational Noise Assessment

The assessment was made of the predicted operational noise levels from the Proposed Development based on the limits described in Section 10.2.3.1 in the 2006 Guidelines and taking into consideration the recent 2023 An Bord Pleanála decision described in Section 10.2.3.2.

As can be seen from **Table 10.17** that the predicted noise levels are lower than the noise limit of 43 dB at all receptors at all wind speeds used as part of the predicted modelling and are therefore compliant with the noise limits and are not significant in terms of EIA.

The predicted noise levels assume that all turbines are directly down-wind to nearest receptors.

Table 10.17: Margin between Predicted Noise Levels and 43dBA Noise Limit

	ITM	ITM	4m/s	5m/s	6m/s	7m/s	8m/s	9+m/s
House ID	Easting	Northing	dBA	dBA	dBA	dBA	dBA	dBA
H1	512574	560249	-18.2	-14.1	-10.4	-8.9	-8.7	-8.7
H2	512548	560240	-18.4	-14.3	-10.6	-9.1	-8.9	-8.9
H3	512576	560296	-18.3	-14.2	-10.5	-9	-8.8	-8.8
H4	512607	560021	-19.8	-15.7	-12	-10.5	-10.3	-10.3
H5	513258	560218	-15.2	-11.1	-7.4	-5.9	-5.7	-5.7
H6	513280	560045	-14.5	-10.4	-6.7	-5.2	-5	-5
H7	514664	561741	-20.8	-16.7	-13	-11.5	-11.3	-11.3
H8	517491	561675	-25.5	-21.4	-17.7	-16.2	-16	-16
H9	517560	561620	-25.9	-21.8	-18.1	-16.6	-16.4	-16.4
H10	516223	559500	-12.8	-8.7	-5	-3.5	-3.3	-3.3
H11	516345	559495	-13.9	-9.8	-6.1	-4.6	-4.4	-4.4
H12	516426	559436	-14.8	-10.7	-7	-5.5	-5.3	-5.3
H13	516455	559391	-15.2	-11.1	-7.4	-5.9	-5.7	-5.7
H14	516453	559491	-14.8	-10.7	-7	-5.5	-5.3	-5.3
H15	516742	559597	-16.8	-12.7	-9	-7.5	-7.3	-7.3
H16	516913	559519	-18.2	-14.1	-10.4	-8.9	-8.7	-8.7
H17	517205	559763	-19.9	-15.8	-12.1	-10.6	-10.4	-10.4
H18	517186	559907	-20	-15.9	-12.2	-10.7	-10.5	-10.5
H19	516995	559974	-18.7	-14.6	-10.9	-9.4	-9.2	-9.2
H20	517058	560064	-19.2	-15.1	-11.4	-9.9	-9.7	-9.7
H21	517237	560043	-20.3	-16.2	-12.5	-11	-10.8	-10.8
H22	517355	560026	-21	-16.9	-13.2	-11.7	-11.5	-11.5
H23	517505	560096	-21.8	-17.7	-14	-12.5	-12.3	-12.3
H24	517525	560068	-21.9	-17.8	-14.1	-12.6	-12.4	-12.4
H25	517602	560034	-22.2	-18.1	-14.4	-12.9	-12.7	-12.7
H26	517766	560044	-23.1	-19	-15.3	-13.8	-13.6	-13.6
H27	517833	560174	-23.5	-19.4	-15.7	-14.2	-14	-14
H28	517746	560332	-23.3	-19.2	-15.5	-14	-13.8	-13.8
H29	515967	558698	-14.1	-10	-6.3	-4.8	-4.6	-4.6

