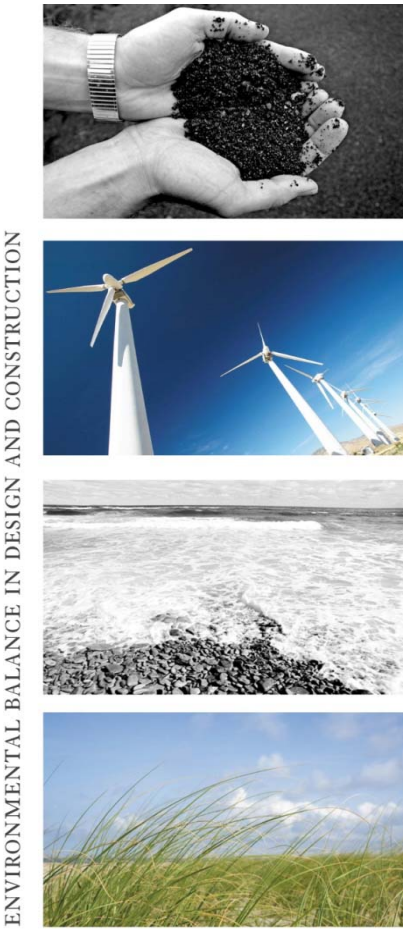

ELEMENT POWER IRELAND LTD.

ENVIRONMENTAL IMPACT STATEMENT FOR THE PROPOSED MAIGHNE WIND FARM IN COUNTY KILDARE AND COUNTY MEATH

VOLUME 2 – MAIN EIS

CHAPTER 6 – Noise & Vibration

March 2015

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6 NOISE & VIBRATION

6.1 Introduction

This chapter contains an assessment of the potential noise and vibration impacts associated with the introduction of the proposed Maighne Wind Farm Development. The assessment has been carried out by Hayes McKenzie Partnership Ltd, based on information provided by Element Power, FTC and noise survey data provided by Enfonic. Descriptions of the proposed development are provided in Chapter 2 – The Proposed Development of Volume 2 of the EIS.

Construction noise and vibration impacts have been discussed with reference to BS 5228:2009 *Code of Practice for Noise and Vibration Control on Construction and Open Sites*.

Predictions of the potential operational noise levels associated with the proposed development have been carried out with reference to the recommendations of the UK Institute of Acoustics', *A Good Practice Guide to the Application of ETSU-R-97 for the Assessment and Rating of Wind Turbine Noise* (2013), and compared with noise limits based on those presented in the Department of the Environment, Heritage and Local Government's *Wind Energy Planning Guidelines* (2006).

The noise limits provided in the latter document may be updated based on information contained within a draft consultation document which has not yet been formally adopted as relevant planning policy. As such, the revised noise limits provided within the consultation document have not been referred to here, although it should be noted that it is possible to comply with the noise limits specified in the updated guidelines through appropriate curtailment or shut down of particular turbines during daytime or night-time periods, as appropriate.

Operational noise associated with the introduction of the proposed substation has been assessed with reference to BS 4142:2014, *Methods for rating and assessing industrial and commercial sound*.

Decommissioning noise and vibration impacts have been discussed with similar references to the construction noise discussion.

6.2 Potential Noise and Vibration Impacts

6.2.1 Construction Noise & Vibration

Noise may arise from the construction of the turbine foundations, the erection of the turbines, the excavation of trenches for cables, excavation of borrow pits, and the construction of associated hard standings, access tracks, construction compounds and sub-stations.

Noise from vehicles on local roads and access tracks would also result from the delivery of the turbine components and construction materials, notably aggregates, concrete and steel reinforcement. Furthermore, it is unlikely that vibration arising from onsite construction activities would be perceptible at nearby residential locations and, whilst vibration associated with HGV movements passing near to residential properties may be perceptible, the impacts are temporary and unlikely to exceed typical thresholds for determining potential structural damage to dwellings.

6.2.2 Operational Noise & Vibration

Noise is generated by wind turbines as they rotate to generate power. This only occurs above the 'cut-in' wind speed and below the 'cut-out' wind speed. Below the cut-in wind speed there is insufficient strength in the wind to generate efficiently and above the cut-out wind speed the turbine is automatically shut down to prevent any malfunctions from occurring. The cut-in speed at turbine hub-height is typically about 3 metres per second (m/s) and the cut out wind speed is about 25 m/s.

The principal sources of noise are from the blades rotating in the air (aerodynamic noise) and from internal machinery, normally the gearbox and, to a lesser extent, the generator (mechanical noise). The blades are carefully designed to minimize noise whilst optimising power transfer from the wind.

Noise may also be generated from ancillary equipment such as sub-stations. However, these generally have particularly low source noise levels as compared to wind turbines themselves and, provided they are not to be located within the immediate vicinity of a residential dwelling, are unlikely to cause disturbance in the context of the other noise sources.

6.2.2.1 Blade Swish (Amplitude Modulation of Aerodynamic Noise)

The variation in noise level associated with turbine operation, at the rate at which turbine blades pass any fixed point of their rotation (the blade passing frequency), is often referred to as blade swish and amplitude or aerodynamic modulation (AM). This effect is identified within the UK document ETSU-R-97, *The Assessment and Rating of Noise from Wind Farms* (1996), upon which the Department of the Environment, Heritage, and Local Government, *Wind Energy Planning Guidelines* noise limits are based. ETSU-R-97 states that *'… modulation of blade noise may result in variation of the overall A-Weighted noise level by as much as 3 dB(A) (peak to trough) when measured close to a wind turbine… '* and that at distances further from the turbine where there are*'… more than two hard, reflective surfaces, then the increase in modulation depth may be as much as 6 dB(A) (peak to trough)'*. It concludes that '*the noise levels* (i.e. limits) *recommended in this report take into account the character of noise described … as blade swish*'.

Despite ongoing concern about amplitude modulation effects, especially where the spectrum of the modulated noise moves from the 800-1000 Hz identified in ETSU-R-97 to lower frequencies, and the modulated noise increases in depth, the UK Government continues to support the limits in ETSU-R-97 for regulation of wind farm noise and no modifications to the 2006 DoELHG limits have been proposed in this respect.

