MATRIX ACOUSTIC DESIGN CONSULTANTS

Quarry House Farm
Penistone Road
Huddersfield
HD8 8XY

Repowering of existing wind turbine (replacement)

NOISE ASSESSMENT

Acoustics Report M2628/R01
26th June 2026

To: Harrison Pick Ltd
Station Farm Office
Wansford Road
Nafferton
Driffield
East Yorkshire
YO25 8NJ

By: Paul Smith BSc MIOA

Brookfield Coach House
Weston Lane
Bath BA1 4AG

M: 07765 518035
T: 01225 667 470
E: mail@matrixacoustics.co.uk

1. Introduction

This acoustic report documents a noise assessment for the proposed replacement (repowering) wind turbine at Quarry House Farm, Huddersfield; Figures 1 and 2.

The report is divided into the following sections:

- Section 2: Overview of the Development
- Section 3: Planning Guidance and Methodology
- Section 4: Noise Assessment
- Section 5: Conclusion
- Appendix A: Calculations
- Appendix B: ISO 9613-2 Calculation Parameters

2. Overview of the Development

The proposal relates to the repowering of an existing wind turbine at Quarry House, Huddersfield. As shown in Figure 2, the replacement turbine is to be sited at the same location as the turbine it replaces (OS SE 2189306916)

The proposed replacement turbine is a Vestas V29 - 225kW, with a 30m hub height. Table 1 provides the manufacturers sound power levels of the proposed turbine for wind speeds 5 – 10m/s.

For the assessment ten noise sensitive receptors (Receptors A – J, Figure 1), which in all cases are dwellings, have been considered. These range between 268m – 477m from the wind turbine location (existing and proposed); Table 2.

Receptors A - C are client owned and occupied, whereas Receptors D - J are privately owned. As a conservative approach it has been taken that there will be an unobstructed noise path between the turbine and Receptors A - J.

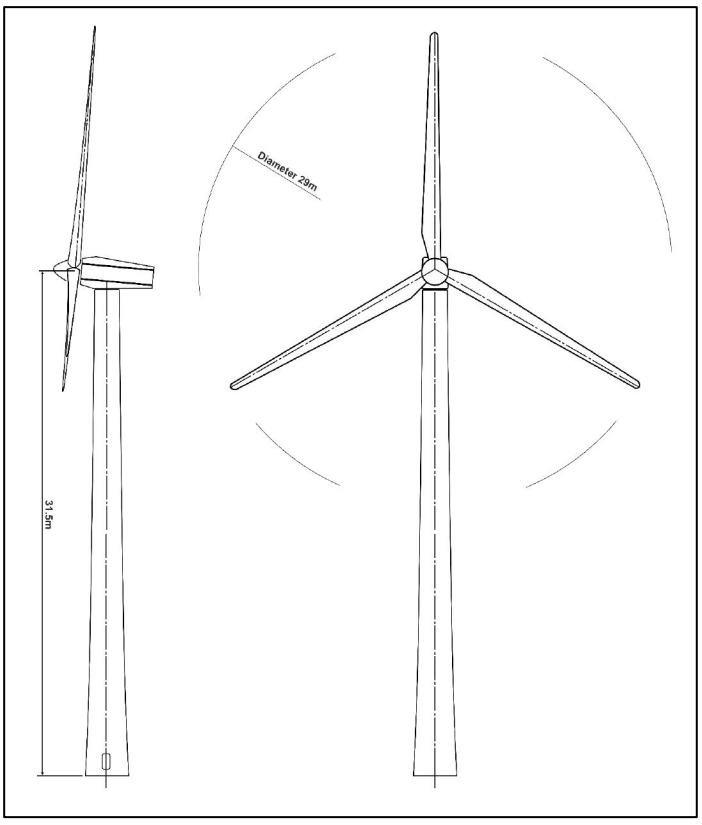


Figure 1. Elevations Vestas V29-225kW turbine



Figure 2. Aerial view (source: bing.com) with the location of the existing and proposed replacement wind turbine and assessed noise sensitive receptors identified

3. Planning Guidance and Methodology

3.1 ETSU-R-97

ETSU-R 97 provides guidance on the assessment of noise emissions from large turbines schemes (i.e., turbines with a rotor diameter of >16m and/or >50kW system).

- ***General Noise Limitations*:** Wind farm noise emissions should not exceed the typical background noise levels by more than 5dB(A) during both the day and night periods, with specific exceptions noted below.
- ***Day-time Noise Standards for Quiet Areas:*** In areas with a low noise environment, the day period L_{A90} level from wind farm should be restricted to between 35 - 40dB(A). When determining the appropriate value within this range, the following factors should be considered:
  - Density of residential dwellings near the wind farm
  - Impact of noise restrictions on energy production (kWh)
  - The extent and duration of noise exposure

