Noise Assessment

Harrington Parks Farm
Land West of Harrington Parks Farm, Cumbria

December 2011

NOISE ASSESSMENT

CONTENTS

1. INTRODUCTION

1.1. This report describes a noise assessment of a proposed single wind turbine at Harrington Parks Farm, Harrington, Cumbria, including a baseline noise survey and predictions of turbine noise levels.

1.2. The noise assessment has been carried out according to the Energy Technology Support Unit (ETSU) report ETSU-R-97[1] which is the assessment method stipulated in Planning Policy Statement 22 (PPS 22)[2]. The ETSU guidance advises on noise limits for wind farms which are thought to *"offer a reasonable degree of protection to wind farm neighbours, without placing unreasonable restrictions on wind farm development"*.

1.3. Noise predictions for wind turbine noise are presented here based on manufacturer's data for an Enercon E-33 330 kW turbine with a hub height of 44m. The proposed turbine is relatively close to the existing Lowca Wind Farm which features seven Vestas V47 wind turbines. A cumulative assessment of noise from the existing wind farm is also provided here.

1.4. In addition to the operational noise assessed in this report, there will be a short-term noise impact from the construction of the wind turbine. This is not considered here as any construction noise generally occurs during the daytime and is short-term in nature.

1.5. Noise contour plots are presented in Figures 1 and 2. These also show the locations of nearby residential properties. A series of appendices to this report provide supplementary information including a glossary of noise terms, Appendix A. This report has been prepared by Ion Acoustics Ltd for Savills.

2. NOISE FROM WIND TURBINES

2.1. Wind turbines are not noisy in absolute terms. It is possible to stand at the base of a turbine tower and hold a normal conversation. However, wind turbines are often situated in rural environments where there are few other sources of noise.

2.2. ETSU-R-97 requires wind farms to meet noise levels of 35 - 40 dB L_{A90} at residential properties, or 5dB(A) above background noise levels, whichever is the greater.

2.3. This is put into context in Table 1 below and by reference to the National Noise Incidence Survey carried out in 2000 / 2001 which indicated that 54% of the population were exposed to daytime noise levels at, or above, 55 dB L_{Aeq} and 67% of the population were exposed to night-time noise levels exceeding 45 dB L_{Aeq}. For these people, a wind farm would rarely be audible.

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[1] ETSU-R-97 The Assessment and Rating of Noise from Wind Farms. ETSU for the Department of Trade and Industry (1996). Available online from: http://webarchive.nationalarchives.gov.uk/+/http://www.berr.gov.uk/files/file20433.pdf

[2] Planning Policy Statement (PPS) 22: Renewable Energy – ODPM – 2004
Available online from: http://www.communities.gov.uk/documents/planningandbuilding/pdf/147444.pdf

Table 1 Noise from wind farms compared with other sources (from Planning for Renewable Energy – A Companion Guide)

Source/Activity	Indicative noise level dB (A)
Threshold of pain	120 - 140
Jet aircraft at 250 m	105
Pneumatic drill at 7m	95
Truck at 30 mph at 100 m	65
Busy general office	50 - 60
Car at 40 mph at 100 m	55
Wind farm at 350 m	35 – 45
Quiet Bedroom	20
Rural night-time background	20 – 40

2.4. Noise from wind turbines comprises aerodynamic noise from the turbine blades turning in the wind, and mechanical noise from the generator and gearbox (if present). Over recent years, turbine manufacturers have succeeded in substantially reducing the mechanical noise sources so that for most modern turbines aerodynamic noise is dominant. Aerodynamic noise is characterised as a broadband sound not unlike wind blowing through trees, but modulated, so it appears as a swishing sound at regular intervals. As the distance from the turbines increases, the swishing becomes less prominent.

2.5. The proposed Enercon E33 wind turbine will 'cut-in' and start producing power at a hub height wind speed of approximately 3 m/s. The noise and power output then gradually increases with increasing wind speed until the rated power is reached at a wind speed of about 9 m/s. Above this, the noise levels generally flatten off and there is little or no increase in noise with wind speed as the turbine blades are pitched to shed energy and maintain constant electrical power. To prevent damage the turbine will shut down with a mechanical brake at hub height wind speeds between 28 m/s to 34 m/s.

3. PLANNING GUIDANCE AND METHODOLOGY

PPS 22 Renewable Energy

3.1. Government planning guidance for wind farms is contained within Planning Policy Statement 22 "Renewable Energy" and it's associated Companion Guide.

3.2. PPS 22 States: *"Renewable technologies may generate small increases in noise levels (whether from machinery such as aerodynamic noise from wind turbines, or from associated sources – for example, traffic). Local planning authorities should ensure that renewable energy developments have been located and designed in such a way to minimise increases in ambient noise levels. Plans may include criteria that set out the minimum separation distances between different types of renewable energy projects and existing developments. The 1997 report by ETSU for the DTI should be used to assess and rate noise from wind energy development".*

3.3. The companion guide also contains general advice on wind turbine noise including the following: *"Well-specified and well-designed wind farms should be located so that increases in ambient noise levels around noise-sensitive developments are kept to* *acceptable levels with relation to existing background noise. This will normally be achieved through good design of the turbines and through allowing sufficient distance between the turbines and any existing noise-sensitive development so that noise from the turbines will not normally be significant. Noise levels from turbines are generally low and, under most operating conditions, it is likely that turbine noise would be completely masked by wind-generated background noise…*

3.4. *Since the early 1990s there has been a significant reduction in the mechanical noise generated by wind turbines and it is now usually less than, or of a similar level to, the aerodynamic noise. Aerodynamic noise from wind turbines is generally unobtrusive – it is broad-band in nature and in this respect is similar to, for example, the noise of wind in trees…*

3.5. *Wind-generated background noise increases with wind speed, and at a faster rate than the wind turbine noise increases with wind speed. The difference between the noise of the wind farm and the background noise is therefore liable to be greatest at low wind speeds. Varying the speed of the turbines in such conditions can, if necessary, reduce the sound output from modern turbines…*

3.6. *The report, 'The Assessment and Rating of Noise from Wind Farms' (ETSU-R-97), describes a framework for the measurement of wind farm noise and gives indicative noise levels calculated to offer a reasonable degree of protection to wind farm neighbours, without placing unreasonable restrictions on wind farm development or adding unduly to the costs and administrative burdens on wind farm developers or planning authorities. The report presents the findings of a cross-interest Noise Working Group and makes a series of recommendations that can be regarded as relevant guidance on good practice. This methodology overcomes some of the disadvantages of BS 4142[3] when assessing the noise effects of wind farms, and should be used by planning authorities when assessing and rating noise from wind energy developments."*

ETSU-R-97

3.7. ETSU Report ETSU-R-97 published in September 1996, was the result of deliberations of the Working Group on Noise from Wind Turbines, which was set up in 1993 by the Department of Trade and Industry to derive guidelines for assessing noise from wind turbines. ETSU-R-97 is the recommended assessment method stated in PPS 22 and the Government has reaffirmed that noise from wind farms should continue to be assessed according to the ETSU-R-97 guidance.