	ITM	ITM	4m/s	5m/s	6m/s	7m/s	8m/s	9+m/s
House ID	Easting	Northing	dBA	dBA	dBA	dBA	dBA	dBA
H30	516071	558608	-15.2	-11.1	-7.4	-5.9	-5.7	-5.7
H31	516831	558505	-17.7	-13.6	-9.9	-8.4	-8.2	-8.2
H32	516331	558002	-17.2	-13.1	-9.4	-7.9	-7.7	-7.7
H33	516489	557893	-17.7	-13.6	-9.9	-8.4	-8.2	-8.2
H34	516258	557871	-17.5	-13.4	-9.7	-8.2	-8	-8
H35	515815	557831	-16.3	-12.2	-8.5	-7	-6.8	-6.8
H36	512706	558535	-20.7	-16.6	-12.9	-11.4	-11.2	-11.2
H37	513035	558529	-18.7	-14.6	-10.9	-9.4	-9.2	-9.2
H38	512590	558155	-21.5	-17.4	-13.7	-12.2	-12	-12
H39	514019	558165	-13.7	-9.6	-5.9	-4.4	-4.2	-4.2
H40	514606	558023	-14.3	-10.2	-6.5	-5	-4.8	-4.8
H41	514826	557698	-15.7	-11.6	-7.9	-6.4	-6.2	-6.2
H42	514556	557258	-18.1	-14	-10.3	-8.8	-8.6	-8.6
H43	514715	557154	-17.4	-13.3	-9.6	-8.1	-7.9	-7.9
H44	514833	557430	-17.1	-13	-9.3	-7.8	-7.6	-7.6
H45	514870	557636	-16.2	-12.1	-8.4	-6.9	-6.7	-6.7
H46	515012	557597	-16	-11.9	-8.2	-6.7	-6.5	-6.5
H47	516168	557781	-16.9	-12.8	-9.1	-7.6	-7.4	-7.4
H48	512339	560424	-19.9	-15.8	-12.1	-10.6	-10.4	-10.4
H49	512089	560001	-20.9	-16.8	-13.1	-11.6	-11.4	-11.4
H50	511856	559964	-21.8	-17.7	-14	-12.5	-12.3	-12.3
H51	515138	562209	-23.2	-19.1	-15.4	-13.9	-13.7	-13.7
H52	511651	559779	-22.6	-18.5	-14.8	-13.3	-13.1	-13.1
H53	514062	558379	-11.2	-7.1	-3.4	-1.9	-1.7	-1.7
H54	517177	559907	-19.9	-15.8	-12.1	-10.6	-10.4	-10.4
H55	517375	560081	-21.1	-17	-13.3	-11.8	-11.6	-11.6
H56	517485	560120	-21.7	-17.6	-13.9	-12.4	-12.2	-12.2
H57	517582	560131	-22.2	-18.1	-14.4	-12.9	-12.7	-12.7
H58	517565	560150	-22.1	-18	-14.3	-12.8	-12.6	-12.6
H59	517665	560186	-22.7	-18.6	-14.9	-13.4	-13.2	-13.2

	ITM	ITM	4m/s	5m/s	6m/s	7m/s	8m/s	9+m/s
House ID	Easting	Northing	dBA	dBA	dBA	dBA	dBA	dBA
H60	517712	560152	-22.9	-18.8	-15.1	-13.6	-13.4	-13.4
H61	517770	560146	-23.2	-19.1	-15.4	-13.9	-13.7	-13.7
H62	517793	560211	-23.2	-19.1	-15.4	-13.9	-13.7	-13.7
H63	517724	560209	-22.8	-18.7	-15	-13.5	-13.3	-13.3
H64	516185	558817	-15	-10.9	-7.2	-5.7	-5.5	-5.5
H65	516326	559301	-14.3	-10.2	-6.5	-5	-4.8	-4.8
H66	517061	559769	-19.2	-15.1	-11.4	-9.9	-9.7	-9.7
H67	516482	559447	-15.2	-11.1	-7.4	-5.9	-5.7	-5.7
H68	517190	559916	-20	-15.9	-12.2	-10.7	-10.5	-10.5
H69	517202	560097	-20.1	-16	-12.3	-10.8	-10.6	-10.6
H70	517121	559978	-19.6	-15.5	-11.8	-10.3	-10.1	-10.1
H71	517638	560049	-22.4	-18.3	-14.6	-13.1	-12.9	-12.9
H72	517727	560072	-22.9	-18.8	-15.1	-13.6	-13.4	-13.4
H73	517677	560204	-22.7	-18.6	-14.9	-13.4	-13.2	-13.2

A noise contour map of the cumulative effects of all 8 no. turbines is presented with a maximum sound power output at a wind speed of 12 ms^{-1} at 10 m height in **Appendix 10.4**. The contour map in **Appendix 10.4** assumes that all turbines are propagating noise simultaneously in a downwind direction to each location which results in an overprediction of the noise levels.