6.2.2.2 Infra-sound & Low Frequency Noise

Infra-sound is noise occurring at frequencies below that at which sound is normally audible, i.e. at less than about 20 Hz, due to the significantly reduced sensitivity of the ear at such frequencies. In this frequency range, for sound to be perceptible, it has to be at very high amplitude and it is generally considered that when such sounds are perceptible then they can cause considerable annoyance.

The UK Department of Trade and Industry Low Frequency Noise Study, W/45/00656/00/00, *The Measurement of Low Frequency Noise at Three UK Windfarms*, concluded that *'infrasound noise emissions from wind turbines are significantly below the recognised threshold of perception for acoustic energy within this frequency range. Even assuming that the most sensitive members of the population have a hearing threshold which is 12 dB lower than the median hearing threshold, measured infrasound levels are well below this criterion'*. It goes on to state that, based on information from the World Health Organisation, '*there is no reliable evidence that infrasound below the hearing threshold produce physiological or psychological effects' and that 'it may therefore be concluded that infrasound associated with modern wind turbines is not a source which may be injurious to the health of a wind farm neighbour'*.

Noise from modern wind turbines is essentially broad band in nature in that it contains similar amounts of acoustic energy in all frequency bands from low to high frequency. As distance from a wind farm site increases the noise level decreases as a result of the spreading out of the sound energy and also due to air absorption which increases with increasing frequency. This means that, although the energy across the whole frequency range is reduced, higher frequencies are reduced more than lower frequencies with the effect that as distance from the site increases the ratio of low to high frequencies also increases. This effect may be observed with road traffic noise or natural sources, such as the sea, where higher frequency components are diminished relative to lower frequency components at long distances. At such distances, however, the overall noise level is so low, such that any bias in the frequency spectrum is insignificant.

6.2.2.3 Vibration

Vibration from operational wind farms is below the human threshold of perception such that no significant effects are expected. As such, this aspect of the operation of the proposed turbines is not discussed further.

6.3 Methodology

6.3.1 Study Area

The study area, in terms of both construction and operational noise, is restricted to the residences located within 1.31 km of the proposed wind farm developments.

6.3.2 Relevant Guidance

A list of relevant guidance documents are provided below. These have been referred to where appropriate in the sections below.

- Irish Wind Energy Association, Best Practice Guidelines for the Irish Wind Energy Industry (2012)
- Department of the Environment, Heritage, and Local Government, *Wind Energy Planning Guidelines* (2006)
- UK Institute of Acoustics', *A Good Practice Guide to the Application of ETUS-R-97 for the Assessment at Rating of Wind Turbine Noise* (2013)
- UK Department of Trade and Industry (DTI), ETSU-R-97, *The Assessment and Rating of Noise from Wind Farms* (1996)
- International Standard Organisation, ISO 9613-2, Acoustics – *Attenuation of Sound During Propagation Outdoors* (1996)
- BS 4142:2014, *Methods for rating and assessing industrial and commercial sound*
- BS 5228:2009: *Code of Practice for Noise and Vibration Control on Construction and Open Sites* (2009)
- National Roads Authority, *Guidelines for the Treatment of Noise and Vibration in National Road Schemes (2004).*

6.3.3 Evaluation Criteria

6.3.3.1 Construction Noise Criteria

There is no specific Irish guidance on appropriate noise limits for construction noise, and therefore the noise limits specified in the British Standard, BS 5228:2009, *Code of Practice for Noise and Vibration Control on Construction and Open Sites*, have been referred to, as recommended by the IWEA *Best Practice Guidelines*. There is some information in the National Roads Authority (NRA), *Guidelines for the Treatment of Noise and Vibration in National Road Schemes (2004)*, also referred to in the IWEA guidelines, which have also been referenced below.

British Standard BS5228:2009 contains two example methods are provided for assessing the significance of construction noise.

The first is based on the use of criteria defined in Department of the Environment Advisory Leaflet (AL) 72, *Noise Control On Building Sites*[1] which sets a fixed limit of 70 dB(A) in rural suburban and urban areas away from main roads and traffic. Noise levels are generally taken as façade L_{Aeq} values with free-field levels taken to be 3 dB lower, giving an equivalent noise criterion of 67 dB L_{Aeq}.

The second is based on noise change, with a 5 dB increase in overall noise considered to be significant. However, where existing noise levels are low and construction activities continue for more than one month, minimum criteria are applicable. These are 45, 55 and 65 dB L_{Aeq}, for night-time (23:00-07:00), evening and weekends, and daytime (07:00-19:00) including Saturdays (07:00-13:00) respectively.

The NRA's guidelines include a table of noise levels that it deems typically acceptable for construction activities, reproduced at Table 6.1 below, but states that '*it may be appropriate to apply more stringent limits in areas where pre-existing noise levels are low*'. It should be noted that the values presented below are façade levels, and therefore require a -3 dB correction to free-field for comparison with the BS5228:2009 noise limits.

[1] Department of the Environment, Environment Advisory Leaflet (AL) 72, Noise Control On Building Sites, 1969

Table 6.1: National Roads Authority – Proposed Construction Noise Limits

Days and Times	$L_{Aeq(1hr)}$ dB	$L_{pA(max)slow}$ dB[2]
Monday to Friday (07:00 to 19:00)	70	80
Monday to Friday (19:00 to 22:00)	60	65
Saturdays (08:00 to 16:30)	65	75
Sundays and Bank Holidays (08:00 to 16:30)	60	65

It is considered that existing levels of noise at residential properties surrounding the proposed wind farm are relatively low, and therefore it is proposed that construction noise with a duration greater than one month will be assessed against the BS5228:2009 daytime noise limit of 65dB L_{Aeq} averaged over the daytime working hours period, as this is when construction noise will be generated.

6.3.3.2 Wind Farm Operational Noise Criteria

The Irish Wind Energy Association (IWEA), *Best Practice Guidelines for the Irish Wind Energy Industry*, state (in section 6.3.3) that the Department of the Environment Heritage and Local Government (DoEHLG) *Wind Energy Planning Guidelines*, should be followed. The IWEA guidelines also make reference to the wind farm noise assessment methodology used in the UK, *ETSU-R-97, The Assessment and Rating of Nosie from Wind Farms,* as additional useful documentation that provides guidance on the assessment of noise from wind farms.