  Given the rural location of site, it is expected that the typical day period background noise level will be low at around L_{A90} 35dB and consequently the L_{A90} 35 – 40dB limit range is considered applicable in this case. Taking into account the low density of dwellings in the vicinity of the proposed wind turbine, which are already exposed to turbine noise emissions from the existing unit that will be replaced, the upper L_{A90} 40dB limit is likely to be deemed acceptable.
- ***Night-time Standards:*** A fixed night-time limit of 43dB(A) is recommended. This standard is based on the 35dB(A) sleep disturbance threshold referenced in Planning Policy Guidance Note 24. This calculation includes a 10dB(A) reduction for sound transmission through open windows (free-field to internal) and a 2dB adjustment to account for using $L_{A90,}$ rather than L_{Aeq} measurements.
- ***Special Considerations:*** Where residents are "financially involved" with the wind turbine development, as is the case for Receptors A - C, ETSU-R-97 allows for a higher noise limit; L_{A90} 45 dB, or 5 dB above the background noise, whichever is the greater, for both the day and night-time periods.
- ***Simplified Approach for Certain Installations:*** For single turbines or wind farms with substantial buffer distances between turbines and neighboring properties, a simplified noise condition may be adequate. Limiting noise to an $L_{A90,10min}$ of 35dB(A) at wind speeds up to 10m/s (measured at 10m height) should provide sufficient protection without requiring background noise surveys. When wind speeds exceed 10m/s at the wind farm site, the resulting increase in ambient background noise levels at nearby properties typically provides natural masking effects.

  Taking into account that it is existing wind turbines that are to be replaced and that the distances to the nearest dwellings are not large, this lower fixed limit is not considered applicable in this case.

The ETSU-R-97 limits are set in terms of the L_{A90} parameter, which for wind turbine noise is typically 2 dB less than the L_{Aeq} parameter.

Where the turbine noise spectrum has audible tones, ETSU-R-97 stipulates that a penalty of up to 5 dB be added depending on the audibility of the tone. The manufacturers data sheets advise that the Vestas V29 - 225kW turbine is not tonal.

To undertake ETSU-R-97 compliant calculations, octave frequency band sound power levels for the turbine operating at wind speeds of 10m/s are required.

3.2 ISO 9613-2 Attenuation of sound during propagation outdoors

ETSU-R-97 does not prescribe a calculation method for predicting wind turbine noise. This study has used the prediction method to ISO 9613-2 "Attenuation of sound during propagation outdoors" with certain limitations agreed between various noise consultants working on wind turbine noise assessments as described in paragraph 3.3.

The propagation model, described in Part 2 of the ISO 9613 Standard, allows noise levels to be predicted for short-term downwind conditions, i.e., for wind blowing from the proposed turbine towards the receptor. This provides a typical worst-case illustration, because not all properties will be downwind of the turbine at the same time, and when the wind is blowing in the opposite direction, noise levels will be significantly reduced from that predicted.

Noise from wind turbines is reduced by distance, atmospheric losses, screening effects (if present) and other "miscellaneous" losses. Noise levels can be increased or reduced by the interaction of the sound waves with the ground. The ISO propagation model calculates the predicted sound pressure level at a specified distance by taking the sound power level in octave frequency bands and subtracting a number of attenuation factors according to the various losses and the ground effect as described above. The noise level in each octave band can be represented by the equation:

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

With A-weighting applied, which takes into account our perceived sensitivity to the frequency spectrum, the resultant octave band levels are logarithmically added together to give an overall single figure 'A' weighted sound level. The correction of 2dB is used to convert the L_{Aeq} levels, as used to describe the turbine sound power, to the L_{A90} parameter, used in the ETSU assessment. The attenuation factors in the calculation are described in Appendix B.

3.3 Prediction and Assessment of Wind Turbine Noise – Acoustic Bulletin Article

Following several contentious public inquiries, a number of acoustic consultants agreed various principles for wind turbine noise assessments to ensure greater consistency in the assessments. This agreement is described in an article, which appeared in the March/April 2009 edition of Acoustics Bulletin published by the Institute of Acoustics. The article clarified the following issues:

- *That baseline noise measurements are preferably correlated with the standardised wind speed at 10m height calculated from the hub height wind speed (rather than measured directly), so that the background noise levels and thereby noise limits can be adjusted for wind shear.*
- *ISO 9613-2 is to be used for wind turbine noise predictions, with certain stipulations and limitations.*
- *Research into low frequency noise, infrasound and vibration was summarised, and it was concluded that none of these issues have had adverse effects on wind turbine neighbours.*

The article should be regarded as a refinement of the ETSU-R-97 guidance to ensure consistency and this noise assessment follows the guidelines stated therein.

4. Noise Assessment

4.1 Source Noise Data

Table 1 provides the manufacturers supplied sound power levels for the Vestas V29 – 225kW turbine for wind speeds 5 – 10m/s at a reference 10m height.

The manufacturers test report for the Vestas V29 – 225kW turbine advises that:

- the turbine is not tonal
- there is a ±2dB accuracy in the provided sound power levels

Table 1. Vestas V29 - 225kW Sound Power Levels

Wind Speed, m/s	Octave Band Centre Frequency, Hz							
	63	125	250	500	1k	2k	4k	8k
5	101.1	98.3	95.6	95.0	90.8	86.9	79.1	70.6
6	101.6	98.8	96.1	95.5	91.3	87.4	79.6	71.1
7	102.1	99.3	96.6	96.0	91.8	87.9	80.1	71.6
8	102.6	99.8	97.1	96.5	92.3	88.4	80.6	72.1
9	103.1	100.3	97.6	97.0	92.8	88.9	81.1	72.6
10	103.6	100.8	98.1	97.5	93.3	89.4	81.6	73.1

4.2 Turbine Noise Emissions at Receptors A - J

Using the manufacturers sound power levels (Table 1), the turbine noise emissions at Receptors A - J have been calculated in line with ISO 9613-2's methodology (see Appendix B). Table 2 below provides the resultant single figure noise levels for wind speeds 5 – 10m/s.

