Parc Ynni Calon y Gwynt

ENVIRONMENTAL STATEMENT

Appendix 11J: Prediction of Operational Wind Farm Noise Levels

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1.1 PROPAGATION MODEL

1.1.1. 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 [1] 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. That is, for wind blowing from the Proposed Development towards the nearby houses. When the wind is blowing in opposite direction noise levels may be significantly lower, especially if there is any shielding between the Site and the houses. An additional correction for different wind directions (as detailed in Paragraph 1.10.1 below) has been included within the noise predictions.

1.1.2. The GPG suggests that ISO 9613-2:1996 should be applied to obtain realistic predictions of noise from onshore wind turbines during worst case propagations, provided that the appropriate choice of input parameters and correction factors are made. The input parameters utilised in this assessment are described in the below sections.

1.1.3. A revised version of ISO 9613-2 was published in 2024[2]. Most of the model's main attenuation terms that are utilised in 'GPG compliant' predictions remain the same when compared to the 1996 version (e.g. A_{div}, A_{atm}). However, there is now an informative Annex D, that is designed for wind turbines, that includes suggested refinements towards the assumed barrier attenuation and concave valley corrections. Predictions here have continued to use ISO 9613-2:1996 as: a) at the time of writing it is still the GPG's position to use the old version, b) the refinements of the 2024 version only result in a slightly less conservative prediction. That is, predictions undertaken with the 2024 version give a marginally lower[3] predicted noise level. Hence it is considered more useful at this stage, until the good practice guidance is reviewed, to retain the conservatism of the noise predictions by remaining with the older version of ISO 9613-2:1996.

1.1.4. 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.

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

1.1.5. These factors are discussed in detail below. The predicted octave band levels from each of the turbines are summed together to give the overall 'A' weighted predicted sound level from all the turbines acting together. A 2dB reduction is assumed between the predicted L_{Aeq} and L_{A90} wind turbine noise level.

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1 ISO 9613-2:1996. "Acoustics – Attenuation of sound during propagation outdoors – Part 2: General method of calculation."

2 ISO 9613-2:2024. "Acoustics – Attenuation of sound during propagation outdoors – Part 2: Engineering method for the prediction of sound pressure levels outdoors".

3 For example, of the order of 1 dB depending on receptor location.

1.2 L_W – SOURCE SOUND POWER LEVEL

1.2.1. The sound power level of a noise source is normally expressed in dB re:1pW. Noise predictions here have been based upon sound power levels of a candidate turbine model, a Nordex N163 6.X MW wind turbine.

1.2.2. The noise predictions are based upon specified sound power levels provided by the manufacturer[4], with an additional 2 dB uncertainty factor. The octave band data used in the predictions is based upon the frequency spectra suggested by the manufacturer within the same document. A configuration that includes blades with Serrated Trailing Edges (STE) is proposed. For the unrestricted operation (known as 'Mode 1a', which has a rated power of 6.7 MW), the assumed source sound power level is 109.2 dB(A), for a standardised 10 m wind speed of 7 m/s and above.

1.2.3. The assumed source sound power levels are based upon specified manufacturer data, incorporating a safety factor akin to a warranted sound power level. This assumption adheres to the recommendations of the GPG that suggests such data can be used alongside an assumption of mixed ground. The assumed sound power levels are likely to be similar to those that are normally warranted, but this should be confirmed with the turbine supplier prior to contracts being agreed.

1.2.4. This particular turbine model has various restricted modes available, which allow for lower noise outputs (whilst also restricting power generation), by up to approximately 6 dB at some wind speeds, if required.

1.2.5. **Table 11J 1** below details the source sound power level assumed for unrestricted operation.

