

Technical Appendix 10.1

ISO 9613-2 Prediction Parameters

The ISO 9613-2 method calculates the sound pressure level at a specified distance by taking the source sound power level for each turbine in octave frequency bands and subtracting a number of attenuation factors. The noise level in each octave band can be represented by the equation:

$$\text{Predicted Level } L_{90} = L_{w(\text{eq})} + D - A_{\text{div}} - A_{\text{atm}} - A_{\text{gr}} - A_{\text{bar}} - A_{\text{misc}} - 2\text{dB}$$

The predicted octave band levels from each of the turbines are then summed together to give the overall 'A' weighted predicted sound level from all the turbines acting together. The correction of 2dB in the formula above is used to convert the L_{eq} levels, as used to describe the turbine sound power, to the background level L_{90} , used in the ETSU assessment. The various factors are described below.

Source Data - $L_{w(\text{eq})}$

The sound power level of a noise source is normally expressed in dB re 1pW (1×10^{-12} Watts). The predictions have been made using the sound power data detailed in the main report.

Directivity Factor - D

For some sources, a directivity factor, D, due to the source must be considered. However, for wind turbines, the sound power level is measured downwind and predicted in downwind conditions and therefore no directivity correction is necessary as any effect is inherent in the measurement. Therefore, D is taken as zero.

Geometrical Divergence (Distance Loss) – A_{div}

Geometrical divergence is the name given to the distance loss which occurs as the source sound power is spread out over an increasing surface area as the distance from the source increases. This is the most significant loss associated with propagation and the loss rate is the same at all frequencies. A wind turbine is considered to be a point source and therefore there is a 6dB loss per doubling of distance. This is expressed mathematically according to:

$$A_{\text{div}} = 20\log(d) + 11\text{dB}, \text{ where } d \text{ is the distance from the turbine, in metres.}$$

Atmospheric Attenuation - A_{atm}

Atmospheric losses occur as the energy in the sound wave is converted to heat. This is a frequency-dependent process, and high frequencies are more readily attenuated than low frequencies. The losses are dependent on humidity and temperature and are represented by the following equation:

$$A_{\text{atm}} = d\alpha, \text{ where } d \text{ is distance from the turbine (in metres), and } \alpha \text{ is atmospheric absorption coefficient (dB/m).}$$

Part 1 of ISO 9613 provides tables with the values of α corresponding to various temperatures and humidity. The calculations take a conservative approach as outlined

in the Institute of Acoustics Good Practice Guide, assuming a temperature of 10°C and a relative humidity of 70% which give low levels of atmospheric attenuation, as shown in the table below.

Atmospheric Absorption Coefficients (dB/m) at 10°C and 70% RH

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

It can be seen in the table that at low frequencies (63-125 Hz) atmospheric loss factors are very small compared with the values at higher frequencies. Over large distances, this has the effect of shifting the dominant sound of wind turbines downwards towards the lower frequencies.

Ground Effect - A_{gr}

This factor describes the effect of sound waves reflected off the ground interfering with the sound waves propagating directly from source to receiver. The prediction of ground effect depends on the source height, receiver height, and propagation distance 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 (which includes paving, water, ice, concrete and any sites with low porosity) and 1 for “soft” ground (which includes ground covered by grass, crops, trees and other vegetation). For propagation close to soft ground, significant attenuation can occur, but this effect is diminished for an elevated source such as a wind turbine.

The predictions have been carried out using a source height corresponding to the proposed tip height and a receiver height of 4m which corresponds to the height of a 1st floor window. Mixed ground attenuation ($G = 0.5$) has been used which in accordance with the Institute of Acoustics Good Practice Guide.

Barrier Attenuation - A_{bar}

When a source is not visible behind an impermeate element, a loss occurs as the sound waves are refracted around the barrier. A barrier could include screening by topographical features as well as other man-made objects such as fences and buildings. For wind farms, the ISO 9613-2 barrier attenuation factor has been shown to over-estimate the attenuation measured in practice under downwind conditions. The prediction method outlined in the Institute of Acoustics Good Practice Guide limits the barrier attenuation to 2dB.

Miscellaneous Losses - A_{misc}

Miscellaneous losses in the ISO 9613-2 calculation can be used to account for losses through propagation through trees and across housing and reflections off buildings. These losses are not considered in our calculations, however. Reflections off buildings are not considered because in theory, the predictions (and baseline measurements as required by ETSU) are made in ‘free-field’ locations away from reflections.