

SI 2021 Technical Appendix 14.3

Noise Prediction Methodology and Assumptions

Noise Prediction Methodology

1. The ISO 9613-2 standard is used for predicting sound pressure level for downwind propagation 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:

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

2. These factors are discussed in detail below together with an additional term for taking wind direction into account where required. The predicted octave band levels from each turbine are summed together to give the overall 'A' weighted predicted sound level.

L_w - Source Sound Power Level

3. The sound power level of a noise source is normally expressed in dB re: 1pW. Noise predictions are based on sound power levels detailed for the turbines installed at Clashindarroch wind farm (Senvion MM82) and those assumed for the proposed development (Nordex N133) as taken from the EIA Report. In practice, the noise specification for the N133 turbines is now lower than assumed in the EIA Report especially if serrated trailing edge technology is used.
4. The octave band noise spectra used for the predictions have been taken from the technical specifications of the turbine with the results shown in the main body of the report. For both turbines the tables show noise levels with no curtailment and an additional uncertainty of +2 dB has been included in accordance with good practice.

Nordex N133 – Octave Band Sound Power Levels (dBA)

Standardised 10 m Height Wind Speed	Frequency (Hz)								Total
	63	125	250	500	1000	2000	4000	8000	
3	78.5	85.5	90.0	91.3	91.1	88.6	82.9	71.8	97.0
4	80.0	87.0	91.5	92.8	92.6	90.1	84.4	73.3	98.5
5	84.0	91.1	95.9	98.3	98.9	96.4	88.9	76.6	104.0
6	88.2	95.3	100.1	102.5	103.1	100.6	93.1	80.8	108.2
7	89.5	96.6	101.4	103.8	104.4	101.9	94.4	82.1	109.5
8	91.0	96.8	100.0	102.4	104.3	103.4	98.0	84.2	109.5
9	91.0	96.8	100.0	102.4	104.3	103.4	98.0	84.2	109.5
10	91.0	96.8	100.0	102.4	104.3	103.4	98.0	84.2	109.5
11	91.0	96.8	100.0	102.4	104.3	103.4	98.0	84.2	109.5
12	91.0	96.8	100.0	102.4	104.3	103.4	98.0	84.2	109.5

Senvion MM82 – Octave Band Sound Power Levels (dBA)

Standardised 10 m Height Wind Speed	Frequency (Hz)								Total
	63	125	250	500	1000	2000	4000	8000	
3	70.9	78.8	85.8	86.1	83.0	80.5	75.9	66.4	90.9
4	76.1	84.0	91.0	91.3	88.2	85.7	81.1	71.6	96.1
5	81.7	89.6	96.6	96.9	93.8	91.3	86.7	77.2	101.7
6	85.6	93.5	100.5	100.8	97.7	95.2	90.6	81.1	105.6
7	86.0	93.9	100.9	101.2	98.1	95.6	91.0	81.5	106.0
8	86.0	93.9	100.9	101.2	98.1	95.6	91.0	81.5	106.0
9	86.0	93.9	100.9	101.2	98.1	95.6	91.0	81.5	106.0
10	86.0	93.9	100.9	101.2	98.1	95.6	91.0	81.5	106.0
11	86.0	93.9	100.9	101.2	98.1	95.6	91.0	81.5	106.0
12	86.0	93.9	100.9	101.2	98.1	95.6	91.0	81.5	106.0

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 down wind 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 an attenuation depending on distance according to:

$$A_{geo} = 20 \times \log(d) + 11$$

where d = distance from the turbine

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

A_{atm} - Atmospheric Absorption

- 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:

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

where d = distance from the turbine

α = atmospheric absorption coefficient in dB/m

9. Values of ' α ' from ISO 9613 Part 1¹ corresponding to a temperature of 10°C and a relative humidity of 70%, the values specified in the UK Institute of Acoustics, A Good Practice Guide to the Application of ETSU-R-97 for the Assessment and Rating of Wind Turbines Noise (IoA GPG), which give relatively low levels of atmospheric attenuation and correspondingly worst case noise predictions, as given below.

Frequency dependent atmospheric absorption coefficients

Octave Band Centre Frequency (Hz)	63	125	250	500	1k	2k	4k	8k
Atmospheric Absorption Coefficient (dB/m)	0.000122	0.000411	0.00104	0.00193	0.0037	0.00966	0.0328	0.117

A_{gr} - Ground Effect

10. 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 & any sites with low porosity) and 1 for 'soft' ground (includes ground covered by grass, trees or other vegetation). The IoA GPG states that where wind turbine source noise data includes a suitable allowance for uncertainty, a ground factor of G = 0.5 and a receptor height of 4m should be used.

A_{bar} - Barrier Attenuation

11. 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 down wind conditions. The results of a study of propagation of noise from wind farm sites

1 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

carried out for ETSU² 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.

A_{misc} – Miscellaneous Other Effects

12. 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.

Additional Term - Concave Valley Correction

13. Sound propagation across a concave ground profile, for example valleys or where the ground falls away significantly between the turbine and the receptor, incurs an additional correction of +3 dB(A) to the overall A-weighted noise levels. 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.
14. A condition is recommended in the IOA 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 is the mean height above ground along the direct path between the source and the receptor, h_s is the absolute source height above ground level and h_r is the absolute receptor height above ground level.

15. Whilst this condition is useful at highlighting where the ground profile beneath a source – receptor path may be concave, it is inherently non-robust and can produce false positives. It should therefore be used in conjunction with a visual assessment of the ground profile when determining whether a correction should be applied.
16. A computer programme is used to generate the ground profiles beneath each source – receptor path. From these plots it is possible to determine where a correction is appropriate.

² ETSU W/13/00385/REP, A Critical Appraisal of Wind Farm Noise Propagation, DTI 2000