Table 11J 1 – Assumed Sound Power Level of N163 6.X MW STE Wind Turbine, Mode 1a

Standardised 10m Wind Speed (m/s)	L_{WA}	Octave Band Centre Frequency (Hz)							
		63	125	250	500	1k	2k	4k	8k
3	97.8	79.0	86.6	88.7	89.9	91.7	92.4	86.8	72.4
4	99.4	80.6	88.2	90.3	91.5	93.3	94.0	88.4	74.0
5	104.2	85.4	93.0	95.1	96.3	98.1	98.8	93.2	78.8
6	108.6	89.8	97.4	99.5	100.7	102.5	103.2	97.6	83.2
7	109.2	90.4	98.0	100.1	101.3	103.1	103.8	98.2	83.8
8	109.2	90.4	98.0	100.1	101.3	103.1	103.8	98.2	83.8
9	109.2	90.4	98.0	100.1	101.3	103.1	103.8	98.2	83.8
10	109.2	90.4	98.0	100.1	101.3	103.1	103.8	98.2	83.8
11	109.2	90.4	98.0	100.1	101.3	103.1	103.8	98.2	83.8

4 Nordex Energy SE & Co. KG (2024). Sales document. Octave sound power levels. Nordex N163/6.X VPC. Document: F008_277a_A14_EN, Revision 05, Dated 03 May 2024.

Standardised 10m Wind Speed (m/s)	L_{WA}	Octave Band Centre Frequency (Hz)							
		63	125	250	500	1k	2k	4k	8k
12	109.2	90.4	98.0	100.1	101.3	103.1	103.8	98.2	83.8

EMBEDDED MEASURES

1.2.6. For the purposes of ensuring the noise impact will be within the ETSU-R-97 noise criteria, a scheme of restricted operation is proposed. This is applicable for the currently chosen candidate turbine model, a Nordex N163 STE. If a quieter turbine model was ultimately chosen for installation, it may be the case that less power restrictions would be required.

1.2.7. A turbine model that has STEs is proposed. This will generally give lower operational noise levels when compared to a turbine configuration that does not have STE. Experience of some turbine models suggest that incorporating STE within the turbine design may reduce the risk of higher amplitude modulation levels occurring.

1.2.8. **Table 11J 2** below outlines how these embedded measures influence the noise assessment.

Table 11J 2 – Summary of embedded measures

Receptor	Potential changes and effects	Embedded measures	Compliance mechanism
Operation Phase			
All receptors	Lower operational wind turbine noise levels. Lower risk of high AM levels occurring	A turbine model with serrated trailing edges	
H3 (Llyn Mawr)	Restricted modes of turbine operation, so that cumulative wind farm noise levels can meet the ETSU-R-97 noise criterion for financially involved residents	Operational Scheme	DNS Planning Condition
H4 (Lakeside View)	Restricted modes of turbine operation, so that cumulative wind farm noise levels can meet the Upper Daytime Hours ETSU-R-97 noise criterion	Operational Scheme	DNS Planning Condition
H6 (Ty-uchaf)	Restricted modes of turbine operation, so that cumulative wind farm noise levels can meet the Upper Daytime Hours ETSU-R-97 noise criterion	Operational Scheme	DNS Planning Condition

H19/H20/H44/H46	Restricted modes of turbine operation, so that the Proposed Development is not within 10 dB of Upper Daytime Hours ETSU-R-97 noise criterion	Operational Scheme	DNS Planning Condition

1.2.9. **Table 11J 3** below details the source sound power levels assumed for the restricted modes: Mode 2a, Mode 4a, Mode 6a, Mode 8a, Mode 9a, Mode 10a. The same frequency spectrum shape was assumed as detailed in **Table 11J 1** above (as is suggested by the manufacturer specification document), normalised to the below overall sound power levels.

Table 11J 3 – Assumed Sound Power Level of N163 6.X MW STE Wind Turbine, Operational Modes

	Standardised 10m Wind Speed (m/s)									
	3	4	5	6	7	8	9	10	11	12
Mode 1a - 6700kW	97.8	99.4	104.2	108.6	109.2	109.2	109.2	109.2	109.2	109.2
Mode 2a - 6595kW	97.8	99.4	104.2	108.4	108.8	108.8	108.8	108.8	108.8	108.8
Mode 4a - 6290kW	97.8	99.4	104.2	107.8	107.8	107.8	107.8	107.8	107.8	107.8
Mode 6a - 5990kW	97.8	99.4	104.2	106.8	106.8	106.8	106.8	106.8	106.8	106.8
Mode 8a - 5740kW	97.8	99.4	104.2	105.8	105.8	105.8	105.8	105.8	105.8	105.8
Mode 9a - 5190kW	97.8	99.4	103.6	103.8	103.8	103.8	103.8	103.8	103.8	103.8
Mode 10a - 5110kW	97.8	99.4	103.1	103.3	103.3	103.3	103.3	103.3	103.3	103.3