3.8. The ETSU report provides a method for assessing wind turbine noise and in particular, the setting of external noise limits which are either;

1) relative to the background noise (L_{A90} dB), or;

2) fixed when background noise levels are otherwise very low.

3.9. In most rural locations, the background noise depends on the wind speed. For rural environments, the "fixed" part of the ETSU limit usually applies at low wind speeds. At high wind speeds, noise from wind in the trees and flowing over local features such as roofs can be considerable, and is often sufficient to mask the sound of the wind turbine. Therefore it is often at lower wind speeds that the turbines are more audible.

3.10. The ETSU limits are set in terms of the L_{A90} noise parameter. This is defined as the noise level exceeded for 90% of the measurement time. It is taken to represent the

[3] British Standard BS 4142: 1997 - Rating industrial noise affecting mixed residential and industrial areas.

"background noise", that is the underlying noise level in the absence of short-term events. This unit was chosen to assess the turbine noise as it is fairly steady and because extraneous short-term events such as discrete car passes and aircraft do not usually affect the L_{A90} parameter. For wind turbine noise, the L_{A90} noise parameter is typically 2 dB less than the L_{Aeq} parameter. The L_{Aeq} can be regarded as an average noise level over a time period.

3.11. For single turbine schemes, or for remote sites a long way from residential properties, ETSU-R-97 reports the opinion of the noise working group that: *"if the noise is limited to an $L_{A90,10min}$ of 35dB(A) up to wind speeds of 10m/s at 10m height, then this condition alone would offer sufficient protection of amenity and background noise surveys would be unnecessary".* However, where the background noise has been measured, noise limits can be set relative to the prevailing background noise levels.

3.12. The ETSU-R-97 limits set relative to the background noise are derived separately for "amenity hours" daytime periods and for the night-time periods, defined as 11pm to 7am. The amenity hours daytime periods are chosen to reflect periods when people might be outside in their gardens and are defined as:

- All evenings from 6pm to 11pm;
- Saturday afternoons from 1pm to 11pm and;
- All day Sunday (7am to 11pm)

3.13. For the day-time periods, the suggested external noise limits are 35 to 40 dB L_{A90} or 5 dB above the prevailing background, whichever is the greater. A degree of judgment is required in determining the fixed limit within the 35 to 40 dB L_{A90} range and ETSU-R-97 states that this will depend on:

- The number of dwellings in the neighbourhood of the wind farm;
- The effect of noise limits on the number of kWh generated; and
- The duration and level of exposure.

3.14. For this scheme which comprises a single turbine, the lower ETSU daytime limit is appropriate, that is 35 dB L_{A90} or 5 dB above the background noise.

3.15. For night-time periods, the external noise limit is 43 dB L_{A90} or 5 dB above the background, whichever is the greater. The 43 dB L_{A90} limit is based on a sleep disturbance limit of 35 dB L_{Aeq} (internally) with an allowance of 10 dB for the attenuation of an open window to derive the corresponding external noise level and with 2 dB subtracted to account for the use of the L_{A90} noise index rather than the L_{Aeq}.

3.16. The ETSU-R-97 night-time limit was derived from the World Health Organisation (WHO) internal noise standard of 35 dB L_{Aeq}. Since the publication of ETSU-R-97, a later WHO document "Guidelines for Community Noise", has reduced the internal night-time noise standard to 30 dB L_{Aeq} *"to avoid negative effects on sleep"*. The same WHO guidelines recommend that *"at night-time, outside sound levels about 1 metre from facades of living spaces should not exceed 45 dB L_{Aeq}, so that people may sleep with bedroom windows open"*. This was based on a reduction of 15 dB for the sound level difference between the inside and outside with an open window. The 45 dB L_{Aeq} external noise limit at 1m from a façade translates to a limit of 42 dB L_{Aeq} in free-field conditions, away from the façade, or 40 dB L_{A90}. In many cases, the value of the night-time limit is not critical because the quiet daytime limit (35 dB to 40 dB L_{A90}) is more onerous. PPS 22 was published after the revision of the WHO guideline values, but nevertheless recommends use of the ETSU guidelines.

3.17. ETSU-R-97 allows for a higher limit where the residents are *"financially involved"* with the wind turbine development. The suggested limit is 45 dB L_{A90} for both the quiet day and night-time periods and *"that consideration should be given to increasing the permissible margin above background"*. The farm house at Harrington Parks Farm and the property Copper Bank are occupied by family members and are considered to be financially involved with this scheme.

3.18. Where audible tones are present in the noise spectrum ETSU recommends that a tonal penalty of up to 5dB be added. The magnitude of the tonal penalty depends on the prominence of the tone. A prominent tone is associated with the Enercon E-33 turbine at wind speeds of 6 and 7 m/s at 10m height. Therefore the assessment includes a +5dB tonal penalty for those wind speeds. A tonal assessment of the candidate Enercon E-33 Turbine is included in an extract from a Turbine Test Report in Appendix C.

ISO 9613-2 Attenuation of sound during propagation outdoors

3.19. 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 farm noise assessments.

3.20. 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 houses. 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.

3.21. 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:

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

3.22. The predicted octave band levels are then summed together to give the overall 'A' weighted predicted 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.

Prediction and Assessment of Wind Turbine Noise – Acoustic Bulletin Article

3.23. 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[4] which appeared in the March/April 2009 edition of Acoustics Bulletin published by the Institute of Acoustics. The article clarified three main issues:

[4] Dick Bowdler et. al. Prediction and assessment of wind turbine noise – agreement about relevant factors for noise assessment from wind energy projects. Acoustics Bulletin Vol 34 No. 2 March / April 2009

- That baseline noise measurements are preferably correlated with the derived wind speed at 10m height calculated using wind speed measurements at several heights, so that the background noise levels and thereby noise limits can be adjusted for the 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.

3.24. 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. The article is not official IOA guidance. For brevity, it will be referred to as the Acoustics Bulletin article in this report.