The DoEHLG guidelines contain recommended noise limits to control operational noise from wind farms. The limits are summarised below and are stated to be dB L_{A90}[3] values:

- 35-40 dB(A) for quiet daytime environments of less than 30 dB(A)
- 45 dB(A) for daytime environments greater than 30 dB(A)
- 5 dB(A) above background levels when background is greater than 40 dB(A) during the daytime
- It is stated that '*A fixed limit of 43 dB(A) will protect sleep inside properties during the night*'

For the proposed Maighne wind farm, operational noise levels will be compared with noise limits based on the results of baseline noise measurements carried out at a number of residential properties surrounding each the proposed wind farms. It should be noted that the DoEHLG noise limits are based on the UK ETSU-R-97 methodology, where both the day and night time noise limits are typically related to background noise, subject to fixed limits where background noise levels are low.

[2] The maximum sound pressure level occurring during a given measurement interval.
[3] dB L_{A90} is the noise level in dB(A) exceeded for 90% of any given measurement period and the index normally used for quantifying 'background noise' but also wind farm noise in Ireland and the UK amongst others.

Table 6.2: Noise Limits for the Assessment of Operational Wind Farm Noise

Times	Limits (dB L_{A90})
Daytime 07:00 to 23:00 hours	40 dB where background noise levels are below 30 dB, and the greater of 45 dB or plus 5 dB above background where background noise levels are greater than 30 dB
Night-time 23:00 to 07:00 hours	The greater of 43 dB or plus 5 dB above background

The background noise levels, referenced at Table 6.2 are taken as the derived prevailing background noise levels calculated with a best fit regression line though measured background noise levels, correlated with on-site wind speed.

It should be noted that the Department of the Environment, Community and Local Government is conducting a targeted review of its Wind Energy Development Guidelines. It is anticipated that this review will include proposing revised noise limits for wind energy developments, although, at this time, the review has not been completed and the potential revised limits are unknown.

6.3.3.3 Substation Operational Noise Criteria

BS 4142:2014, *Methods for rating and assessing industrial and commercial sound*, provides an assessment methodology for determining the likely effects of external sound experienced at residential properties due to industrial and commercial sound sources. The standard describes a method for rating noise levels based on the difference between the level of existing background sound (in absence of the industrial or commercial source) and the sound immission level of the source at a particular receiver location (known as the specific sound level). In instances where the specific noise level exhibits an identifiable or perceived character (such as tonality, impulsiveness, intermittency or any other distinguishing characteristic) then a penalty, depending on the nature of the sound, should be added to give the rating level. The difference between the background level and the rating level (rating noise level minus the background sound level) is then used to determine the impact of the sound, as shown at Table 6.3 below.

Table 6.3: Extract from BS 4142

Difference	Assessment
Around 10 dB or more	'…likely to be an indication of a significant adverse impact.'
Around 5 dB	'…likely to be an indication of an adverse impact, depending on the context.'
0 dB	'… this is an indication of the specific sound source having a low impact, depending on the context.'

However, it is acknowledged and stressed within the standard that the source of noise should be described and assessed both in terms of the margin above background sound and in the context of the existing sound environment, especially in instances where the existing environment may already have ambient (or residual) sound levels that are high in relation to background sound level and when existing sound is similar in character to the assessed source.

Whilst BS 4142 provides a general approach to the assessment of sound impact on residential amenity, there are no guidelines for the specific approach to be taken in particular circumstances and for acceptable criteria in terms of defining potential noise limits. In these respects, the standard is left entirely open to interpretation. However, the standard states that *'Where background sound levels and rating levels are low, absolute levels might be as, or more, relevant than the margin by which the rating level exceeds the background. This is especially true at night'*.

The previous version of BS 4142, issued in 1997 and in which a similar statement was given, contained a clarifying note stating that *'…for the purposes of this standard, background noise levels below 30 dB and rating levels below about 35 dB are considered to be very low'*. It is therefore considered that, in general and for urban or industrialised sound environments in particular, if the rated noise level is below 35 dB L_{Aeq} then this would offer sufficient protection against noise for neighbouring residents.

The substation is to be located in a particularly rural area. However, it is considered that future background noise levels at dwellings neighbouring the location of the proposed substation will generally exceed 35 dB L_{A90} during periods when the substation would be expected to emit noise due to the generation of noise from the proposed Maighne turbines. As a result, similarly to the above, it is considered that if the rated noise level is below 35 dB L_{Aeq} then this would also offer sufficient protection against noise for neighbouring residents.

6.4 Existing Environment

6.4.1 Baseline Noise Measurements

A period of baseline noise monitoring has been undertaken at locations surrounding each cluster of wind turbines, which comprise the entire Maighne Wind Farm development, in order to establish the existing levels of background noise at dwellings neighbouring the sites:

- Ballynakill (5 monitoring locations)
- Windmill (1 monitoring location)
- Drehid-Hortland (7 monitoring locations)
- Derrybrennan (1 monitoring location)
- Cloncumber (8 monitoring locations)

These locations are shown on Figure 6.1 of Volume 2a of the EIS.

The noise and wind measurement locations were arranged by Fehily Timoney & Company, Element Power and Enfonic Ltd (who also undertook the baseline noise measurements).

The installation reports, supplied by Enfonic Ltd, are included at Appendices E1 to E5. These describe the measurement locations including photographs of the installations at residences neighbouring each of the turbine clusters.

Concurrent wind and rainfall data was measured at the various on-site meteorological masts relating to each cluster for the duration of the baseline noise measurements.

6.4.2 Analysis of the Baseline Data

6.4.2.1 Wind Data Analysis

The approach to wind speed measurement is not specified in the DoELHG guidance. However, it is well established that wind speed experienced by a wind turbine cannot be correctly predicted from direct wind speed measurements made at 10 m height and ground roughness conditions alone.

In some instances, hub height wind speed (i.e. the wind speed experienced by the wind turbine and which most directly relates to the potential turbine noise output), may be under-predicted in conditions where wind shear conditions are higher than assumed through ground roughness conditions.