4.3 Noise Impact

As can be seen in Table 2, the noise emissions from the proposed replacement wind turbine do not exceed:

- *Receptors A - C (client owned):* ETSU-R 97's relaxed L_{A90} 45dB day and night limit for "financially involved" properties
- Receptors D - J (private ownership): ETSU-R 97's L_{A90} 40dB upper day period noise limit for areas with low noise environments and the fixed L_{A90} 43dB night period limit

We therefore conclude that the noise emissions from the proposed replacement wind turbine (Vestas V29 – 225kW), will be acceptable.

5. Conclusion

Using the manufacturers sound power levels for the proposed replacement wind turbine (Vestas V29 – 225kW) at Quarry House Farm (Table 1), the noise emissions have been calculated (Appendix A and Table 2) at the nearest dwellings (Receptors A - J, Figure 2) for wind speeds 5 – 10m/s. Receptors A - C are in the client's ownership, whereas Receptor D - J are privately owned.

The calculations have been undertaken in accordance with the methodology given in ISO 9613-2 and ETSU-R 97.

The noise emissions from the proposed replacement wind turbine do not exceed:

- *Receptors A - C (client owned):* ETSU-R 97's relaxed L_{A90} 45dB day and night limit for "financially involved" properties

- Receptors D – J (private ownership): ETSU-R 97's L_{A90} 40dB upper day period noise limit for areas with low noise environments and the fixed L_{A90} 43dB night period limit

We therefore conclude that the noise emissions from the proposed replacement wind turbine (Vestas V29 – 225kW) will be acceptable.

Table 2. Calculated replacement turbine noise emissions, L_{A90} dB, at Receptors A - J

Receptor; Figure 2		OS coordinates	Distance, m	Wind speed at 10m above ground m/s					
				5	6	7	8	9	10
A	Client owned	SE 2163606841	268	35	35	36	36	37	37
B		SE 2156006857	338	33	33	34	34	35	35
C		SE 2151307077	413	31	31	32	32	33	33
D	Private ownership	SE 2170407113	273	35	35	36	36	37	37
E		SE 2177107186	296	34	34	35	35	36	36
F		SE 2209507188	339	33	33	34	34	35	35
G		SE 2233806931	445	30	30	31	31	32	32
H		SE 2235707027	477	29	30	30	31	31	32
I		SE 2233606753	472	29	30	30	31	31	32
J		SE 2179206648	286	34	35	35	36	36	37

Table A1. Calculation of wind turbine noise emissions at Receptor A											
		Wind speed	Octave Band Centre Frequency, Hz 63	125	250	500	1k	2k	4k	8k	dB(A)
Replacement Turbine: Vestas V29-225kW											
Source Data	Vestas V29-225kW sound power level	5 m/s	101.1	98.3	95.6	95.0	90.8	86.9	79.1	70.6	
		6 m/s	101.6	98.8	96.1	95.5	91.3	87.4	79.6	71.1	
		7 m/s	102.1	99.3	96.6	96.0	91.8	87.9	80.1	71.6	
		8 m/s	102.6	99.8	97.1	96.5	92.3	88.4	80.6	72.1	
		9 m/s	103.1	100.3	97.6	97.0	92.8	88.9	81.1	72.6	
		10 m/s	103.6	100.8	98.1	97.5	93.3	89.4	81.6	73.1	
Corrections	D: Directivity, dB		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	A_{geo}: Distance correction, 268 m		59.6	59.6	59.6	59.6	59.6	59.6	59.6	59.6	
	A_{atm}: Atmosphere correction, dB		0.0	0.1	0.3	0.5	1.0	2.6	8.8	31.4	
	A_{gr}: Ground absorption, dB ($A_{gr} = A_s + A_r + A_m$)										
	Source region, A_s		-1.5	-0.8	-0.8	-0.8	-0.8	0.8	0.8	0.8	
	Receiver region, A_r		-1.5	0.9	0.3	-0.7	-0.7	0.8	0.8	0.8	
	Middle region, A_m		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	Ground absorption, A_{gr}		-3.0	0.2	-0.5	-1.5	-1.5	1.5	1.5	1.5	
	A_{bar}: Barrier attenuation, dB		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	A_{misc}: Miscellaneous Losses, dB		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	L_{eq} to L_{90} correction, dB		-2.0	-2.0	-2.0	-2.0	-2.0	-2.0	-2.0	-2.0	
Lp at Receptor A, dB		5 m/s	42.5	36.5	34.3	34.4	29.7	21.2	7.2	-23.8	35
		6 m/s	43.0	37.0	34.8	34.9	30.2	21.7	7.7	-23.3	35
		7 m/s	43.5	37.5	35.3	35.4	30.7	22.2	8.2	-22.8	36
		8 m/s	44.0	38.0	35.8	35.9	31.2	22.7	8.7	-22.3	36
		9 m/s	44.5	38.5	36.3	36.4	31.7	23.2	9.2	-21.8	37
		10 m/s	45.0	39.0	36.8	36.9	32.2	23.7	9.7	-21.3	37