4. BASELINE NOISE CONDITIONS

Background Noise Survey

4.1. A baseline noise survey was carried out for a two-week period from 25th November to 12th December 2011 to determine baseline noise conditions and to set ETSU-R-97 limits for the development. Two monitoring locations were identified and agreed with Matthew Crouchley; an Environmental Protection Officer with Allerdale Borough Council. The monitoring locations are shown in Table 2 along with; Ordnance Survey grid coordinates determined by a GPS device, the approximate distances from the proposed turbine and a description of the monitoring location. Photos of the measurement locations are provided in Appendix D.

Table 2 Noise Monitoring Locations

Address	Easting	Northing	Distance from Turbine (m)	Monitoring Location
No 2, Harrington Parks Cottages	298933	524650	500	In front (east-facing) garden.
Foxpit House	298692	523928	530	In rear (west facing) garden. (There was no garden or amenity space on the east side of the property.)

4.2. There are several residential properties to the north of the proposed turbine site. However, Copper Bank and the Farmhouse at Harrington Parks Farm are both financially involved in the scheme so the closest third party residence is No. 2 Harrington Parks Cottages at around 500m from the turbine. This is a semi-detached property with No. 1 adjacent to it but slightly further away. The monitoring position at Foxpit House represented the closest residential location to the south at a plan distance of 530m.

4.3. Larson-Davis Type LD-820 sound level meters were used for the survey. Gavin Irvine from Ion Acoustics installed the equipment. The microphones of the sound level meters were fitted with a double-skin windshield designed in line with the recommendations of ETSU report W/13/00386/REP and mounted on a tripod at a height of 1.5m above ground level. The sound level meters were configured to measure noise levels in 10-minute periods with the clocks of the sound level meters synchronised to GMT.

4.4. On the 8th December 2011 very high winds caused the wind shield to blow off the meter installed at No. 2 Harrington Parks Cottages. Therefore, all data collected after this time, at this location, has been discounted.

4.5. The meters were calibrated with a Brüel & Kjær Type 4231 sound level calibrator. The deviation in the calibration level between the start and end of the measurements was 0dB at Foxpit House and 0.2dB at No.2 Harrington Parks Cottages; this indicates that good measurement accuracy has been achieved. The meters and calibrator are calibrated to national standards biannually and annually respectively in line with standard recommendations.

4.6. During installation and collection of the noise monitors, a significant amount of wind generated noise in the vegetation and from the sea was noted at both monitoring locations. The closest main road carrying regular traffic is the A595 at approximately 1.5km from both monitoring locations. Road traffic was not noted as a significant contributor to the local ambient noise climate during site visits. The resident at Foxpit House states that he cannot hear the existing wind turbines at Lowca. Nevertheless, by listening carefully some turbine noise was just audible at this location.

4.7. The wind speed and direction measurements were made during the survey with a 40-metre anemometry mast installed near the wind turbine site at Ordnance Survey grid reference 299110E, 524224N. Rainfall data was collected with a tipping bucket rain gauge installed in the garden of Foxpit House.

Determination of 10m Wind Speed

4.8. As is required by ETSU-R-97, the background noise measurements have been referenced to the wind speed at 10m height above ground level (AGL). The assessment has been made using a derived wind speed at 10m height as required by the Acoustics Bulletin article. Turbine sound power levels are stated in terms of the wind speed at this height, in accordance with the turbine noise measurement standard IEC 61400-11. Therefore, background noise levels varying with the wind speed at 10m height can be compared with noise predictions showing the variation in turbine noise level with wind speed assessed at the same height.

4.9. When a wind turbine is tested to determine the sound output in accordance with IEC 61400-11, the measured noise levels are determined first in relation to the hub height wind speed derived from the turbine's electrical power curve and then converted to the standard height of 10m using the 'log' law equation with a standard roughness length (z_0) of 0.05 m. This is equation (2) below.

$$v_{10} = v_{hh} \times \left(\frac{\ln\left[10 / z_0 \right]}{\ln\left[hh / z_0 \right]} \right) \qquad \text{................(2)}$$

4.10. Where v_{10} and v_{hh} are wind speeds at heights of 10m and hub height (hh) respectively, and z_0 is the roughness length (0.05m).

4.11. The anemometry mast installed on the site has anemometers at 30m and 40 metres. To derive the hub-height wind speed, the wind speeds at 30m and 40 metres have been used to determine the hub height (44m) wind speed according to the 'power' law, equation 3:

$$v_1 = v_2 \times \left(\frac{h_1}{h_2}\right)^m \qquad \text{................(3)}$$

4.12. Where v_1 and v_2 are wind speeds at heights h_1 and h_2 and the exponent 'm' is a variable which depends on the stability of the atmospheric conditions, the terrain and the surface roughness. The value of 'm' has been calculated using the results from the 30m and 40m anemometers and then used to determine the typical hub-height wind speed.

4.13. The hub height wind speed was then corrected down to 10m wind speed using Equation 2 above with z_0 = 0.05. This is method allows for wind shear to be factored directly into the background noise limits to reduce the uncertainties due to the wind shear experienced on site.

Noise Survey Results

4.14. The results of the noise survey have been plotted as a series of time history charts showing the variation in noise with wind speed. These results are only of interest to the most dedicated readers and are therefore not provided here. However they are available on request in spreadsheet format.

4.15. The noise data has then been analysed to obtain scatter plots showing the relationship between background noise levels and wind speed derived at 10m height for night-time and daytime amenity hours periods as described above. Data has been removed when the rain gauge registered rainfall. No data logged at No. 2 Harrington Parks Cottages on or after 8th December 2011 (when the windshield was found to have blown off) has been used. The scatter plots are presented in Appendix E.

4.16. Each scatter plot includes a best-fit trend line describing the prevailing variation in background noise with wind speed. The background noise levels derived from the best-fit trendline are shown in Table 3 below.

Table 3 Prevailing Background Noise Levels, L_{A90} dB derived from Scatter Plots

Measurement Location		Wind Speed @ 10m Height AGL, m/s						
		4	5	6	7	8	9	10
		Prevailing Background Noise Level, L_{A90} dB						
Foxpit House	Amenity Hours	46.3	47.2	48.1	49.1	50.0	51.0	52.1
	Night-time Hours	44.3	45.3	46.5	47.6	48.9	50.1	51.4
No.2 Harrington Parks Cottages	Amenity Hours	36.3	37.9	39.7	41.6	43.6	45.7	47.7
	Night-time Hours	35.8	37.8	39.8	41.9	43.9	45.9	47.8

4.17. Background noise levels at both locations are considerable and are dominated by the wind and to a certain extent by noise from the sea. At both locations, the prevailing background noise levels indicate a consistent rising trend of background noise with wind speed. The lowest background noise levels were obtained at No.2 Harrington Parks Cottages. The difference is particularly pronounced at low wind speeds and the higher noise levels at Foxpit House are probably attributed to the increase vegetation in the garden of the property and possibly a small effect due to the existing Lowca Wind Farm.