There are seven properties within 5 dB of the 43 dB lower fixed limit, when all of the turbines are operating at their maximum noise levels. There is an inherent conservatism in the prediction noise modelling when it is carried out in line with ETSU-R-97 and the IOA Good Practice Guide.

The turbines to be installed on this site are able to operate in various modes. If specific conditions arise that AM is generated, the operator can amend the operating mode to sufficiently mitigate the generation of AM or reduce the overall noise level in compensation to achieved set noise limits.

10.4.3 Cumulative Effects Assessment

An assessment of the cumulative effects of noise from the Proposed Development together with nearby operational wind farms in a proximity of the Proposed Development has been undertaken. There are eight operational wind farms in a proximity, detailed in **Table 10.18** below. The impacts from the Onsite Substation and Control Building are negligible so have not been included in this assessment.

Table 10.18: Cumulative Wind Farms

Wind Farm	Wind Turbine
Millane Hill WF	9 x Vestas V47 0.6MW, 49m hub height
Grousemount WF	38 x SWT-3.4-101, 71m hub height
Derreenacrinnig WF	7 x Vestas V52/850, 55m hub height
Derragh WF	6 x Nordex N100 3.3MW, 100m hub height
Cleanrath WF	11 x Nordex N117 3.6MW, 91m hub height
Shehy More WF	11 x Nordex N100 3.3MW, 81m hub height
Carrigarierk WF	5 x Nordex N117 3.6MW, 76m hub height
Carrigarierk 2 WF	3 x Nordex N133 4.8MW, 110m hub height

The sound power levels associated with the turbines installed have been detailed in **Table 10.19** below.

Table 10.19: Noise Emission Data for Cumulative Wind Farms at Standardised 10m Height wind Speed

Wind Farm	Sound Power Level, dB LWA at Varying Wind Speeds								
	4	5	6	7	8	9	10	11	12
Millane Hill WF	98.9	98.9	99.2	99.6	100	100.4	100.8	101.1	101.1
Grousemount WF	95.1	99.6	104.3	106.5	107	107	107	107	107
Derreenacrinnig WF	99.7	100.8	101.9	103	104.1	105.2	106.3	106.3	106.3
Derragh WF	96.7	99.2	103.6	104.6	105.2	105.5	105.5	105.5	105.5
Cleanrath WF	94.5	100	103	103.5	103.5	103.5	103.5	103.5	103.5
Shehy More WF	96.5	98.5	102.8	104.4	105	105.5	105.5	105.5	105.5
Carrigarierk WF	94.4	99.3	102.8	103.5	103.5	103.5	103.5	103.5	103.5
Carrigarierk 2 WF	95	100.6	104.3	104.5	104.5	104.5	104.5	104.5	104.5

10.4.3.1 Cumulative Assessment Locations

The same receptor locations used for the Proposed Development are also used in the cumulative assessment. The assessment is a worst-case scenario with the assumption made that the predicted noise levels to receptors are downwind from all wind farms at the same time, a scenario that cannot occur in practise.

The location of those wind farms included in the cumulative assessment has been detailed in **Table 10.18**.

10.4.3.2 Noise Limits

The noise limits are the same as that used in **Table 10.11**.

10.4.3.3 Cumulative Noise Levels

Table 10.20 gives details of the predicted cumulative noise levels for the nearest receptors to the development.