To account for this in the assessment methodology, background noise is normally referenced to hub height wind speed, based on the methodology described in the UK Institute of Acoustics', *Good Practice Guide to the Application of ETSU-R-97 for the Assessment at Rating of Wind Turbine Noise* (GPG). However, in this instance, only 10 m height wind speed measurements are available and, as a result, appropriate assumptions regarding wind shear should be applied to the predicted noise levels in order ensure a robust approach to the assessment.

The GPG recommends at Paragraph 4.5.4 that, in the instances where only 10 m height wind speed and direction measurements are available, the following factors may be subtracted from the wind speed reference used in the turbine predictions (standardised 10 m height) such that the results may be compared with noise limits referenced to directly measured 10 m height wind speeds.

These factors are 1 m/s, 2 m/s and 3 m/s for turbine hub-heights of up to 30 m, up to 60 m and over 60 metres respectively. The turbines considered within this planning application have a hub-height of approximately 110 m. As a result, a 3 m/s correction has been applied to the predicted noise levels.

Table 6.4 below provides the comparative wind speeds associated with the assumption above for measured 10 m height, standardised 10 m height and at hub-height of the proposed turbines, for reference purposes.

Table 6.4: Wind Speed Conversion

Measured 10 m Height Wind Speed (m/s)	Standardised 10 m Height Wind Speed, GPG Assumption (m/s)	110 m Hub-height Wind Speed, assuming 0.05 m ground roughness length (m/s)
1	4	5.8
2	5	7.3
3	6	8.7
4	7	10.2
5	8	11.6
6	9	13.1
7	10	14.5
8	11	16.0
9	12	17.4
10	13	18.9

The GPG further goes on to say at Paragraph 4.5.5 *that 'If it can be demonstrated that the predicted noise levels are below the applicable lower fixed limits regardless if wind shear, it can be seen that wind shear would not have an effect on the assessment…'*.

6.4.2.2 Calculating the Prevailing Background Noise Levels

The prevailing background noise levels for daytime (07:00-23:00) and night-time (23:00-07:00) periods have been calculated by plotting a second or third order polynomial regression line though the noise and wind data for each period for each measurement location.

It should be noted that periods of rainfall were excluded from the derivation of the prevailing noise levels as periods of rainfall can elevate the derived prevailing background noise level curves, particularly due to the pattering on rain on the microphone wind shield.

The resultant prevailing background noise levels are presented graphically at Appendices E1 to E5, which show the measured wind and background noise levels together with the corresponding DoEHLG derived noise limit for each relevant measurement location. It should be noted that, in instances where baseline noise levels are not available at high wind speeds (i.e. above 8 m/s) derived limits are 'capped' at the relevant level for the highest wind speeds and corresponding prevailing background noise level experienced.

Further discussion of the derived prevailing background noise levels is contained within the section below.

6.4.2.3 Proposed Wind Farm Noise Limits

The derived noise limits, according to the discussion within Section 6.3.3.2 Wind Farm Operational Noise Criteria for each of the proposed clusters are considered below with reference to the background noise environmental found at dwellings surrounding each site and, where necessary, the meteorological conditions experienced during the survey. The resultant limits are summarised at Table 6.4.

Appendix E6 details the prevailing background noise levels and derived limits for the Ballynakill cluster based on the noise monitoring data obtained during the survey at the 5 measurement locations. The data indicates that background noise levels are heavily influenced by noise associated with vehicle movements along the nearby motorway located to the south of the development. During the survey, wind speeds were predominantly southerly which indicates that traffic noise levels would be at their maximum due to the favourable propagation conditions. During periods of northerly wind conditions, it is possible that prevailing background noise levels would be significantly lower (although unlikely to be below 30 dB). As a result, it is proposed that 43 and 45 dB L_{A90} noise limits are applied this cluster for the night-time and daytime respectively and provides a conservative basis of approach in some instances.

Appendix E7 details the prevailing background noise levels and derived limits for the Windmill cluster based on the noise monitoring data obtained during the survey at one measurement location. The data indicates that a 43 and 45 dB L_{A90} night-time and daytime noise limit should apply at dwellings neighbouring the site.
Appendix E8 details the prevailing background noise levels and resultant noise limits for dwellings neighbouring the proposed Drehid-Hortland cluster. The prevailing background noise levels are typically above 30 dB during the daytime at all locations surrounding the site. As a result, it is considered that a 43 and 45 dB L_{A90} night-time and daytime noise limit should apply at dwellings neighbouring the site.

Appendix E9 details the prevailing background noise levels and noise limits derived for dwellings neighbouring the Derrybrennan cluster. The provided measurement data indicates that noise levels increased during four days at end of the survey which is potentially due to a fault in the measurement equipment (i.e. water ingress) or an additional noise source affecting the measurements (although no additional noise sources were noted by the surveyor dealing with the measurement equipment). As a result, the last four days of data have been removed from the analysis and, based on the remaining data, this indicates that a 43 and 45 dB L_{A90} night-time and daytime noise limit should apply at dwellings neighbouring the site.

Appendix E10 details the prevailing background noise levels and noise limits derived for dwellings neighbouring the Cloncumber cluster. The measurement data indicates that, in general, prevailing background noise levels remain low (i.e. below 30 dB L_{A90}) for measured 10 m height wind speeds up to approximately 3.5 m/s and not greater than 5 m/s. As a result, it is proposed that a fixed 40 dB L_{A90} daytime noise limit (corresponding to low background noise levels, see Table 6.2) is applied at this site for measured 10 m height wind speeds up to 4.5 m/s and 45 dB L_{A90} thereafter. A fixed 43 dB L_{A90} noise limit is proposed for night-time periods. The equivalent standardised 10 m height and hub-height wind speeds can be seen at Table 6.5.