Table A2. Calculation of wind turbine noise emissions at Receptor B											
		Wind speed	Octave Band Centre Frequency, Hz 63	125	250	500	1k	2k	4k	8k	dB(A)
Replacement Turbine: Vestas V29-225kW											
Source Data	Vestas V29-225kW sound power level	5 m/s	101.1	98.3	95.6	95.0	90.8	86.9	79.1	70.6	
		6 m/s	101.6	98.8	96.1	95.5	91.3	87.4	79.6	71.1	
		7 m/s	102.1	99.3	96.6	96.0	91.8	87.9	80.1	71.6	
		8 m/s	102.6	99.8	97.1	96.5	92.3	88.4	80.6	72.1	
		9 m/s	103.1	100.3	97.6	97.0	92.8	88.9	81.1	72.6	
		10 m/s	103.6	100.8	98.1	97.5	93.3	89.4	81.6	73.1	
Corrections	D: Directivity, dB		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	A_{geo}: Distance correction, 338 m		61.6	61.6	61.6	61.6	61.6	61.6	61.6	61.6	
	A_{atm}: Atmosphere correction, dB		0.0	0.1	0.3	0.6	1.3	3.3	11.1	39.5	
	A_{gr}: Ground absorption, dB ($A_{gr} = A_s + A_r + A_m$)										
	Source region, A_s		-1.5	-0.8	-0.8	-0.8	-0.8	0.8	0.8	0.8	
	Receiver region, A_r		-1.5	1.1	0.3	-0.7	-0.7	0.8	0.8	0.8	
	Middle region, A_m		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	Ground absorption, A_{gr}		-3.0	0.3	-0.5	-1.5	-1.5	1.5	1.5	1.5	
	A_{bar}: Barrier attenuation, dB		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	A_{misc}: Miscellaneous Losses, dB		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	L_{eq} to L_{90} correction, dB		-2.0	-2.0	-2.0	-2.0	-2.0	-2.0	-2.0	-2.0	
Lp at Receptor B, dB		5 m/s	40.5	34.3	32.2	32.3	27.5	18.5	2.9	-34.0	33
		6 m/s	41.0	34.8	32.7	32.8	28.0	19.0	3.4	-33.5	33
		7 m/s	41.5	35.3	33.2	33.3	28.5	19.5	3.9	-33.0	34
		8 m/s	42.0	35.8	33.7	33.8	29.0	20.0	4.4	-32.5	34
		9 m/s	42.5	36.3	34.2	34.3	29.5	20.5	4.9	-32.0	35
		10 m/s	43.0	36.8	34.7	34.8	30.0	21.0	5.4	-31.5	35

Table A3. Calculation of wind turbine noise emissions at Receptor C										
		Wind speed	Octave Band Centre Frequency, Hz 63	125	250	500	1k	2k	4k	8k	dB(A)
Replacement Turbine: Vestas V29-225kW											
Source Data	Vestas V29-225kW sound power level	5 m/s	101.1	98.3	95.6	95.0	90.8	86.9	79.1	70.6	
		6 m/s	101.6	98.8	96.1	95.5	91.3	87.4	79.6	71.1	
		7 m/s	102.1	99.3	96.6	96.0	91.8	87.9	80.1	71.6	
		8 m/s	102.6	99.8	97.1	96.5	92.3	88.4	80.6	72.1	
		9 m/s	103.1	100.3	97.6	97.0	92.8	88.9	81.1	72.6	
		10 m/s	103.6	100.8	98.1	97.5	93.3	89.4	81.6	73.1	
Corrections	D: Directivity, dB		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	A_{geo}: Distance correction, (413 m		63.3	63.3	63.3	63.3	63.3	63.3	63.3	63.3	
	A_{atm}: Atmosphere correction, dB		0.0	0.2	0.4	0.8	1.5	4.0	13.5	48.3	
	A_{gr}: Ground absorption, dB ($A_{gr} = A_s + A_r + A_m$)										
	Source region, A_s		-1.5	-0.8	-0.8	-0.8	-0.8	0.8	0.8	0.8	
	Receiver region, A_r		-1.5	1.3	0.3	-0.7	-0.7	0.8	0.8	0.8	
	Middle region, A_m		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	Ground absorption, A_{gr}		-3.0	0.5	-0.5	-1.5	-1.5	1.5	1.5	1.5	
	A_{bar}: Barrier attenuation, dB		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	A_{misc}: Miscellaneous Losses, dB		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	L_{eq} to L_{90} correction, dB		-2.0	-2.0	-2.0	-2.0	-2.0	-2.0	-2.0	-2.0	
Lp at Receptor C, dB		5 m/s	38.7	32.3	30.3	30.4	25.5	16.1	-1.3	-44.5	31
		6 m/s	39.2	32.8	30.8	30.9	26.0	16.6	-0.8	-44.0	31
		7 m/s	39.7	33.3	31.3	31.4	26.5	17.1	-0.3	-43.5	32
		8 m/s	40.2	33.8	31.8	31.9	27.0	17.6	0.2	-43.0	32
		9 m/s	40.7	34.3	32.3	32.4	27.5	18.1	0.7	-42.5	33
		10 m/s	41.2	34.8	32.8	32.9	28.0	18.6	1.2	-42.0	33