Table 10.20: Predicted Cumulative Noise Levels

	ING	ING	4m/s	5m/s	6m/s	7m/s	8m/s	9+m/s
House ID	Easting	Northing	dBA	dBA	dBA	dBA	dBA	dBA
H1	512574	560249	25.6	29.4	33.2	34.7	35.0	35.0
H2	512548	560240	25.4	29.2	33.0	34.5	34.8	34.8
H3	512576	560296	25.6	29.4	33.1	34.6	34.9	35.0
H4	512607	560021	24.3	28.0	31.8	33.3	33.6	33.7
H5	513258	560218	28.9	32.6	36.4	37.9	38.2	38.3
H6	513280	560045	29.4	33.2	37.0	38.5	38.8	38.8
H7	514664	561741	30.5	32.9	37.1	38.6	39.2	39.6
H8	517491	561675	33.3	35.5	39.8	41.3	41.9	42.4
H9	517560	561620	32.9	35.1	39.3	40.9	41.4	41.9
H10	516223	559500	30.6	34.5	38.3	39.8	40.0	40.0
H11	516345	559495	29.6	33.5	37.3	38.8	39.0	39.0
H12	516426	559436	28.8	32.7	36.4	37.9	38.2	38.2
H13	516455	559391	28.4	32.3	36.0	37.5	37.8	37.8
H14	516453	559491	28.8	32.7	36.4	37.9	38.2	38.2
H15	516742	559597	27.3	31.0	34.8	36.3	36.6	36.7

	ING	ING	4m/s	5m/s	6m/s	7m/s	8m/s	9+m/s
House ID	Easting	Northing	dBA	dBA	dBA	dBA	dBA	dBA
H16	516913	559519	26.2	30.0	33.8	35.2	35.5	35.6
H17	517205	559763	25.5	29.1	32.9	34.4	34.7	34.8
H18	517186	559907	25.8	29.3	33.1	34.6	34.9	35.1
H19	516995	559974	26.8	30.2	34.1	35.6	35.9	36.1
H20	517058	560064	26.8	30.2	34.1	35.5	35.9	36.1
H21	517237	560043	26.2	29.5	33.4	34.9	35.2	35.4
H22	517355	560026	25.7	29.0	32.9	34.4	34.7	34.9
H23	517505	560096	25.0	28.4	32.3	33.7	34.0	34.3
H24	517525	560068	24.9	28.3	32.2	33.6	33.9	34.1
H25	517602	560034	24.6	28.0	31.9	33.3	33.6	33.8
H26	517766	560044	24.1	27.7	31.5	32.8	33.2	33.4
H27	517833	560174	24.3	27.8	31.6	33.0	33.3	33.5
H28	517746	560332	25.1	28.4	32.3	33.7	34.0	34.3
H29	515967	558698	29.1	33.2	36.9	38.4	38.6	38.6
H30	516071	558608	28.1	32.1	35.8	37.3	37.5	37.6
H31	516831	558505	25.7	29.7	33.4	34.9	35.2	35.2
H32	516331	558002	26.1	30.1	33.8	35.3	35.5	35.5
H33	516489	557893	25.6	29.6	33.3	34.8	35.0	35.0
H34	516258	557871	25.8	29.8	33.5	35.0	35.2	35.2
H35	515815	557831	26.9	30.9	34.6	36.1	36.3	36.4
H36	512706	558535	22.7	26.6	30.4	31.9	32.1	32.1
H37	513035	558529	24.6	28.6	32.3	33.8	34.0	34.1
H38	512590	558155	21.8	25.8	29.5	31.0	31.2	31.2
H39	514019	558165	29.4	33.5	37.2	38.7	38.9	38.9
H40	514606	558023	28.8	32.9	36.6	38.1	38.3	38.3
H41	514826	557698	27.4	31.5	35.2	36.7	36.9	36.9
H42	514556	557258	25.0	29.1	32.8	34.3	34.5	34.5
H43	514715	557154	25.7	29.8	33.5	35.0	35.2	35.2
H44	514833	557430	26.0	30.1	33.8	35.3	35.5	35.5
H45	514870	557636	26.9	31.0	34.7	36.2	36.4	36.4