4.18. ETSU-R-97 advises: *"…that absolute noise limits and margins above background should relate to the cumulative effect of all wind turbines in the area which contribute to the noise received at the properties in question. It is clearly unreasonable to* *suggest that, because a wind farm was constructed in the vicinity in the past, which resulted in increased noise levels at some properties, the residents of those properties are now able to tolerate still higher noise levels. The existing wind farm should not be considered as part of the prevailing background noise."*

4.19. Noise levels at Foxpit House are possibly affected by wind turbine noise under some circumstances, but any effect must be small as the resident states that he cannot hear the wind turbines and predicted downwind noise levels from Lowca Wind Farm are around 8dB lower than the measured levels. Predicted noise levels from Lowca wind farm are shown on the scatter plots in Appendix E.

5. PREDICTED NOISE LEVELS

Methodology

5.1. Computer noise modelling software (IMMI) implementing the ISO9613-2 methodology described above has been used to predict wind turbine noise levels near the proposed turbine. The following modelling assumptions have been made in line with the current agreed best practice described in the Acoustics Bulletin article:

- Mixed ground absorption (G=0.5);
- Ambient air temperature of 10°C;
- 70% relative humidity;
- Barrier attenuation limited to 2dB based on the tip height of the turbines.

5.2. To carry out the modelling, the terrain information has been obtained from Ordnance Survey at a 50m resolution and imported into the model.

5.3. A candidate turbine for this site is an Enercon E-33 330kW wind turbine with a 44m hub height located at Ordnance Survey grid reference 299130E and 524200N. Turbine sound power levels have been provided by the turbine manufacturer (Enercon) and will form part of the warranty agreement. Frequency spectra have been derived from a Carl Bro Engineering test report. Both the Enercon data sheet and extracts from the Carl Bro test report are included in Appendix C.

5.4. The manufacturers state a maximum sound power level of 100.0 dB L_{WA} for this turbine; this occurs at wind speeds of 9 m/s and above. To account for various uncertainties, a factor of 1 dB has been added to the manufacturer's values as recommended by Enercon. At 6m/s and 7m/s the Carl Bro test report indicates an audible tone at around 108 Hz. The ETSU-R-97 guidance indicates that a tonal penalty of up to 5 dB shall apply, if a prominent tone is detected at a dwelling. The tonal assessment method used in the ISO 61400-11 test standard is similar, but not the same as the ETSU method and is based on measurements relatively close to the turbine. Therefore it is not certain that the tonal assessment in the test report will apply at every dwelling. However to account for a possible tonal penalty under the ETSU method, a 5dB tonal penalty has been added to the turbine sound power levels at 6 and 7 m/s.

5.5. The sound power levels and frequency spectra (including the addition of the uncertainty factor and tonal penalty) used for calculations are given for each wind speed in Table 4 below.

Table 4: Enercon E-33 330 kW Sound Power Levels used in the Assessment

Wind Speed (m/s) at 10m Height	A-weighted Noise Level dB $L_{WA(eq)}$	A-weighted Frequency Spectra Octave Band Sound Power Level dB $L_{WA(eq)}$							
		63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz
4*	90.3	63.6	84.4	79.2	82.1	84.4	83.0	77.6	69.9
5	92.0	65.3	86.1	80.9	83.8	86.1	84.7	79.3	71.6
6	102.0	75.3	96.1	90.9	93.8	96.1	94.7	89.3	81.6
7	104.9	83.3	95.3	95.3	98.1	100.0	97.8	91.6	85.1
8	100.8	79.9	89.5	91.6	94.2	95.9	93.5	87.9	81.8
9	101.0	79.8	89.7	91.6	94.2	96.1	94.0	88.5	82.8
10	101.0	79.8	89.7	91.6	94.2	96.1	94.0	88.5	82.8

*The current Enercon data sheet does not provide noise levels at 4 m/s. Values at 4 m/s are based on an earlier Enercon data sheet.

5.6. From Table 4 the worst case sound power level including a tonal penalty is 104.9 dB L_{WA}. This occurs at a wind speed of 7 m/s at 10m height. Therefore the initial predictions and contour plots have been carried out for this wind speed.

5.7. For commercial reasons, it is not possible to definitively state which turbine will be selected for the development if planning permission were to be granted. The final choice of turbine for this site will depend on many factors, not least the noise output. However, in the event that a different turbine is chosen it will be selected to meet the ETSU noise limits.

Results

5.8. A noise contour plot showing the predicted downwind noise levels for a wind speed at 7 m/s is shown in Figure 1. Figure 1 also shows the location of nearby residential receptors.

5.9. Predicted turbine noise levels at the closest local receptors are shown in Table 5 for wind speeds between 4 m/s and 10 m/s.

Table 5 Predicted downwind noise levels for Harrington Parks Farm Enercon E33

Location	Easting	Northing	Wind Speed at 10m Height, m/s						
			4	5	6	7	8	9	10
			Predicted Noise Level, L_{A90} dB						
Foxpit House	298680	523932	21.9	23.6	33.6	36.7	32.5	32.6	32.6
Harrington Parks Farm House	298975	524557	24.8	26.5	36.5	39.6	35.5	35.6	35.6
Harrington Parks Cottages	298933	524650	22.5	24.2	34.2	37.3	33.1	33.3	33.3
Copper Bank	298952	524605	23.6	25.3	35.3	38.4	34.2	34.3	34.3
Park House Farm	298930	523588	19.8	21.5	31.5	34.6	30.4	30.5	30.5

5.10. ETSU-R-97 states that if the noise is limited to a level of 35 dB L_{A90} up to wind speeds of 10m/s at 10m height, then this condition alone would offer sufficient protection of amenity. There are four receptors where worst case turbine noise levels over 35 dB L_{A90} are predicted. Of these, Copper Bank and Harrington Parks Farm House are financially involved in the scheme and therefore the higher fixed ETSU limit of 45dB

L_{A90} applies. Predicted noise levels at Harrington Parks Farmhouse and Copper Bank are well below ETSU financially involved limits at all wind speeds.