Table 6.5: Proposed Noise Limits

Wind Farm	Night-time Noise Limit	Daytime Noise Limit
Ballynakill	43 dB L_{A90}	45 dB L_{A90}
Windmill	43 dB L_{A90}	45 dB L_{A90}
Drehid-Hortland	43 dB L_{A90}	45 dB L_{A90}
Derrybrennan	43 dB L_{A90}	45 dB L_{A90}
Cloncumber	43 dB L_{A90}	40 dB L_{A90} (at measured 10 m height wind speed less than 4.5 m/s) 45 dB L_{A90} (at measured 10 m height wind speed greater than 4.5 m/s)

Although the noise limits shown within the various appendices are often shown to increase at relatively high wind speeds, due to the potential wind shear effects at the site (see Section 6.4.2.1), it is not considered appropriate to apply higher noise limits in these instances as the derivation of prevailing background noise levels with reference to measured, rather than standardised 10m height wind speeds, creates a high uncertainty as to the relative background noise levels and limits compared with predicted turbine noise levels. The above approach also provides a simplified basis for assessment and for specifying potential planning conditions should the proposed development be granted consent.

6.5 Potential Impacts

6.5.1 Potential Impacts during Construction

6.5.1.1 Potential Direct Impact

Detailed noise predictions have not been carried out for construction activities because due to the specific plant and schedule for construction activities is not being known at this stage. The only construction activities that have the potential to result in construction noise levels at residential properties above 65 dB L_{Aeq} adopted criterion would be track construction and activities at borrow pits (depending on their location relative to dwellings), however it is unlikely that track construction activities would continue at above the noise limit for a duration exceeding one month, and therefore no significant construction noise effects are predicted.

An assessment of the potential noise impact associated with activities associated with the proposed Borrow Pits has been carried out for a set of assumed plant with noise data taken from BS5228:2009, *Code of practice for noise and vibration control on construction and open sites*. A list of plant is detailed at Table 6.6 with the corresponding octave band noise data presented at Table 6.7. Predicted construction noise levels have been calculated according to BS 5228:2009 and assume that the 50% soft ground attenuation, no topographical barrier attenuation, and atmospheric attenuation for 10 degrees Celsius (ºC) and 70% humidity conditions. In practice, it is likely that at least some of the plant would be screened from view.

The results of the construction noise predictions based on the information below indicate that construction noise levels will not exceed 65 dB L_{Aeq} if the distance between a borrow pit and a received location is greater than 120 m (i.e. the approximate distance from the nearest neighbouring dwelling to any of the proposed borrow pits). Nonetheless there will be times when noise associated with the borrow pit will be audible at residential properties surrounding the wind farm site.

It is possible that some turbine deliveries may be carried out at night, and that pouring concrete for the turbine foundations may have to also be carried out at night, however, it is unlikely that these activities would result in any significant noise impact due to the distances between the turbine bases and the nearby residential locations.

Table 6.6: Borrow Pit Plant Assumptions

Plant No.	Table Ref	Ref No.	Equipment	Power Rating, kW	Number of Plant	% On Time
1	C.1	12	Tracked Excavator	228	2	25%
2	C.2	21	Tracked Excavator	107	2	25%
3	C.2	10	Dozer (41 tonne) - ground excavation/ earthworks	239	1	25%
4	C.9	8	Wheeled loader	364	1	15%
5	C.2	31	Dump truck (29 tonne) - empty	306	4	15%
6	C.9	15	Tracked Semi-mobile crusher	310	1	25%

Table 6.7: Borrow Pit Plant Noise Levels

Plant No.	A-weighted Sound Pressure Level, dB L_{Aeq} at 10 m	Octave Band Centre Frequency (Hz)							
		63	125	250	500	1 k	2 k	4 k	8 k
1	82	79	81	83	79	77	75	70	62
2	71	75	76	72	68	65	63	57	49
3	80	89	90	81	73	74	70	68	64
4	91	91	94	90	86	86	83	77	69
5	87	86	79	79	79	79	84	69	60
6	90	91	91	88	87	85	83	78	68

6.5.1.2 Potential Cumulative Impacts

There are not expected to be any significant cumulative noise impacts associated with the construction of the Maighne Wind Farm development.

6.5.2 Potential Impacts during Operation

6.5.2.1 Operational Wind Turbine Direct Impacts

Noise predictions have been carried out using International Standard ISO 9613, *Acoustics – Attenuation of Sound during Propagation Outdoors*. The propagation model described in Part 2 of this standard provides for the prediction of sound pressure levels based on either short-term downwind (i.e. worst case) conditions or long term overall averages. Only the worst-case downwind condition has been considered in this assessment, that is – for wind blowing from the proposed turbines towards the nearby houses. When the wind is blowing in the opposite direction noise levels may be significantly lower, especially where there is any shielding between the turbines and the houses.

The ISO propagation model calculates the predicted sound pressure level by taking the source sound power level for each turbine in separate octave bands and subtracting a number of attenuation factors according to the following:

$$\text{Predicted Octave Band Noise Level} = L_W + D - A_{geo} - A_{atm} - A_{gr} - A_{bar} - A_{misc}$$

These factors are discussed in detail below. The predicted octave band levels from the turbine are summed together to give the overall 'A' weighted predicted sound level.

L_W - Source Sound Power Level

The actual turbines to be installed at the proposed wind farm will be determined through a procurement process following the potential consent of the development, prior to it being built. It will be ensured that the turbines selected will meet the noise limits presented in this assessment. Noise predictions carried out here are for a candidate turbine model that fits the dimensions of the proposed development, and will not necessarily be the model that would be installed at the site.

The sound power level of a noise source is normally expressed in dB re:1pW. Noise predictions are based on sound power levels provided for the GE 2.75-120 with an 110 m hub height. It should be noted that this GE turbine was selected as the candidate turbine for the noise assessment as it has source noise levels that can be considered to be higher than other turbines of similar dimensions. The Nordex N131 3 MW turbine, for example, has lower sound power levels than the GE 2.75-120 turbine.

The assumed sound power level values for the turbine, given at Table 6.8, are based on the noise levels provided by the manufacturer, for a variety of operational modes, with 2 dB added to account for uncertainty. The UK Institute of Acoustics', *Good Practice Guide to the Application of ETSU-R-97 for the Assessment and Rating of Wind Turbine Noise* (IoA GPG) states that it should be ensured that a margin of uncertainty is included within source wind turbine noise data used in noise predictions. The source levels shown here are likely to be akin to a declared apparent sound power level derived in accordance with the 2005 version of IEC 61400-14 *'Declaration of apparent sound power level and tonality values'*.