1.2.10. The proposed operational scheme is a function of wind speed and wind direction. It is proposed to operate the same scheme for both daytime and night-time hours. The modes of operation are detailed in **Tables 11L.1 – 11L.11** within **Appendix 11L.**

CHARACTER - TONALITY

1.2.11. No allowance has been made for the tonal character of the noise emitted by the wind turbines. In general, wind turbines exhibit little tonality within the radiated noise. However, an appropriate method to control such character is through the imposition of a condition which limits the level of tonality that a site may emit. ETSU-R-97 defines a method by which tonality may be assessed and proposes a penalty system for any tonality which might be measured. The necessity of minimising tonal components in the noise output from the turbines is usually well understood by the turbine manufacturers and a guarantee should always be sought that any tonal noise will be below that requiring a penalty under the ETSU-R-97 scheme.

CHARACTER - AMPLITUDE MODULATION

1.2.12. In a similar manner to tonality, no allowance has been made for any modulating character, that potentially may be part of the noise emitted by the wind turbines. An appropriate method to control such character would be the inclusion of a condition that limits the level of Amplitude Modulation (AM) that the site may emit. A robust method of measuring and quantifying the levels of AM is available via the method proposed by the Institute of Acoustics working group . It is recommended that this, alongside an appropriate penalty (or similar) scheme, is part of the noise-related planning conditions.

1.2.13. A candidate turbine model has been proposed here that includes STE. It has been found at some operational wind farms, that relatively lower levels of amplitude modulation have coincided with turbine units that have included STE.

1.3 D – DIRECTIVITY FACTOR

1.3.1. 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 down wind direction, corresponding to the worst- case propagation conditions considered here and needs no further adjustment.

1.3.2. In reality, the turbine noise will not spread equally in all directions, when in the plane of the rotor noise levels radiated in this direction may be significantly less, of the order of 2dB.

1.4 A_{DIV} – GEOMETRIC SPREADING

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

$A_{div} = 20.\log(d) + 11$

Where d = distance from the receptor to the turbine (m)

1.4.2. The wind turbines may be considered as point sources beyond distances corresponding to one rotor diameter.

1.4.3. **Table 11J 4** details the grid coordinates used to represent the turbine locations in the prediction of the incident noise levels at neighbouring receptors.

Table 11J 4 – Turbine Locations

Turbine	Assumed Model	Assumed Source Height (m)	Easting	Northing
T1	N163 6.X MW STE (118 m hub height)	210	301390	297769
T2	N163 6.X MW STE (118 m hub height)	210	300902	297852
T3	N163 6.X MW STE (118 m hub height)	210	300318	297758

Turbine	Assumed Model	Assumed Source Height (m)	Easting	Northing
T4	N163 6.X MW STE (118 m hub height)	210	300220	298151
T5	N163 6.X MW STE (118 m hub height)	210	299473	297686
T6	N163 6.X MW STE (118 m hub height)	210	299352	298063
T7	N163 6.X MW STE (98.5 m hub height)	190	299257	298539
T8	N163 6.X MW STE (118 m hub height)	210	299857	298767
T9	N163 6.X MW STE (118 m hub height)	210	300371	298812
T10	N163 6.X MW STE (118 m hub height)	210	300395	299410
T11	N163 6.X MW STE (118 m hub height)	210	301024	298755

1.5 A_{GR} – GROUND EFFECT

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

1.5.2. The ground conditions are described according to a variable defined as G, which varies between 0 for 'hard' ground (includes paving, water, ice, concrete & any sites with low porosity) and 1 for 'soft' ground (includes ground covered by grass, trees or other vegetation). Our predictions have been carried out using a source height corresponding to 10 m above the proposed tip height (of 200 m), a receiver height of 4 m and an assumed ground factor G = 0.5. This ground factor corresponds to a mixed ground condition between the source and receiver. As a Digital Terrain Model (DTM) of the local topography has been used in the predictions, a source height corresponding to 10 m above tip height has been assumed. This is to avoid over-estimating the barrier attenuation that is sometimes associated with assuming sources are located at hub height.

1.5.3. The GPG recommends the use of a ground factor of G = 0.5 (with appropriate source noise level assumptions), provided that the majority of the propagation between source and receiver does not occur over paved ground or over large bodies of water such as wide rivers or lakes. The Site and its surroundings, are comprised mainly of moorland or forestry, with no large bodies of water, hence a mixed ground assumption is appropriate in this instance.