	ING	ING	4m/s	5m/s	6m/s	7m/s	8m/s	9+m/s
House ID	Easting	Northing	dBA	dBA	dBA	dBA	dBA	dBA
H46	515012	557597	27.1	31.2	34.9	36.4	36.6	36.6
H47	516168	557781	26.3	30.3	34.1	35.6	35.8	35.8
H48	512339	560424	24.0	27.8	31.6	33.1	33.4	33.4
H49	512089	560001	22.9	26.7	30.5	32.0	32.2	32.3
H50	511856	559964	21.9	25.8	29.5	31.0	31.3	31.4
H51	515138	562209	28.5	30.9	35.1	36.6	37.2	37.6
H52	511651	559779	21.4	25.2	29.0	30.5	30.7	30.8
H53	514062	558379	31.9	35.9	39.7	41.2	41.4	41.4
H54	517177	559907	25.9	29.3	33.2	34.7	35.0	35.2
H55	517375	560081	25.5	28.9	32.8	34.2	34.5	34.7
H56	517485	560120	25.2	28.5	32.4	33.8	34.2	34.4
H57	517582	560131	24.9	28.3	32.2	33.6	33.9	34.1
H58	517565	560150	25.1	28.4	32.3	33.7	34.0	34.3
H59	517665	560186	24.9	28.2	32.1	33.5	33.8	34.1
H60	517712	560152	24.6	28.0	31.9	33.3	33.6	33.8
H61	517770	560146	24.4	27.8	31.7	33.1	33.4	33.6
H62	517793	560211	24.6	28.0	31.9	33.3	33.6	33.8
H63	517724	560209	24.8	28.2	32.1	33.5	33.8	34.0
H64	516185	558817	28.3	32.3	36.0	37.5	37.8	37.8
H65	516326	559301	29.1	33.1	36.8	38.3	38.5	38.6
H66	517061	559769	26.0	29.5	33.4	34.8	35.1	35.3
H67	516482	559447	28.4	32.3	36.1	37.6	37.8	37.8
H68	517190	559916	25.9	29.3	33.2	34.6	34.9	35.1
H69	517202	560097	26.5	29.8	33.7	35.1	35.5	35.7
H70	517121	559978	26.3	29.7	33.6	35.0	35.3	35.5
H71	517638	560049	24.5	28.0	31.9	33.2	33.6	33.8
H72	517727	560072	24.3	27.8	31.7	33.0	33.3	33.5
H73	517677	560204	24.9	28.3	32.2	33.6	33.9	34.1

A noise contour map of the cumulative effects of all turbines is presented with a maximum sound power output at a wind speed of 12 m/s at 10 m height in **Appendix 10.4**. This contour map assumes that all turbines are simultaneously downwind at the same time to each location which results in an overprediction of the noise levels.

10.4.3.4 Cumulative Noise Assessment

The assessment was made with predicted operational noise levels from the Proposed Development and wind farms located in the vicinity and stated in **Table 10.16** against noise limits in the Wind Energy Development Guidelines 2006. All predicted noise levels are within the noise limits. **Table 10.20** gives the difference between the predicted cumulative noise levels in **Table 10.20** and noise limits for each receptor. A negative margin indicates that the predicted noise levels are within the lower fixed 43dBA limit (45dBA for financially involved properties), which means the levels are within the day and night limits.

Table 10.21: Margin between Predicted Cumulative Noise Levels and Lower Fixed Limit of 43dBA

	ITM	ITM	4m/s	5m/s	6m/s	7m/s	8m/s	9+m/s
House ID	Easting	Northing	dBA	dBA	dBA	dBA	dBA	dBA
H1	512574	560249	-17.4	-13.6	-9.8	-8.3	-8.0	-8.0
H2	512548	560240	-17.6	-13.8	-10.0	-8.5	-8.2	-8.2
H3	512576	560296	-17.4	-13.6	-9.9	-8.4	-8.1	-8.0
H4	512607	560021	-18.7	-15.0	-11.2	-9.7	-9.4	-9.3
H5	513258	560218	-14.1	-10.4	-6.6	-5.1	-4.8	-4.7
H6	513280	560045	-13.6	-9.8	-6.0	-4.5	-4.2	-4.2
H7	514664	561741	-12.5	-10.1	-5.9	-4.4	-3.8	-3.4
H8	517491	561675	-9.7	-7.5	-3.2	-1.7	-1.1	-0.6
H9	517560	561620	-10.1	-7.9	-3.7	-2.1	-1.6	-1.1
H10	516223	559500	-12.4	-8.5	-4.7	-3.2	-3.0	-3.0
H11	516345	559495	-13.4	-9.5	-5.7	-4.2	-4.0	-4.0
H12	516426	559436	-14.2	-10.3	-6.6	-5.1	-4.8	-4.8
H13	516455	559391	-14.6	-10.7	-7.0	-5.5	-5.2	-5.2
H14	516453	559491	-14.2	-10.3	-6.6	-5.1	-4.8	-4.8
H15	516742	559597	-15.7	-12.0	-8.2	-6.7	-6.4	-6.3
H16	516913	559519	-16.8	-13.0	-9.2	-7.8	-7.5	-7.4
H17	517205	559763	-17.5	-13.9	-10.1	-8.6	-8.3	-8.2