Table A4. Calculation of wind turbine noise emissions at Receptor D										
		Wind speed	Octave Band Centre Frequency, Hz 63	125	250	500	1k	2k	4k	8k	dB(A)
Replacement Turbine: Vestas V29-225kW											
Source Data	Vestas V29-225kW sound power level	5 m/s	101.1	98.3	95.6	95.0	90.8	86.9	79.1	70.6	
		6 m/s	101.6	98.8	96.1	95.5	91.3	87.4	79.6	71.1	
		7 m/s	102.1	99.3	96.6	96.0	91.8	87.9	80.1	71.6	
		8 m/s	102.6	99.8	97.1	96.5	92.3	88.4	80.6	72.1	
		9 m/s	103.1	100.3	97.6	97.0	92.8	88.9	81.1	72.6	
		10 m/s	103.6	100.8	98.1	97.5	93.3	89.4	81.6	73.1	
Corrections	D: Directivity, dB		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	A_{geo}: Distance correction, (273 m		59.7	59.7	59.7	59.7	59.7	59.7	59.7	59.7	
	A_{atm}: Atmosphere correction, dB		0.0	0.1	0.3	0.5	1.0	2.6	9.0	31.9	
	A_{gr}: Ground absorption, dB ($A_{gr} = A_s + A_r + A_m$)										
	Source region, A_s		-1.5	-0.8	-0.8	-0.8	-0.8	0.8	0.8	0.8	
	Receiver region, A_r		-1.5	0.9	0.3	-0.7	-0.7	0.8	0.8	0.8	
	Middle region, A_m		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	Ground absorption, A_{gr}		-3.0	0.2	-0.5	-1.5	-1.5	1.5	1.5	1.5	
	A_{bar}: Barrier attenuation, dB		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	A_{misc}: Miscellaneous Losses, dB		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	L_{eq} to L_{90} correction, dB		-2.0	-2.0	-2.0	-2.0	-2.0	-2.0	-2.0	-2.0	
Lp at Receptor D, dB		5 m/s	42.3	36.3	34.1	34.3	29.6	21.0	6.9	-24.6	35
		6 m/s	42.8	36.8	34.6	34.8	30.1	21.5	7.4	-24.1	35
		7 m/s	43.3	37.3	35.1	35.3	30.6	22.0	7.9	-23.6	36
		8 m/s	43.8	37.8	35.6	35.8	31.1	22.5	8.4	-23.1	36
		9 m/s	44.3	38.3	36.1	36.3	31.6	23.0	8.9	-22.6	37
		10 m/s	44.8	38.8	36.6	36.8	32.1	23.5	9.4	-22.1	37

Table A5. Calculation of wind turbine noise emissions at Receptor E											
		Wind speed	Octave Band Centre Frequency, Hz 63	125	250	500	1k	2k	4k	8k	dB(A)
Replacement Turbine: Vestas V29-225kW											
Source Data	Vestas V29-225kW sound power level	5 m/s	101.1	98.3	95.6	95.0	90.8	86.9	79.1	70.6	
		6 m/s	101.6	98.8	96.1	95.5	91.3	87.4	79.6	71.1	
		7 m/s	102.1	99.3	96.6	96.0	91.8	87.9	80.1	71.6	
		8 m/s	102.6	99.8	97.1	96.5	92.3	88.4	80.6	72.1	
		9 m/s	103.1	100.3	97.6	97.0	92.8	88.9	81.1	72.6	
		10 m/s	103.6	100.8	98.1	97.5	93.3	89.4	81.6	73.1	
Corrections	D: Directivity, dB		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	A_{geo}: Distance correction, r 296 m		60.4	60.4	60.4	60.4	60.4	60.4	60.4	60.4	
	A_{atm}: Atmosphere correction, dB		0.0	0.1	0.3	0.6	1.1	2.9	9.7	34.6	
	A_{gr}: Ground absorption, dB ($A_{gr} = A_s + A_r + A_m$)										
	Source region, A_s		-1.5	-0.8	-0.8	-0.8	-0.8	0.8	0.8	0.8	
	Receiver region, A_r		-1.5	1.0	0.3	-0.7	-0.7	0.8	0.8	0.8	
	Middle region, A_m		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	Ground absorption, A_{gr}		-3.0	0.2	-0.5	-1.5	-1.5	1.5	1.5	1.5	
	A_{bar}: Barrier attenuation, dB		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	A_{misc}: Miscellaneous Losses, dB		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	L_{eq} to L_{90} correction, dB		-2.0	-2.0	-2.0	-2.0	-2.0	-2.0	-2.0	-2.0	
Lp at Receptor E, dB		5 m/s	41.6	35.5	33.4	33.5	28.8	20.1	5.5	-28.0	34
		6 m/s	42.1	36.0	33.9	34.0	29.3	20.6	6.0	-27.5	34
		7 m/s	42.6	36.5	34.4	34.5	29.8	21.1	6.5	-27.0	35
		8 m/s	43.1	37.0	34.9	35.0	30.3	21.6	7.0	-26.5	35
		9 m/s	43.6	37.5	35.4	35.5	30.8	22.1	7.5	-26.0	36
		10 m/s	44.1	38.0	35.9	36.0	31.3	22.6	8.0	-25.5	36