It is possible to run the GE turbines in noise reduced modes of operation (NROs) whereby the noise level is reduced by reducing the rotational speed of the turbines, with a resultant loss of electrical energy production. These modes have been referred to in the relevant section below in terms of determining any relevant mitigation measures in order for the proposed development to meet the proposed noise limits.

Table 6.8: Wind Turbine (GE2.75-120) Sound Power Levels, dB L_{WA}

Turbine	Standardised 10 m height Wind Speed (m/s)							
	3	4	5	6	7	8	9	>10
	Relative Measured 10 m height Wind Speed (m/s)							
	-	1	2	3	4	5	6	>7
GE 2.75-120 (Normal Operation)	99.2	101.7	107.0	108.0	108.0	108.0	108.0	108.0
NRO 105	99.2	101.7	107.0	107.0	107.0	107.0	107.0	107.0
NRO 104	99.2	101.7	106.0	106.0	106.0	106.0	106.0	106.0
NRO 103	99.2	101.7	105.0	105.0	105.0	105.0	105.0	105.0
NRO 102	99.2	101.7	104.0	104.0	104.0	104.0	104.0	104.0
NRO 101	99.2	101.7	103.0	103.0	103.0	103.0	103.0	103.0
NRO 100	99.2	101.7	102.0	102.0	102.0	102.0	102.0	102.0

The assumed octave band spectrum used for the noise predictions are shown Table 6.9 and are based on information produced by the manufacturer, normalised to the above sound power levels above, corresponding to standardised 10 m height wind speeds of 6 to greater than 10 m/s.

Table 6.9: Wind Turbine (GE2.75-120) Octave Band Noise Levels, dB L_{WA}

Turbine	Octave Band Centre Frequency (Hz)								
	Overall	63	125	250	500	1k	2k	4k	8k
GE 2.75-120 (Normal Operation)	108.0	90.4	96.7	100.5	102.6	102.7	99.7	91.2	74.2
NRO 105	107.0	86.4	95.3	99.6	101.6	101.8	98.7	90.3	73.2
NRO 104	106.0	86.0	94.6	98.6	100.6	100.8	97.7	89.2	72.2
NRO 103	105.0	85.5	93.8	97.6	99.6	99.8	96.7	88.2	71.2
NRO 102	104.0	85.0	93.1	96.6	98.5	98.7	95.6	87.2	70.1
NRO 101	103.0	84.5	92.3	95.6	97.5	97.7	94.6	86.1	69.1
NRO 100	102.0	84.1	91.6	94.6	96.5	96.6	93.6	85.1	68.0

D – Directivity Factor

The directivity factor allows for an adjustment to be made where the sound radiated in the direction of interest is higher than that for which the sound power level is specified. In this case the sound power level is measured in a downwind direction, corresponding to the worst case propagation conditions considered here and needs no further adjustment.

A_{geo} – Geometrical Divergence

The geometrical divergence accounts for spherical spreading in the free-field from a point sound source resulting in attenuation depending on distance according to the following:

$A_{geo} = 20 \times \log(d) + 11$
where, d = distance from the turbine

A wind turbine may be considered as a point source beyond distances corresponding to one rotor diameter.

A_{atm} - Atmospheric Absorption

The atmospheric absorption accounts for the frequency dependant linear attenuation with distance of sound power over the frequency spectrum according to:

$A_{atm} = d \times \alpha$
where, α = the atmospheric absorption coefficient of the relevant frequency band

Published values of 'α' from ISO9613 Part 1[4] have been used, corresponding to a temperature of 10ºC and a relative humidity of 70%, the values specified in the IoA GPG, which give relatively low levels of atmospheric attenuation, and subsequently conservative noise predictions as given in Table 6.10.

Table 6.10: Atmospheric Octave Band Attenuation coefficients, dB/m

Octave Band Centre Frequency (Hz)							
63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz
0.00012	0.00041	0.00104	0.00193	0.00366	0.00966	0.03280	0.11700

A_{gr} - Ground Effect

Ground effect is the interference of sound reflected by the ground with the sound propagating directly from source to receiver. The prediction of ground effects are inherently complex and depend on the source height, receiver height, propagation height between the source and receiver and the ground conditions. The ground conditions are described according to a variable G which varies between 0 for 'hard' ground (includes paving, water, ice, concrete and any sites with low porosity) and 1 for 'soft' ground (includes ground covered by grass, trees or other vegetation). The GPG states that use of G = 0.5 and a receptor height of 4 m should be used to predict the resultant turbine noise level at dwellings neighbouring a proposed development provided that an appropriate allowance for measurement uncertainty is accounted for within the stated source noise levels. Therefore, predictions in this report are based on G = 0.5 with a receptor height of 4 m and, due to the inclusion of the assumed uncertainty within the source noise levels, these predictions are considered to be conservative.

[4] ISO 9613-1, Acoustics - Attenuation of sound during propagation outdoors, Part 1: Method of calculation of the attenuation of sound by atmospheric absorption, International Organization for Standardization, 1992

A_{bar} - Barrier Attenuation

The effect of any barrier between the noise source and the receiver position is that noise will be reduced according to the relative heights of the source, receiver and barrier and the frequency spectrum of the noise. The barrier attenuations predicted by the ISO 9613 model have, however, been shown to be significantly greater than that measured in practice under downwind conditions. The results of a study of propagation of noise from wind farm sites carried out for ETSU concludes that an attenuation of just 2 dB(A) should be allowed where the direct line of site between the source and receiver is just interrupted and that 10 dB(A) should be allowed where a barrier lies within 5 m of a receiver and provides a significant interruption to the line of site.

The GPG states that *'Topographic screening effects of the terrain (ISO 9631-2, Equation 2) should be limited to a reduction of no more than 2 dB, and then only if there is no direct line of sight between the highest point on the turbine rotor and the receiver location'*. There are no significant topographical barriers surrounding the proposed site. As a result, this has not been accounted for within the predictions.

A_{misc} – Miscellaneous Other Effects

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

Predicted Noise Levels

The predicted turbine noise L_{Aeq} has been adjusted by subtracting 2 dB to give the equivalent L_{A90} as suggested in the IoA GPG. It should be noted that noise levels will be lower at lower wind speeds.

The results are provided in tabular form, for dwelling locations supplied by Element Power, at Appendix E11.