5.11. At Harrington Parks Cottages and Foxpit House an assessment must be made by comparing the predicted noise levels with the ETSU noise limit derived from the measured background noise levels.

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5.12. The ETSU assessments of predicted noise levels from the proposed Enercon E-33 at Harrington Parks Farm are shown in Table 6.1 and 6.2. A positive margin below the limit indicates compliance with the ETSU limits.

Table 6.1 ETSU Assessment Table for Foxpit House

ETSU Assessment	Wind Speed at 10m AGL, m/s						
	4	5	6	7	8	9	10
	Noise Levels dB L_{A90}						
Predicted Noise Level dB L_{A90}	21.9	23.6	33.6	36.7	32.5	32.6	32.6
Day-time Assessment							
Daytime Background Noise dB L_{A90}	46.3	47.2	48.1	49.1	50.0	51.0	52.1
ETSU Lower Limit dB L_{A90}	51.3	52.2	53.1	54.1	55.0	56.0	57.1
Margin below Lower Limit dB	29.4	28.6	19.5	17.4	22.5	23.4	24.5
Night-time Assessment							
Night-time Background Noise dB L_{A90}	44.3	45.3	46.5	47.6	48.9	50.1	51.4
ETSU Night Limit dB L_{A90}	49.3	50.3	51.5	52.6	53.9	55.1	56.4
Margin below Night-time Limit dB	27.4	26.7	17.9	15.9	21.4	22.5	23.8

5.13. Predicted noise levels at Foxpit House are well below ETSU limits at all wind speeds and in excess of 10dB below background noise levels even with the addition of the tonal penalty. Therefore, turbine noise from the proposed Enercon E-33 is unlikely to be audible at any time.

Table 6.2 ETSU Assessment Table for Harrington Parks Cottages

ETSU Assessment	Wind Speed at 10m AGL, m/s						
	4	5	6	7	8	9	10
	Noise Levels dB L_{A90}						
Predicted Noise Level dB L_{A90}	22.5	24.2	34.2	37.3	33.1	33.3	33.3
Day-time Assessment							
Daytime Background Noise dB L_{A90}	36.3	37.9	39.7	41.6	43.6	45.7	47.7
ETSU Lower Limit dB L_{A90}	41.3	42.9	44.7	46.6	48.6	50.7	52.7
Margin below Lower Limit dB	18.8	18.7	10.5	9.3	15.5	17.4	19.4
Night-time Assessment							
Night-time Background Noise dB L_{A90}	35.8	37.8	39.8	41.9	43.9	45.9	47.8
ETSU Night Limit dB L_{A90}	43.0	43.0	44.8	46.9	48.9	50.9	52.8
Margin below Night-time Limit dB	20.5	18.8	10.6	9.6	15.8	17.6	19.5

5.14. Noise levels at Harrington Parks Cottages are well below ETSU limits and background noise levels at all wind speeds. Turbine noise is unlikely to be audible at this location.

5.15. As some turbine noise from the existing Lowca wind farm may have affected measurements at Foxpit House the ETSU assessment at this location has been repeated in Table 6.3 with the measured background noise levels at No.2 Harrington Parks Cottages. No.2 Harrington Parks Cottages is almost three times further from the nearest Lowca turbine than Foxpit House at 1.2km. Background noise levels at No. 2 Harrington Parks Cottages are currently unaffected by any discernible wind turbine noise.

Table 6.3 ETSU Assessment Table for Foxpit House using measured Data from No. 2 Harrington Parks Cottages

ETSU Assessment	Wind Speed at 10m AGL, m/s						
	4	5	6	7	8	9	10
	Noise Levels dB L_{A90}						
Predicted Noise Level dB L_{A90}	21.9	23.6	33.6	36.7	32.5	32.6	32.6
Day-time Assessment							
Daytime Background Noise dB L_{A90}	36.3	37.9	39.7	41.6	43.6	45.7	47.7
ETSU Lower Limit dB L_{A90}	41.3	42.9	44.7	46.6	48.6	50.7	52.7
Margin below Lower Limit dB	19.4	19.3	11.1	9.9	16.1	18.1	20.1
Night-time Assessment							
Night-time Background Noise dB L_{A90}	35.8	37.8	39.8	41.9	43.9	45.9	47.8
ETSU Night Limit dB L_{A90}	43.0	43.0	44.8	46.9	48.9	50.9	52.8
Margin below Night-time Limit dB	21.1	19.4	11.2	10.2	16.4	18.3	20.2

5.16. Even when compared to the lower background noise levels at No. 2 Harrington Parks Cottages predicted noise levels at Foxpit House are 10dB or more below the derived ETSU limits and below the background noise at all wind speeds. Even if the impact of the existing Lowca turbines were completely excluded it is likely that the background noise level at Foxpit House would not be as low as Harrington Parks Cottages, however, this comparison gives a clear indication that noise levels from the proposed Harrington Parks wind turbine will be well within ETSU limits at all wind speeds.

6. CUMULATIVE ASSESSMENT

6.1. There are seven existing turbines at Lowca; approximately 425m south of Foxpit House. All these turbines Vestas V-47 660kW. The exact variant is not known but the highest sound power levels for any variant have been taken from the manufacturer's data. The assumed sound power levels for the Lowca turbines with the addition of a 2dB uncertainty correction (as specified by the manufacturer) are shown in Table 7.

Table 7: Vestas V-47 660 kW Sound Power Levels used in the Assessment

Wind Speed (m/s) at 10m Height	A-weighted Noise Level dB $L_{WA(eq)}$	A-weighted Frequency Spectra Octave Band Sound Power Level dB $L_{WA(eq)}$							
		63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz
4	101.0	78.4	86.3	90.0	95.4	97.2	93.1	88.1	69.4
5	101.5	78.9	86.8	90.5	95.9	97.7	93.6	88.6	69.9
6	101.9	79.3	87.2	90.9	96.3	98.1	94.0	89.0	70.3
7	102.4	79.8	87.7	91.4	96.8	98.6	94.5	89.5	70.8
8	102.8	80.2	88.1	91.8	97.2	99.0	94.9	89.9	71.2
9	103.3	80.7	88.6	92.3	97.7	99.5	95.4	90.4	71.7
10	103.7	81.1	89.0	92.7	98.1	99.9	95.8	90.8	72.1

6.2. The turbine locations for the Lowca Wind Farm have been taken from Google earth and are assumed to be as follows:

Table 8: Lowca Wind Farm Turbine Locations

Turbine	Easting	Northing
t1	298386	523624
t2	298389	523428
t3	298379	523241
t4	298260	523072
t5	298314	522873
t6	298104	522953
t7	298008	522794

6.3. The ETSU assessment from the previous section has been repeated with the predicted levels for both the proposed and Lowca turbines. Cumulative contour plots are included in Figure 2. Note that downwind noise levels are predicted. Locations which are in between the proposed turbine and Lowca wind farm such as Foxpit House and Park House Farm clearly cannot be downwind of both all turbines at the same time. Therefore in reality noise levels will be less than predicted.