Table A6. Calculation of wind turbine noise emissions at Receptor F											
		Wind speed	Octave Band Centre Frequency, Hz 63	125	250	500	1k	2k	4k	8k	dB(A)
Replacement Turbine: Vestas V29-225kW											
Source Data	Vestas V29-225kW sound power level	5 m/s	101.1	98.3	95.6	95.0	90.8	86.9	79.1	70.6	
		6 m/s	101.6	98.8	96.1	95.5	91.3	87.4	79.6	71.1	
		7 m/s	102.1	99.3	96.6	96.0	91.8	87.9	80.1	71.6	
		8 m/s	102.6	99.8	97.1	96.5	92.3	88.4	80.6	72.1	
		9 m/s	103.1	100.3	97.6	97.0	92.8	88.9	81.1	72.6	
		10 m/s	103.6	100.8	98.1	97.5	93.3	89.4	81.6	73.1	
Corrections	D: Directivity, dB		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	A_{geo}: Distance correction, r 339 m		61.6	61.6	61.6	61.6	61.6	61.6	61.6	61.6	
	A_{atm}: Atmosphere correction, dB		0.0	0.1	0.3	0.6	1.3	3.3	11.1	39.7	
	A_{gr}: Ground absorption, dB ($A_{gr} = A_s + A_r + A_m$)										
	Source region, A_s		-1.5	-0.8	-0.8	-0.8	-0.8	0.8	0.8	0.8	
	Receiver region, A_r		-1.5	1.1	0.3	-0.7	-0.7	0.8	0.8	0.8	
	Middle region, A_m		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	Ground absorption, A_{gr}		-3.0	0.3	-0.5	-1.5	-1.5	1.5	1.5	1.5	
	A_{bar}: Barrier attenuation, dB		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	A_{misc}: Miscellaneous Losses, dB		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	L_{eq} to L_{90} correction, dB		-2.0	-2.0	-2.0	-2.0	-2.0	-2.0	-2.0	-2.0	
Lp at Receptor F, dB		5 m/s	40.5	34.2	32.1	32.2	27.4	18.5	2.9	-34.2	33
		6 m/s	41.0	34.7	32.6	32.7	27.9	19.0	3.4	-33.7	33
		7 m/s	41.5	35.2	33.1	33.2	28.4	19.5	3.9	-33.2	34
		8 m/s	42.0	35.7	33.6	33.7	28.9	20.0	4.4	-32.7	34
		9 m/s	42.5	36.2	34.1	34.2	29.4	20.5	4.9	-32.2	35
		10 m/s	43.0	36.7	34.6	34.7	29.9	21.0	5.4	-31.7	35

Table A7. Calculation of wind turbine noise emissions at Receptor G											
		Wind speed	Octave Band Centre Frequency, Hz 63	125	250	500	1k	2k	4k	8k	dB(A)
Replacement Turbine: Vestas V29-225kW											
Source Data	Vestas V29-225kW sound power level	5 m/s	101.1	98.3	95.6	95.0	90.8	86.9	79.1	70.6	
		6 m/s	101.6	98.8	96.1	95.5	91.3	87.4	79.6	71.1	
		7 m/s	102.1	99.3	96.6	96.0	91.8	87.9	80.1	71.6	
		8 m/s	102.6	99.8	97.1	96.5	92.3	88.4	80.6	72.1	
		9 m/s	103.1	100.3	97.6	97.0	92.8	88.9	81.1	72.6	
		10 m/s	103.6	100.8	98.1	97.5	93.3	89.4	81.6	73.1	
Corrections	D: Directivity, dB		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	A_{geo}: Distance correction, (445 m		64.0	64.0	64.0	64.0	64.0	64.0	64.0	64.0	
	A_{atm}: Atmosphere correction, dB		0.0	0.2	0.4	0.8	1.6	4.3	14.6	52.1	
	A_{gr}: Ground absorption, dB ($A_{gr} = A_s + A_r + A_m$)										
	Source region, A_s		-1.5	-0.8	-0.8	-0.8	-0.8	0.8	0.8	0.8	
	Receiver region, A_r		-1.5	1.3	0.3	-0.7	-0.7	0.8	0.8	0.8	
	Middle region, A_m		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	Ground absorption, A_{gr}		-3.0	0.6	-0.5	-1.5	-1.5	1.5	1.5	1.5	
	A_{bar}: Barrier attenuation, dB		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	A_{misc}: Miscellaneous Losses, dB		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	L_{eq} to L_{90} correction, dB		-2.0	-2.0	-2.0	-2.0	-2.0	-2.0	-2.0	-2.0	
Lp at Receptor G dB		5 m/s	38.1	31.6	29.7	29.7	24.7	15.1	-3.0	-48.9	30
		6 m/s	38.6	32.1	30.2	30.2	25.2	15.6	-2.5	-48.4	30
		7 m/s	39.1	32.6	30.7	30.7	25.7	16.1	-2.0	-47.9	31
		8 m/s	39.6	33.1	31.2	31.2	26.2	16.6	-1.5	-47.4	31
		9 m/s	40.1	33.6	31.7	31.7	26.7	17.1	-1.0	-46.9	32
		10 m/s	40.6	34.1	32.2	32.2	27.2	17.6	-0.5	-46.4	32