1.6 A_{ATM} – ATMOSPHERIC ABSORPTION

1.6.1. Sound propagation through the atmosphere is attenuated by the conversion of the sound energy into heat. This attenuation is dependent on the temperature and relative humidity of the air through which the sound is travelling and is frequency dependent with increasing attenuation towards higher frequencies. The attenuation depends on distance according to:

$A_{atm} = d.\alpha$

Where d = distance from the turbine (m)

α = atmospheric absorption coefficient (dB/m)

1.6.2. Published values have been used for 'α' from ISO 9613 Part 1 [5] corresponding to a temperature of 10 ºC and a relative humidity of 70 % which give relatively low levels of atmospheric attenuation, as given in **Table 11J 5**.

Table 11J 5 – Atmospheric Absorption Coefficient at 10ºC and a Relative Humidity of 70%

Octave Band Centre Frequency (Hz)	63	125	250	500	1k	2k	4k	8k
Atmospheric Absorption Coefficient (dB/m)	0.0001	0.0004	0.0010	0.0019	0.0037	0.0097	0.0328	0.1170

1.6.3. This follows the guidance in the GPG which recommends the use of atmospheric conditions of 10 ºC and 70 % to represent a reasonably low level of air absorption.

1.7 A_{BAR} – BARRIER ATTENUATION

1.7.1. 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 attenuation predicted by the ISO 9613 model have, however, been shown to be significantly greater than that measured in practice under down wind conditions for predictions of wind farm noise. The results of a study of propagation of noise from wind farm sites carried out for ETSU[6] concludes that an attenuation of just 2 dB(A) should be allowed where the direct line of sight 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 sight.

1.7.2. The GPG re-iterates the above points and suggests that topographic screening effects from the terrain should be limited to 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. It also suggests that higher barrier attenuation values of up to 10 dB(A) may be appropriate if significant screening from a landform barrier is present in close proximity to the receiver.

1.7.3. Screening between the proposed turbine and the nearest houses has been taken into account using a propagation model that includes a digital terrain model of the proposed Site. In order to not over-estimate the potential barrier attenuation, the source has been assumed at 10 m above the uppermost tip height. As a consequence of this methodology, no more than 1.6 dB attenuation is assumed for barrier attenuation in the prediction of cumulative wind farm noise levels, at any assessed receptor location.

[5] ISO 9613-1:1993. “Acoustics – Attenuation of sound during propagation outdoors – Part 1: Calculation of the absorption of sound by the atmosphere.”

[6] Department of Trade and Industry (2000). ETSU W/13/00385/REP. “A Critical Appraisal of Wind Farm Noise Propagation”.

1.7.4. In terms of barrier attenuation from terrain, ISO 9613-2:2024 suggests that for wind turbines, the applied barrier attenuation should be limited to no more than 3 dB (rather than 2 dB as the GPG currently suggests). As the current predictions assume no more than 1.6 dB (in a cumulative sense), it is considered that the current predictions remain appropriate.

1.8 A_{MISC} – MISCELLANEOUS OTHER EFFECTS

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

1.9 CONCAVE VALLEY CORRECTIONS

1.9.1. Some studies[7] [8] have shown that for sound propagation across a concave ground profile, for example valleys or where the ground falls away significantly between the turbine and the receptor, higher noise levels may be expected. The GPG suggests that an additional correction of +3 dB(A) should be applied to the overall A-weighted noise levels in this scenario. This correction is implemented in order to take account of the reduced ground effects and, under some rare circumstances, the potential for multiple reflection paths caused by the concave profile.

1.9.2. A condition is recommended in the GPG for indicating where this correction should be applied:

$$h_m \geq 1.5 \times \left(\frac{\text{abs}(h_s - h_r)}{2}\right)$$

Where h_m = mean height above ground along the direct path between the source and the receptor (m)

h_s = the absolute source height above ground level (m)

h_r = the absolute receptor height above ground level (m)

1.9.3. Whilst this condition is useful at highlighting where the ground profile beneath a source - receptor path may potentially be concave, it is not robust and regularly produces false positives (for instance, when a hill at the centre of a large propagation path obstructs the line of sight). As the GPG suggests, care needs to be exercised when evaluating this condition. It should therefore be used in conjunction with a visual assessment of the ground profile when determining whether a correction should be applied.