6.5.2.2 Potential Operational Sub-Station Direct Impacts

Noise will be produced by the transformer located in the substation and will be a combination of a 'hum' from the unit together with noise generated by the cooling fans. The noise level is likely to depend on the load on the transformer which is dependent on the wind speed (as the wind turbines producing more energy in high wind speeds).

Predictions have been carried out based on an example transformer; the TrafoStar 63 MVA. The specification sheet includes a table detailing achievable noise levels for 80, and 93 dB(A) under typical and high conditions respectively, and that 65 dB(A) is achievable if requested. The transformer is to be located externally in the substation compound.

Hayes McKenzie have been informed that the noise levels presented in the TrafoStar documentation are measured sound pressure levels at 2m from the transformer. Predicted noise levels have been calculated based on hemispherical propagation from the transformer to the nearest residential property (approximately 730 m distant). The results of the predictions are presented in Table 6.11 for the achievable, typical and high noise conditions described in the transformer documentation. It is assumed that all other plant location in the substation will be quieter than the transformers, although it should be noted that there may be a diesel generator located at the sub-station compound, this is for emergency use only.

The character of noise often associated with the operation of transformers is typically described as a buzzing sound (i.e. potentially tonal at a particular frequency). Whilst it is considered that, due to the large distance between the site and the neighbouring receptors, any potential tonal noise would likely be masked by the existing noise environment found at the neighbouring dwellings, a maximum 6 dB penalty for the potential noise character as detailed at 6.3.3.3 has been provided for informative purposes. It should be noted that BS 4142:2014 specifies that *"…for sound ranging from not tonal to prominently tonal the Joint Nordic Method gives a correction of between 0 dB and +6 dB for tonality. Subjectively, this can be converted to a penalty of 2 dB for a tone which is just perceptible at the noise receptor, 4 dB where it is clearly perceptible and 6 dB where it is highly perceptible"*.

Table 6.11: Sub-station Transformer Noise Levels

Transformer Model	Operational Mode	Reference Sound Pressure Level, dB(A)	Sound Power Level, dB L_{WA}	Predicted Sound Pressure Level at 730 m, dB L_{Aeq}	Rating Level including character penalty, dB L_{Aeq},T_r
TrafoStar Transformer 63 MVA	Achievable	65	79	14	20
	Typical	80	94	29	35
	High	93	108	43	49

The results of the operational transformer noise predictions show that predicted rating noise levels at the nearest residential property range from 20 to 49 dB $L_{Aeq,Tr}$. It should be noted that rating levels below about 35 dB $L_{Aeq,Tr}$ are considered to be very low (see Section 6.3.3.3), and therefore if the transformers are operating at their 'typical' or 'achievable' noise level then operational noise levels at the nearest residential location are not considered to be significant.

6.5.2.3 Potential Cumulative Impacts

The predicted noise levels include the effects of the five wind farm clusters considered within this Environmental Statement. It is considered that, because there are no other development located within 6 km of the development considered here, cumulative operational noise impacts will be kept to a minimum and, as a result, are not expected to be significant.

6.5.3 Potential Impacts during Decommissioning

The potential impacts during decommissioning arise from the dismantling of the turbines, breaking up of the turbine bases, and removal of the access tracks. These activities would be undertaken during daytime hours, and noise, which be of lesser impact than for construction, will be controlled through the relevant guidance and standards in place at the time of decommissioning.

6.5.4 Summary of Potential Impacts

Construction and decommissioning noise levels, including for borrow pit activities, are likely to be below the relevant noise limit of 65 dB L_{Aeq} for operations exceeding one month, and therefore construction noise impacts are not considered to be significant.

Operational noise from the proposed turbines is predicted to exceed the proposed daytime and night-time noise limit at several dwellings surrounding the five proposed clusters at a number of properties not involved with the developments. Therefore, mitigation will be required for the relevant periods where these exceedances occur.

Operational noise associated with the introduction of the proposed substation is not considered to be significant in the context of the potential noise environment resulting from the introduction of the proposed turbines providing it is operating at its 'typical' and/or 'achievable' noise output.

6.6 Mitigation Measures

6.6.1 Mitigation Measures during Construction

The noise impact for construction works traffic would be mitigated by generally restricting movements along access routes to the standard working hours and exclude Sundays, unless specifically agreed otherwise. For example, during turbine erection, an extension to the working day may be required, i.e. 05:00 to 21:00, but this would be necessary only on a relatively small number of occasions. If turbine deliveries are required at night it would be ensured that vehicles on local roads do not wait outside residential properties with their engines idling, and that the local residents will be informed of any activities likely to occur outside of normal working hours.

Consultation with the local community is important in minimising the likelihood of complaints and therefore construction will be undertaken in consultation with the local authority as well as the residents being informed of construction activities through a community liaison group.

The construction works on site would be carried out in accordance with the guidance set out in BS5228: 2009, and the noise control measures set out in the Construction Environmental Management Plan (CEMP).

The hours of construction activity will be limited to avoid unsociable hours where possible. Construction operations shall generally be restricted to between 08:00 hours and 19:00 hours Monday to Saturday. However, to ensure that optimal use is made of fair weather windows, or at critical periods within the programme, it could occasionally be necessary to work out with these hours. Any such out of hours working would be agreed in advance with the local planning authority.

6.6.2 Mitigation Measures during Wind Farm Operation

The results of the noise predictions presented at Appendix E11 show that operational noise levels are above the proposed daytime and night-time noise limits at a number of dwellings surrounding the clusters. As a result, the required mitigation to ensure that predicted noise levels meet the relevant noise limits has been calculated based on the information pertaining to noise reduced modes of turbine operation, as contained at Table 6.8 and 6.9.

The proposed daytime and night-time noise limits may be met by operating the potential turbines in the noise modes specified at Table 6.12.

As discussed previously, the operational noise predictions have been carried out for a candidate turbine and, therefore, the proposed mitigation measures only apply to the assumed turbine considered here. It may be the case that mitigation would not be required for the turbine that is selected for the site, assuming that the site is granted planning consent. It should be noted that the proposed curtailment strategies are not exhaustive; there may be several other configurations/alternatives that would allow noise limits to be met and that an appropriate mitigation strategy may be specified for the procured turbine model prior to construction of the wind farm. The finalised mitigation measures to be implemented at the site will be chosen to ensure that the relevant noise limits set out within this chapter are met.