Table A8. Calculation of wind turbine noise emissions at Receptor H											
		Wind speed	Octave Band Centre Frequency, Hz 63	125	250	500	1k	2k	4k	8k	dB(A)
Replacement Turbine: Vestas V29-225kW											
Source Data	Vestas V29-225kW sound power level	5 m/s	101.1	98.3	95.6	95.0	90.8	86.9	79.1	70.6	
		6 m/s	101.6	98.8	96.1	95.5	91.3	87.4	79.6	71.1	
		7 m/s	102.1	99.3	96.6	96.0	91.8	87.9	80.1	71.6	
		8 m/s	102.6	99.8	97.1	96.5	92.3	88.4	80.6	72.1	
		9 m/s	103.1	100.3	97.6	97.0	92.8	88.9	81.1	72.6	
		10 m/s	103.6	100.8	98.1	97.5	93.3	89.4	81.6	73.1	
Corrections	D: Directivity, dB		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	A_{geo}: Distance correction, (477 m		64.6	64.6	64.6	64.6	64.6	64.6	64.6	64.6	
	A_{atm}: Atmosphere correction, dB		0.0	0.2	0.5	0.9	1.8	4.6	15.6	55.8	
	A_{gr}: Ground absorption, dB ($A_{gr} = A_s + A_r + A_m$)										
	Source region, A_s		-1.5	-0.8	-0.8	-0.8	-0.8	0.8	0.8	0.8	
	Receiver region, A_r		-1.5	1.4	0.3	-0.7	-0.7	0.8	0.8	0.8	
	Middle region, A_m		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	Ground absorption, A_{gr}		-3.0	0.7	-0.5	-1.5	-1.5	1.5	1.5	1.5	
	A_{bar}: Barrier attenuation, dB		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	A_{misc}: Miscellaneous Losses, dB		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	L_{eq} to L_{90} correction, dB		-2.0	-2.0	-2.0	-2.0	-2.0	-2.0	-2.0	-2.0	
Lp at Receptor H dB		5 m/s	37.5	30.9	29.0	29.0	24.0	14.2	-4.6	-53.3	29
		6 m/s	38.0	31.4	29.5	29.5	24.5	14.7	-4.1	-52.8	30
		7 m/s	38.5	31.9	30.0	30.0	25.0	15.2	-3.6	-52.3	30
		8 m/s	39.0	32.4	30.5	30.5	25.5	15.7	-3.1	-51.8	31
		9 m/s	39.5	32.9	31.0	31.0	26.0	16.2	-2.6	-51.3	31
		10 m/s	40.0	33.4	31.5	31.5	26.5	16.7	-2.1	-50.8	32

Table A9. Calculation of wind turbine noise emissions at Receptor I											
		Wind speed	Octave Band Centre Frequency, Hz 63	125	250	500	1k	2k	4k	8k	dB(A)
Replacement Turbine: Vestas V29-225kW											
Source Data	Vestas V29-225kW sound power level	5 m/s	101.1	98.3	95.6	95.0	90.8	86.9	79.1	70.6	
		6 m/s	101.6	98.8	96.1	95.5	91.3	87.4	79.6	71.1	
		7 m/s	102.1	99.3	96.6	96.0	91.8	87.9	80.1	71.6	
		8 m/s	102.6	99.8	97.1	96.5	92.3	88.4	80.6	72.1	
		9 m/s	103.1	100.3	97.6	97.0	92.8	88.9	81.1	72.6	
		10 m/s	103.6	100.8	98.1	97.5	93.3	89.4	81.6	73.1	
Corrections	D: Directivity, dB		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	A_{geo}: Distance correction, (472 m		64.5	64.5	64.5	64.5	64.5	64.5	64.5	64.5	
	A_{atm}: Atmosphere correction, dB		0.0	0.2	0.5	0.9	1.7	4.6	15.5	55.2	
	A_{gr}: Ground absorption, dB ($A_{gr} = A_s + A_r + A_m$)										
	Source region, A_s		-1.5	-0.8	-0.8	-0.8	-0.8	0.8	0.8	0.8	
	Receiver region, A_r		-1.5	1.4	0.3	-0.7	-0.7	0.8	0.8	0.8	
	Middle region, A_m		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	Ground absorption, A_{gr}		-3.0	0.7	-0.5	-1.5	-1.5	1.5	1.5	1.5	
	A_{bar}: Barrier attenuation, dB		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	A_{misc}: Miscellaneous Losses, dB		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	L_{eq} to L_{90} correction, dB		-2.0	-2.0	-2.0	-2.0	-2.0	-2.0	-2.0	-2.0	
Lp at Receptor I , dB		5 m/s	37.6	31.0	29.1	29.1	24.1	14.3	-4.4	-52.6	29
		6 m/s	38.1	31.5	29.6	29.6	24.6	14.8	-3.9	-52.1	30
		7 m/s	38.6	32.0	30.1	30.1	25.1	15.3	-3.4	-51.6	30
		8 m/s	39.1	32.5	30.6	30.6	25.6	15.8	-2.9	-51.1	31
		9 m/s	39.6	33.0	31.1	31.1	26.1	16.3	-2.4	-50.6	31
		10 m/s	40.1	33.5	31.6	31.6	26.6	16.8	-1.9	-50.1	32