	ITM	ITM	4m/s	5m/s	6m/s	7m/s	8m/s	9+m/s
House ID	Easting	Northing	dBA	dBA	dBA	dBA	dBA	dBA
H18	517186	559907	-17.2	-13.7	-9.9	-8.4	-8.1	-7.9
H19	516995	559974	-16.2	-12.8	-8.9	-7.4	-7.1	-6.9
H20	517058	560064	-16.2	-12.8	-8.9	-7.5	-7.1	-6.9
H21	517237	560043	-16.8	-13.5	-9.6	-8.1	-7.8	-7.6
H22	517355	560026	-17.3	-14.0	-10.1	-8.6	-8.3	-8.1
H23	517505	560096	-18.0	-14.6	-10.7	-9.3	-9.0	-8.7
H24	517525	560068	-18.1	-14.7	-10.8	-9.4	-9.1	-8.9
H25	517602	560034	-18.4	-15.0	-11.1	-9.7	-9.4	-9.2
H26	517766	560044	-18.9	-15.3	-11.5	-10.2	-9.8	-9.6
H27	517833	560174	-18.7	-15.2	-11.4	-10.0	-9.7	-9.5
H28	517746	560332	-17.9	-14.6	-10.7	-9.3	-9.0	-8.7
H29	515967	558698	-13.9	-9.8	-6.1	-4.6	-4.4	-4.4
H30	516071	558608	-14.9	-10.9	-7.2	-5.7	-5.5	-5.4
H31	516831	558505	-17.3	-13.3	-9.6	-8.1	-7.8	-7.8
H32	516331	558002	-16.9	-12.9	-9.2	-7.7	-7.5	-7.5
H33	516489	557893	-17.4	-13.4	-9.7	-8.2	-8.0	-8.0
H34	516258	557871	-17.2	-13.2	-9.5	-8.0	-7.8	-7.8
H35	515815	557831	-16.1	-12.1	-8.4	-6.9	-6.7	-6.6
H36	512706	558535	-20.3	-16.4	-12.6	-11.1	-10.9	-10.9
H37	513035	558529	-18.4	-14.4	-10.7	-9.2	-9.0	-8.9
H38	512590	558155	-21.2	-17.2	-13.5	-12.0	-11.8	-11.8
H39	514019	558165	-13.6	-9.5	-5.8	-4.3	-4.1	-4.1
H40	514606	558023	-14.2	-10.1	-6.4	-4.9	-4.7	-4.7
H41	514826	557698	-15.6	-11.5	-7.8	-6.3	-6.1	-6.1
H42	514556	557258	-18.0	-13.9	-10.2	-8.7	-8.5	-8.5
H43	514715	557154	-17.3	-13.2	-9.5	-8.0	-7.8	-7.8
H44	514833	557430	-17.0	-12.9	-9.2	-7.7	-7.5	-7.5
H45	514870	557636	-16.1	-12.0	-8.3	-6.8	-6.6	-6.6
H46	515012	557597	-15.9	-11.8	-8.1	-6.6	-6.4	-6.4
H47	516168	557781	-16.7	-12.7	-8.9	-7.4	-7.2	-7.2