Table 6.12: Required Turbine Curtailment / Mitigation to Meet Proposed Noise Limits

Wind Turbine ID	Easting	Northing	Required Nosie Modes to meet 40 dB L_{A90}*	Required Nosie Modes to meet 43 dB L_{A90}	Required Noise Modes to meet 45 dB L_{A90}
T1	669469	744518	-	-	-
T2	669934	744277	-	-	-
T3	669636	743875	-	NRO104	-
T4	668580	743303	-	NRO103	-
T5	667965	743346	-	-	-
T6	670172	743889	-	NRO105	-
T7	670700	743942	-	-	-

Wind Turbine ID	Easting	Northing	Required Nosie Modes to meet 40 dB L_{A90}*	Required Nosie Modes to meet 43 dB L_{A90}	Required Noise Modes to meet 45 dB L_{A90}
T8	671205	743629	-	-	-
T9	670546	743503	-	NRO105	-
T10	670977	743250	-	-	-
T11	676429	737651	-	-	-
T12	675881	737430	-	NRO104	-
T13	676322	737179	-	-	-
T14	675025	737010	-	NRO105	-
T15	674567	736303	-	-	-
T16	674100	736517	-	-	-
T17	673401	735952	-	NRO105	-
T18	673994	735895	-	NRO102	NRO104
T19	674439	735556	-	NRO100	NRO103
T20	674583	734792	-	NRO101	NRO104
T21	673678	734832	-	NRO101	NRO104
T22	674325	734242	-	-	-
T23	673750	734266	-	-	-
T24	668401	737494	-	-	-
T25	667970	737750	-	-	-
T26	667750	737323	-	-	-
T27	670213	727662	-	-	-
T28	669705	727544	-	-	-
T29	673597	724603	NRO104	-	-
T30	674046	724610	NRO102	-	-
T31	673946	724139	NRO102	NRO104	-
T32	673499	723939	NRO101	NRO105	-
T33	672765	723287	NRO103	-	-
T34	672485	722719	NRO104	-	-
T35	672097	722917	NRO104	-	-
T36	672028	722439	NRO100	NRO103	-
T37	671644	722720	NRO100	NRO104	-
T38	671213	722382	NRO100	NRO102	NRO105
T39	670963	721968	NRO100	NRO105	-
T40	681485	735017	-	-	-
T41	680622	735262	-	NRO104	-
T42	679941	735038	-	-	-
T43	680139	735678	-	NRO104	-
T44	680074	736225	-	NRO105	-

Wind Turbine ID	Easting	Northing	Required Nosie Modes to meet 40 dB L_{A90}*	Required Nosie Modes to meet 43 dB L_{A90}	Required Noise Modes to meet 45 dB L_{A90}
T45	679536	736234	-	-	-
T46	680157	737199	-	-	-
T47	672665	733496	-	-	-

* Applies to the proposed Cloncumber turbines (T29 to T39) for measured 10 m height wind speeds up to 4.5 m/s, see Table 6.3

The results of the predictions including the mitigation specified at Table 6.12 are shown for the dwellings neighbouring the wind farm at Appendix E12.

As discussed in section 6.3.2, the Department of the Environment, Community and Local Government is currently undertaking a review of the Wind Energy Development Guidelines. Any new noise limits that are proposed following this review could be complied with at this site, if required, by implementing the necessary mitigation through the control systems of the wind farm and wind turbines.

6.6.3 Mitigation Measures during Decommissioning

The noise impact for construction works traffic would be mitigated by generally restricting movements along access routes to the standard working hours and should exclude working on Sundays, unless specifically agreed otherwise with the local authority. The decommissioning works, which will be at a lower impact than construction works, will be carried out in accordance with the policies and guidance required at the time of the works, and restricted to normal working hours, typically 07:00-19:00 hours Monday to Friday, and 07:00-13:00 hours on Saturdays.

6.7 Residual Impacts

Construction activities, including those associated with borrow pits, with duration longer than one month are expected to be below the construction noise limit of 65 dB L_{Aeq} averaged over the working day at residential properties. As a result, residual construction impacts are not considered to be significant when assessed under these criteria. However, it should be noted that construction noise may well be audible at neighbouring dwellings during periods where particularly noisy activities are taking place or when works are undertaken in locations close to residential dwellings.

Operational wind farm noise levels, with the sample mitigation specified, meet the proposed night and daytime noise limits at all residential properties surrounding the wind farm which, under this criteria, is not considered to be of a significant impact. However, it should be noted that the noise limits prescribed within here are designed to offer residents a reasonable level of protection against noise associated with wind turbines, without unduly restricting the potential construction of developments that are generally recognised as having wider global benefits. It should be noted that, whist turbine and construction noise levels can meet the proposed noise limits, this compliance does not necessarily strictly provide an indication of the potential significance of a noise impact, and does not demonstrate that the potential turbines will be inaudible.

Operational noise associated with the introduction of the proposed substation is not considered to be significant in the context of the potential noise environment resulting from the introduction of the proposed turbines provided it is operating at its 'typical' and/or 'achievable' noise output.

6.8 References

- W/45/00656/00/00, The Measurement of Low Frequency Noise at Three UK Windfarms, UK Department of Trade and Industry, 2006
- DEFRA NANR233, Research into amplitude modulation of wind turbine noise, Moorhouse et al., University of Salford, July 2007
- Irish Wind Energy Association, Best Practice Guidelines for the Irish Wind Energy Industry, 2012
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- UK Institute of Acoustics', Good Practice Guide to the Application of ETUS-R-97 for the Assessment at Rating of Wind Turbine Noise, 2013
- UK Department of Trade and Industry (DTI), ETSU-R-97, the Assessment and Rating of Noise from Wind Farms, 1996
- International Standard Organisation, ISO 9613-2, Acoustics – Attenuation of Sound during Propagation Outdoors, 1996
- BS 5228:2009: Code of Practice for Noise and Vibration Control on Construction and Open Sites, 2009
- BS 4142:2014, Methods for rating and assessing industrial and commercial sound.