Table A10. Calculation of wind turbine noise emissions at Receptor J											
		Wind speed	Octave Band Centre Frequency, Hz 63	125	250	500	1k	2k	4k	8k	dB(A)
Replacement Turbine: Vestas V29-225kW											
Source Data	Vestas V29-225kW sound power level	5 m/s	101.1	98.3	95.6	95.0	90.8	86.9	79.1	70.6	
		6 m/s	101.6	98.8	96.1	95.5	91.3	87.4	79.6	71.1	
		7 m/s	102.1	99.3	96.6	96.0	91.8	87.9	80.1	71.6	
		8 m/s	102.6	99.8	97.1	96.5	92.3	88.4	80.6	72.1	
		9 m/s	103.1	100.3	97.6	97.0	92.8	88.9	81.1	72.6	
		10 m/s	103.6	100.8	98.1	97.5	93.3	89.4	81.6	73.1	
Corrections	D: Directivity, dB		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	A_{geo}: Distance correction, (286 m		60.1	60.1	60.1	60.1	60.1	60.1	60.1	60.1	
	A_{atm}: Atmosphere correction, dB		0.0	0.1	0.3	0.5	1.1	2.8	9.4	33.5	
	A_{gr}: Ground absorption, dB ($A_{gr} = A_s + A_r + A_m$)										
	Source region, A_s		-1.5	-0.8	-0.8	-0.8	-0.8	0.8	0.8	0.8	
	Receiver region, A_r		-1.5	0.9	0.3	-0.7	-0.7	0.8	0.8	0.8	
	Middle region, A_m		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	Ground absorption, A_{gr}		-3.0	0.2	-0.5	-1.5	-1.5	1.5	1.5	1.5	
	A_{bar}: Barrier attenuation, dB		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	A_{misc}: Miscellaneous Losses, dB		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	L_{eq} to L_{90} correction, dB		-2.0	-2.0	-2.0	-2.0	-2.0	-2.0	-2.0	-2.0	
Lp at Receptor J, dB		5 m/s	41.9	35.9	33.7	33.8	29.1	20.5	6.1	-26.5	34
		6 m/s	42.4	36.4	34.2	34.3	29.6	21.0	6.6	-26.0	35
		7 m/s	42.9	36.9	34.7	34.8	30.1	21.5	7.1	-25.5	35
		8 m/s	43.4	37.4	35.2	35.3	30.6	22.0	7.6	-25.0	36
		9 m/s	43.9	37.9	35.7	35.8	31.1	22.5	8.1	-24.5	36
		10 m/s	44.4	38.4	36.2	36.3	31.6	23.0	8.6	-24.0	37

B1 ISO 9613-2: Calculation 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:

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

With A-weighting applied, which takes into account our perceived sensitivity to the frequency spectrum, the resultant octave band levels are logarithmically added together to give an overall single figure 'A' weighted sound level. 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 now described in turn.

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

The sound power level of a noise source is normally expressed in dB re 1 pW (1 x 10-12 Watts). The predictions have been made using the sound power data for the turbine 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_{geo}

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_{geo} = 20log(d) + 11dB, where d is the distance from the turbine, in metres.

Atmosphere 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_{atm} = dα, where d is distance from the turbine (in metres), and α 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 agreed between various wind farm noise consultants, assuming a temperature of 10°C and a relative humidity of 70%, which gives low levels of atmospheric attenuation, as shown in the Table B1 below.

Table B1. Atmospheric Absorption Coefficients at 10 C and 70% relative humidity

	Octave Band Centre Frequency, Hz							
	63	125	250	500	1k	2k	4k	8k
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 Table B1 that at low frequencies (63 -125 Hz) the 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 Absorption - 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 hub 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 prediction method agreed between various consultants described in Acoustic Bulletin March / April 2009.

The ground absorption has been calculated using the formulae given in Table 3 of ISO 9613-2, with the total ground absorption being the sum of the attenuation achieved over three component source regions; source, receiver and middle.

In accordance with ISO 9613-2, the ground absorption is taken to be zero if a barrier attenuation correction is applied.

Barrier Attenuation - A_{bar}

When a source is not visible behind an imperforate 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 turbines, the ISO 9613-2 barrier attenuation factor has been shown to over-estimate the attenuation measured in practice under downwind conditions. The prediction method agreed between various wind farm noise consultants 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.