1.9.4. The ground profiles beneath each source - receptor path have been considered, and the appropriateness of the correction in each instance has been determined. For propagation paths that satisfy the above condition, and where the line of sight is not obstructed, a +3 dB correction has been applied. This resulted in a maximum correction of +1.1 dB when considering noise predictions of the Proposed Development.

1.9.5. In terms of a concave valley correction, ISO 9613-2:2024 now suggests that such a correction should be applied, whereas in previous versions, no guidance was given. The condition equation that defines whether a correction should be applied is similar but different to that in the GPG. It is

[7] Bass, J. H. et al (1998). “Development of a Wind Farm Noise Propagation Prediction Model.” Final Report for Contract JOR3 CT95 0051.

[8] Evans, T. & Cooper, J. (2011). “Comparison of predicted and measured wind farm noise levels and implications for assessments of new wind farms.” Proceedings of Acoustics 2011.

understood that the condition in ISO 9613-2:2024 is less conservative than that in the GPG. That is, the condition will be triggered less often than the equation currently utilised in the GPG.

1.9.6. There does not appear to be any instances where the effect goes in the opposite direction where the condition will be triggered more often. Overall, this will result in providing a lower predicted noise level, than if using the GPG equation. As the current predictions assume no more than 1.1 dB, and any updates due to ISO 9613-2:2024 are only going to make this correction smaller, it is considered that the current predictions remain appropriate.

1.10 WIND DIRECTION EFFECTS

1.10.1. Depending on the direction that the wind is blowing, there can be a significant effect on the received sound pressure level at the receiver. Wind direction effects are accounted for within all presented noise predictions[9]. The modelling of wind direction effects is in the form of an assumed additional attenuation value. The additional attenuation takes account of refraction effects for an upwind receptor position. If a receptor is downwind for a particular wind direction no additional attenuation is assumed.

1.10.2. For any given wind direction, each nearby property can be classified as being either downwind, crosswind, or upwind of each of the turbines. If the house is downwind (+/-80°) of the turbine no correction is applied to the predicted turbine noise level. If it is crosswind (+/-10°) of the turbine a 2 dB reduction is made to the predicted turbine noise level. This assumption is based on source directivity observations when a reduced noise output occurs in cross-wind conditions. If the property is upwind of the turbine, a reduction is made to the predicted turbine noise level due to shadow zone effects, which depend on distance and frequency.

The additional upwind attenuation due to a receptor being located in a shadow zone has been based on the model described in the Wyle Report[10], which is one of the approaches suggested by the GPG. The model is dependent upon the hub height of the wind turbines and the distance to the receptor. The model detailed in the Wyle Report is designed for flat, homogeneous terrain. To take into account the hilly terrain that exists in this instance, the excess shadow zone attenuation is reduced by a factor of 0.5 in the noise predictions (as the Wyle Report suggests). In addition, the assumed excess shadow zone attenuation is further reduced[11] for properties that lie in a partial upwind condition.

[9] With the exception of the indicative contour plot shown in Figure 11.1, that assumes downwind conditions.

[10] Wyle Research Report, 1988. “Measurement and Evaluation of Environmental Noise from Wind Energy Conversion Systems in Alameda and Riverside Counties”. Report WR 88-19, dated October 1988.

[11] It is only when a receptor lies directly upwind of a turbine that the full upwind attenuation applies. If a receptor lies in the intermediate directions between upwind and crosswind, then a smaller attenuation is applied. In this case, the upwind attenuation is reduced by a ratio, dependent on the cosine of the angle between the propagation path and the directly upwind direction. For example, say a receptor lies directly south of the wind farm then for a northerly wind direction of 0°, the receptor is downwind and no correction is applied. When modelling a southerly wind direction of 180°, the receptor lies directly upwind of the wind farm, and has the full shadow zone attenuation applied (e.g. 5 dB lower than the downwind prediction). For a wind direction of say 150°, it is partially upwind, and is 30° off being directly upwind. Therefore for that situation, a ratio of (cos(30)) is applied to what would usually be the full shadow zone attenuation (e.g. 4.3 dB lower than the downwind prediction).

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