6.4. To ensure that turbine noise from Lowca has no influence on the assessment, the cumulative predicted levels at both Foxpit House and Harrington Parks Cottages have been compared with the lower measured noise levels at No. 2 Harrington Parks Cottages. The results are shown in table 9.1 and 9.2.

Table 9.1 ETSU Assessment Table for Foxpit House

ETSU Assessment	Wind Speed at 10m AGL, m/s						
	4	5	6	7	8	9	10
	Noise Levels dB L_{A90}						
Proposed (E-33) Predicted dB L_{A90}	21.9	23.6	33.6	36.7	32.5	32.6	32.6
Existing (Lowca) Predicted dB L_{A90}	38.4	38.8	39.3	39.7	40.2	40.6	41.1
Cumulative Predicted Level dB L_{A90}	38.5	38.9	40.3	41.5	40.8	41.2	41.6
Day-time Assessment							
Daytime Background Noise dB L_{A90}	36.3	37.9	39.7	41.6	43.6	45.7	47.7
ETSU Lower Limit dB L_{A90}	41.3	42.9	44.7	46.6	48.6	50.7	52.7
Margin below Lower Limit dB	2.8	4.0	4.4	5.1	7.8	9.5	11.1
Night-time Assessment							
Night-time Background Noise dB L_{A90}	35.8	37.8	39.8	41.9	43.9	45.9	47.8
ETSU Night Limit dB L_{A90}	43.0	43.0	44.8	46.9	48.9	50.9	52.8
Margin below Night-time Limit dB	4.5	4.1	4.5	5.4	8.1	9.7	11.2

6.5. The predicted cumulative noise levels from the existing Lowca turbines and the proposed Enercon E-33 are well below ETSU noise limits at Foxpit House. Predictions are also likely to be below the existing background noise at Foxpit House. Turbine noise levels from the Lowca Turbines are higher than predicted levels from the proposed Enercon E-33 even with the addition of the 5dB tonal penalty to the Enercon E-33 sound power levels. Given that the turbines at Lowca are already considered inaudible by the resident then there will be no impact from the proposed single turbine.

Table 9.2 ETSU Assessment Table for Harrington Parks Cottages

ETSU Assessment	Wind Speed at 10m AGL, m/s						
	4	5	6	7	8	9	10
	Noise Levels dB L_{A90}						
Proposed (E-33) Predicted dB L_{A90}	22.5	24.2	34.2	37.3	33.1	33.3	33.3
Existing (Lowca) Predicted dB L_{A90}	29.3	29.8	30.2	30.7	31.1	31.6	32.0
Cumulative Predicted dB L_{A90}	30.2	30.8	35.7	38.2	35.2	35.5	35.7
Day-time Assessment							
Daytime Background Noise dB L_{A90}	36.3	37.9	39.7	41.6	43.6	45.7	47.7
ETSU Lower Limit dB L_{A90}	41.3	42.9	44.7	46.6	48.6	50.7	52.7
Margin below Lower Limit dB	11.1	12.1	9.0	8.4	13.4	15.2	17.0
Night-time Assessment							
Night-time Background Noise dB L_{A90}	35.8	37.8	39.8	41.9	43.9	45.9	47.8
ETSU Night Limit dB L_{A90}	43.0	43.0	44.8	46.9	48.9	50.9	52.8
Margin below Night-time Limit dB	12.8	12.2	9.1	8.7	13.7	15.4	17.1

6.6. The predicted cumulative noise levels at Harrington Parks Cottages are well below ETSU noise limits and the measured background noise at all wind speeds. There will be no noise impact at these properties therefore.

7. OTHER NOISE ISSUES

Vibration

7.1. Vibration levels from wind farms have been measured by extremely sensitive measurement equipment such as seismic arrays but in terms of human perception, measured vibration levels are well below perception thresholds even on the actual wind farm sites. There is therefore no impact from vibration.

Low Frequency Noise and Infrasound

7.2. A study by the Department of Environment, Food and Rural Affairs (DEFRA) investigated complaints of infrasound and low frequency noise causing adverse health effects. Of the 126 operational wind farms (at the time of the study) there were five with reported complaints from low frequency noise.

7.3. The report concluded that measured wind turbine noise at infra-sound frequencies (<20 Hz) is well below recognized perception thresholds and that there is no evidence of infrasound below perception thresholds having any health effects. Low frequency noise (20 Hz – 250 Hz) from wind farms was measurable and sometimes just above audibility thresholds, but was below the DEFRA night-time low frequency noise criterion and below other sources of low frequency noise such as traffic. There is no evidence of health effects arising from infrasound or low frequency noise generated by wind turbines.

7.4. Many of these issues were summarised in an article in the March / April 2009 issue of Acoustics Bulletin published by the Institute of Acoustics and written by leading authorities on wind farm noise and low frequency noise. The article also concludes: *"From examination of reports of the studies … and other reports widely available on internet sites, we conclude that there is no robust evidence that low frequency noise (including 'infrasound') or ground-borne vibration from wind farms, generally has adverse effects on wind farm neighbours."*

Amplitude Modulation

7.5. In July 2007, the Salford University Report on Amplitude Modulation was published. Amplitude modulation is described as a low frequency sound which varies in amplitude at, or above the blade passage frequency of the wind turbines, typically 1Hz. The Salford study comprised a survey of local authorities to reveal the extent of the problem, a literature review and further detailed investigation of the complaint logs from four affected sites. The report concluded that the mechanism for amplitude modulation was not fully understood, nor could it be predicted. However, there were only four confirmed cases causing complaints, and overall, the level of complaints regarding wind farms was low compared to other noise sources. Furthermore, of the four wind farms where amplitude modulation has occurred, the complaints at three of the sites have been resolved with noise control procedures.