	ITM	ITM	4m/s	5m/s	6m/s	7m/s	8m/s	9+m/s
House ID	Easting	Northing	dBA	dBA	dBA	dBA	dBA	dBA
H48	512339	560424	-19.0	-15.2	-11.4	-9.9	-9.6	-9.6
H49	512089	560001	-20.1	-16.3	-12.5	-11.0	-10.8	-10.7
H50	511856	559964	-21.1	-17.2	-13.5	-12.0	-11.7	-11.6
H51	515138	562209	-14.5	-12.1	-7.9	-6.4	-5.8	-5.4
H52	511651	559779	-21.6	-17.8	-14.0	-12.5	-12.3	-12.2
H53	514062	558379	-11.1	-7.1	-3.3	-1.8	-1.6	-1.6
H54	517177	559907	-17.1	-13.7	-9.8	-8.3	-8.0	-7.8
H55	517375	560081	-17.5	-14.1	-10.2	-8.8	-8.5	-8.3
H56	517485	560120	-17.8	-14.5	-10.6	-9.2	-8.8	-8.6
H57	517582	560131	-18.1	-14.7	-10.8	-9.4	-9.1	-8.9
H58	517565	560150	-17.9	-14.6	-10.7	-9.3	-9.0	-8.7
H59	517665	560186	-18.1	-14.8	-10.9	-9.5	-9.2	-8.9
H60	517712	560152	-18.4	-15.0	-11.1	-9.7	-9.4	-9.2
H61	517770	560146	-18.6	-15.2	-11.3	-9.9	-9.6	-9.4
H62	517793	560211	-18.4	-15.0	-11.1	-9.7	-9.4	-9.2
H63	517724	560209	-18.2	-14.8	-10.9	-9.5	-9.2	-9.0
H64	516185	558817	-14.7	-10.7	-7.0	-5.5	-5.2	-5.2
H65	516326	559301	-13.9	-9.9	-6.2	-4.7	-4.5	-4.4
H66	517061	559769	-17.0	-13.5	-9.6	-8.2	-7.9	-7.7
H67	516482	559447	-14.6	-10.7	-6.9	-5.4	-5.2	-5.2
H68	517190	559916	-17.1	-13.7	-9.8	-8.4	-8.1	-7.9
H69	517202	560097	-16.5	-13.2	-9.3	-7.9	-7.5	-7.3
H70	517121	559978	-16.7	-13.3	-9.4	-8.0	-7.7	-7.5
H71	517638	560049	-18.5	-15.0	-11.1	-9.8	-9.4	-9.2
H72	517727	560072	-18.7	-15.2	-11.3	-10.0	-9.7	-9.5
H73	517677	560204	-18.1	-14.7	-10.8	-9.4	-9.1	-8.9

It can be seen that the predicted noise level at each of the receptors are within the 43 dB limit applicable within the 2006 Guidelines. This considers the predicted noise levels from all of the cumulative turbines to be equivalent of the noise level in a downwind direction from the turbine to the receptor simultaneously. In practice this is not possible due to the location of the turbines.

10.3.1 Description of Effects – Operational Noise

The criteria for description of effects for all operational noise activity and the potential worst-case effects, at the nearest receptors is given below.

Table 10.22: Description of Effects – Operational Noise

Quality	Significance	Duration
Negative	Not Significant	Long Term

10.5 MITIGATION MEASURES AND RESIDUAL EFFECTS

10.5.1 Construction and Decommissioning Noise Mitigation

No significant construction noise effects have been identified. Therefore, no specific mitigation measures are required. However, general guidance for controlling construction noise through the use of good practice given in BS 5228 will be followed. Construction and Decommissioning of the Proposed Development shall be limited to working times given and any controls incorporated in any planning permission.

During the Decommissioning phase of the Proposed Development, noise levels are likely be no more than predicted in **Table 10.11,** however, it is envisaged that decommissioning will be of shorter duration. Any legislation, guidance or best practice relevant at the time of decommissioning will be complied with. Construction and decommissioning is a temporary day time activity.

10.5.1.1 Residual Construction and Decommissioning Effects

The residual effects are the same as the construction and Decommissioning effects identified in this assessment.

10.5.2 Operational Noise Mitigation

The Proposed Development has been designed to comply with the 2006 Guidelines and noise limits attached as conditions to the recent 2023 An Bord Pleanála decision outlined in 10.2.3.2. The operational noise emissions are predicted to be compliant and well within these guidelines with no special mitigation required apart from fitting rotors with STE which is now considered best practice.

In addition, all turbines will have STE fitted as standard to reduce noise emission levels. Mitigation is not considered necessary.

10.5.2.1 Residual Operational Effects

The residual effects are the same as the operational effects identified in this assessment.

10.5.3 Cumulative Effects

The cumulative effects of all nearby wind turbines located within 10 km have been assessed and found to be in compliance with the noise limits set in the Wind Energy Development Guidelines 2006.

10.6 SUMMARY OF EFFECTS

Table 10.23 below summarises the Effects.

Table 10.23: Summary of Effects

	Quality	Significance	Duration
Construction noise	Negative	Not Significant	Temporary
Operational Noise	Negative	Not Significant	Long Term
Decommissioning Noise	Negative	Not Significant	Temporary

10.7 STATEMENT OF SIGNIFICANCE

This Section has assessed the significance of the potential effects of the Proposed Development during operation, construction and decommissioning.

The effects of noise from the operation of the Proposed Development have been assessed using 2006 Guidelines with the methodology described in ETSU-R-97 and the IOA Good Practice Guide. Noise levels during operation of the Proposed Development have been predicted using the best practice of calculation technique. They have been compared with the noise limits in the 2006 Guidelines and recent 2023 An Bord Pleanála limits and found to be compliant.

There has been a consultation process in relation to the revision of the Draft Revised Wind Energy Development Guidelines December 2019. This document provided the basis for a discussion on amendments of the noise limits applicable to wind turbine developments. It is understood that there will be revisions to the draft consultation documents, however a mitigation strategy to incorporate a reduction in sound power level outputs with respect to directionality can be put in place to comply with any specific variation in noise limit levels if new more restrictive guidelines are adopted. All turbines have software incorporated so that the sound power levels can be reduced by direction and energy output.

The noise levels predicted at the nearest receptors are orders of magnitude below the level at which risk of hearing damage, or indeed negative health effects are possible.
Noise during construction of the Proposed Development and decommissioning will be managed to comply with best practice, legislation and guidelines current at that time so that effects are not significant.

10.8 REFERENCES

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2) ETSU-R-97, The Assessment & Rating of Noise from Wind Farms, June 1996

3) Select Committee on Wind Turbines (2014) Wind Energy, Climate and Health: Evidence For The Impacts Of Wind Generated Energy in Australia

4) Fact sheet published by the Australian Government (Greenhouse Office) and the Australian Wind Energy Association

5) Department of Environment, Heritage and Local Government: Wind Energy Development Guidelines, Guidelines for Planning Authorities 2006 Energy

6) Institute of Acoustics (2013) A Good Practice Guide to the Application of ETSU-R-97 for the Assessment and Rating of Wind Turbine Noise

7) ISO 1996/1- Acoustics-Description and Measurement of Environmental Noise - Part 1: Basic Quantities and Procedures

8) ETSU-R-97: Acoustics-The Assessment & Rating of Noise from Wind Farms: ETSU for the DTI, UK, 1996

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10) Wind Turbine AM Review, Phase 2 Report, Department of Energy & Climate Change, WSP/Parsons Brinckerhoff, August 2016

11) IEC Technical Specification 61400-11-2 Wind energy generation systems – Part 11-2: Acoustic noise measurement techniques – Measurement of wind turbine sound characteristics in receptor position, 2024

12) IOA, A Good Practice Guide to the Application of ETSU-R-97 for the Assessment and Rating of Wind Turbine Noise- Supplementary Guidance Note 4: Wind Shear

13) ISO 9613-2 Acoustics -Attenuation of sound during propagation outdoors, Part 2: General Method of Calculation

14) ETSU W/13/00392/REP – 'Low Frequency Noise and Vibration Measurements at a Modern Wind Farm'.

15) Wiss, J. F., and Parmelee, R. A.. (1974) Human Perception of Transient Vibrations, "Journal of Structural Division", ASCE, Vol 100, No. S74, PP. 773-787

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18) Report by Leigh Collins, 21st April 2020 on a study commissioned by the Finnish Government into infrasound and wind turbine syndrome

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