7.6. Following on from this report, the government has stated that it does not consider there to be a need to assess this issue further at the present time, and has confirmed that PPS 22 and ETSU-R-97 should continue to be used to assess the noise of wind farms.

7.7. Given the number of operational wind turbines considered in the study, and the rarity of this problem, it is unlikely that amplitude modulation will occur at this site. Furthermore, excess amplitude modulation when it does occur, is thought to affect only turbines with large rotor diameters. The rotor diameter in this case is 33m and there are no reported problems with smaller turbines

8. SUMMARY

8.1. A noise assessment for a proposed wind turbine at Harrington Parks Farm has been carried out according to ETSU-R-97. This is the guidance method applicable to wind turbine noise as stated in PPS 22. Predictions of the turbine noise according to ISO 9613-2 have been prepared based on the candidate turbine, an Enercon E-33 330kW turbine with a hub height of 44m.

8.2. A background noise survey at two locations near the proposed turbine has been carried out at monitoring positions agreed with Allerdale Borough Council. The background noise survey results were used to set ETSU-R-97 limits which vary with wind speed.

8.3. The background noise levels measured were fairly high due to the noise of the wind in local vegetation and from the sea. The assessment indicates that turbine noise levels well are within the ETSU limits at all wind speeds including after the addition of a +5 dB tonal penalty for wind speeds of 6 m/s and 7 m/s.

8.4. A cumulative assessment of the proposed Harrington Parks wind turbine with the existing Lowca wind farm has been conducted. Combined noise levels from the two wind energy development are well below ETSU-R-97 limits at all receptors.

APPENDICES

APPENDIX A – GLOSSARY OF NOISE TERMS

Decibel dB

Unit used to describe quantify sound pressure levels or noise levels. 0 dB is the approximate threshold of hearing and 120 – 140 dB is the threshold of pain. A decibel is a logarithmic quantity and for sound pressure is calculated relative to a reference sound pressure level of 20 μPa. A change of 1 dB is just detectable under carefully controlled listening conditions.

A weighted decibel dB(A)

The dB(A) unit used to describe a sound pressure level with the frequency spectrum weighted to account for the sensitivity of human hearing at different frequencies. Human hearing is less sensitive at low and high frequencies and most sensitive at speech frequencies, typically 500 Hz to 2kHz. The dB(A) weighting better describes the subjective effect. A change of 3 dB(A) is typically the minimum noticeable difference for noises with a similar character. A change of 10 dB(A) is equivalent to a subjective doubling or halving of loudness. A-weighted noise levels are denoted by a suffix ‘A’ as in L_{Aeq}, L_{Amax} etc.

Hertz, Hz

Unit used to describe frequency of noise equivalent to the number of cycles per second. Human hearing is normally taken to extend from 20 Hz to 20,000 Hz but with reduced sensitivity at lower and higher frequencies (see dB(A) above). The ‘Noise Spectrum’ is the distribution of the noise across different frequency bands.

L_{A90} dB

The L_{A90} noise parameter is A-weighted noise level exceeded for 90% of the measurement period. This noise index is widely accepted as a descriptor of ‘background’ noise levels which is the underlying noise in the absence of short-term events. A “fast” time weighting is used unless stated otherwise.

$L_{Aeq,T}$ dB

The L_{Aeq} noise level is defined as the equivalent steady-state sound level over a specified measurement period with the same energy as the actual fluctuating noise over the same time period. This noise index is widely accepted as a descriptor of ‘ambient’ or average noise level. Note for wind turbine noise, the L_{Aeq} noise level is typically 2dB greater than the L_{A90} noise level. For other sources such as traffic, there is usually a greater variation.

Sound Power Level SWL or L_{WA} dB

The sound power level is the basic quantity describing the output of a noise source. Our ears hear sound *pressure* but a source emits sound *power*. It is a decibel unit relative to a reference level of 1 x 10^{-12} Watts or 1 picoWatt (1pW). Noise from wind turbines can be rated in terms of the sound power level. Note this is an energy average in that it is derived from L_{eq} measurements. The sound power in terms of the L_{90} parameter is 2dB less.

APPENDIX B – 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:

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

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 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 (1×10^{-12} Watts). The predictions have been made using the sound power data for an Enercon E-33 turbine as detailed in the main report. To account for uncertainty, 1dB has been added to the sound power values as a safety factor for modelling purposes. A further 5 dB has been added to the noise levels at 6 and 7 m/s at 10m height to account for a tonal penalty.

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:

$A_{geo} = 20\log(d) + 11dB$, 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:

$A_{atm} = d\alpha$, 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 10ºC and a relative humidity of 70% which gives low levels of atmospheric attenuation, as shown in the table below.

Atmospheric Absorption Coefficients 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 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.

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 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 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.

APPENDIX C – MANUFACTURER'S NOISE DATA

1. Enercon Noise Data Sheet
2. Extract from Carl Bro Test Report

APPENDIX D – SITE PHOTOS

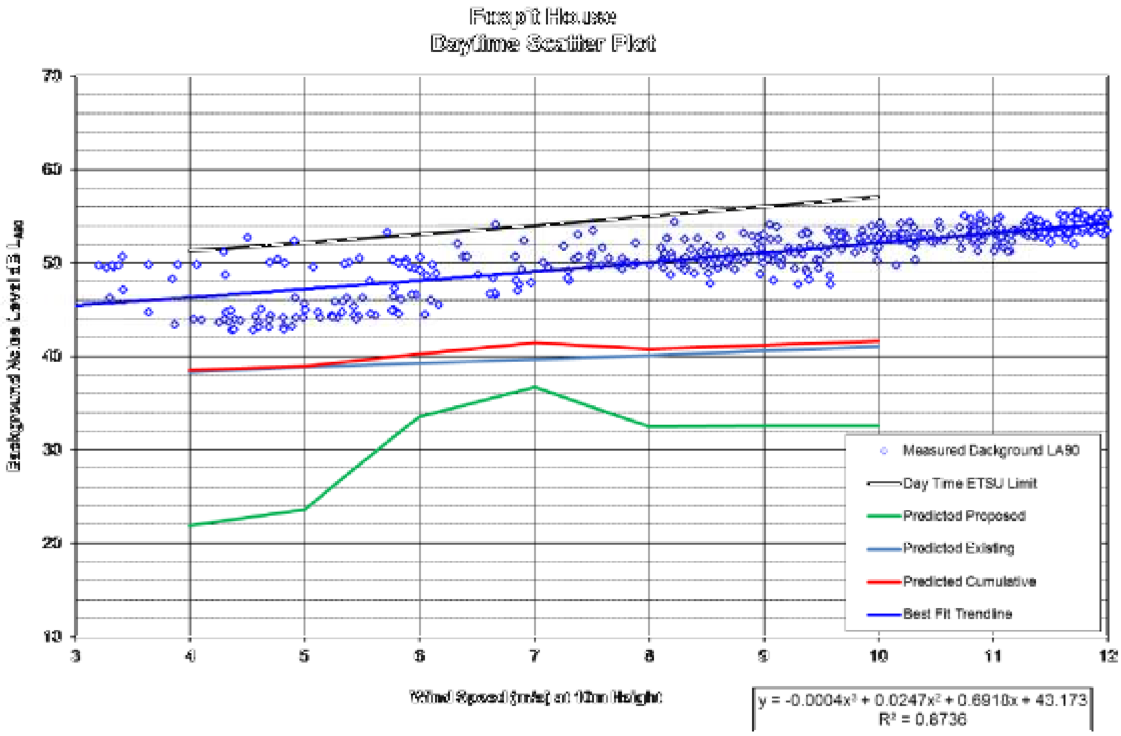
Foxpit House Noise Monitoring Location

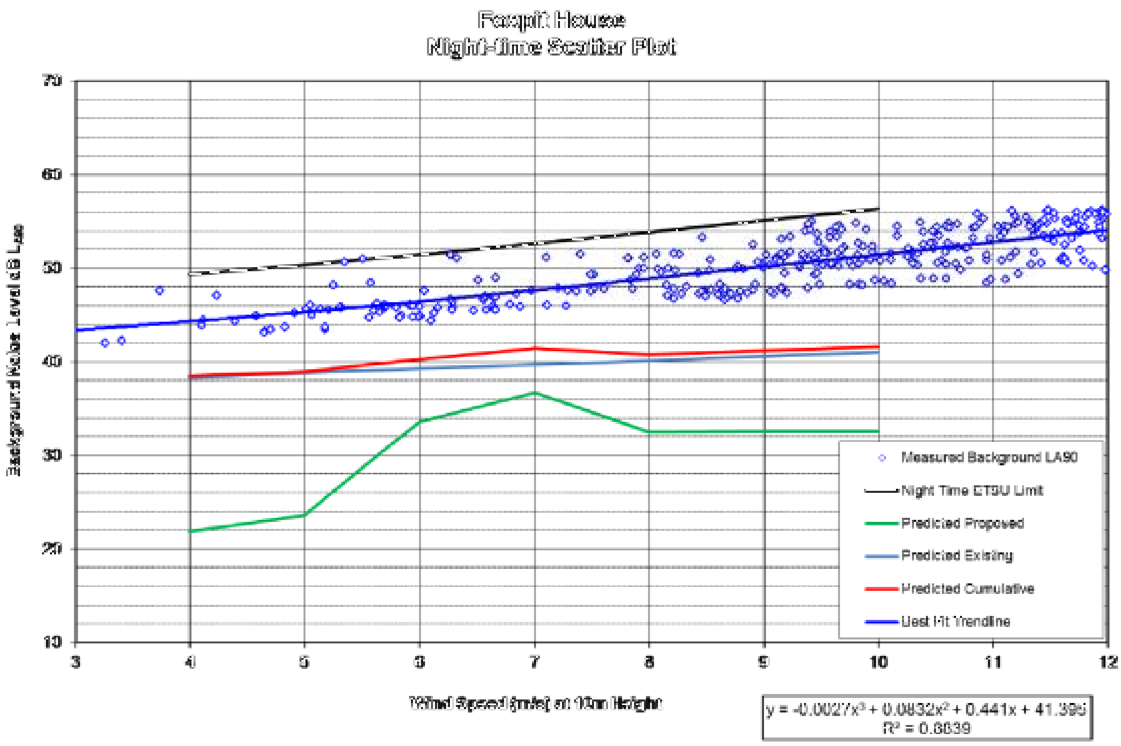
Foxpit House - looking towards existing Lowca turbines

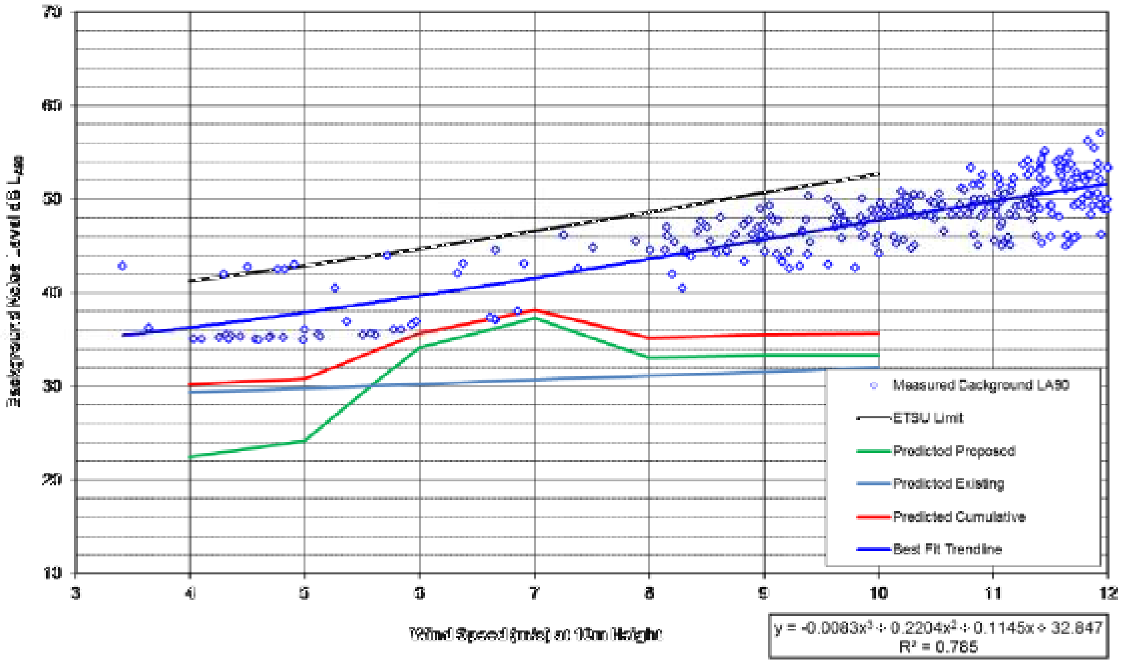
No. 2 Harrington Parks Cottages

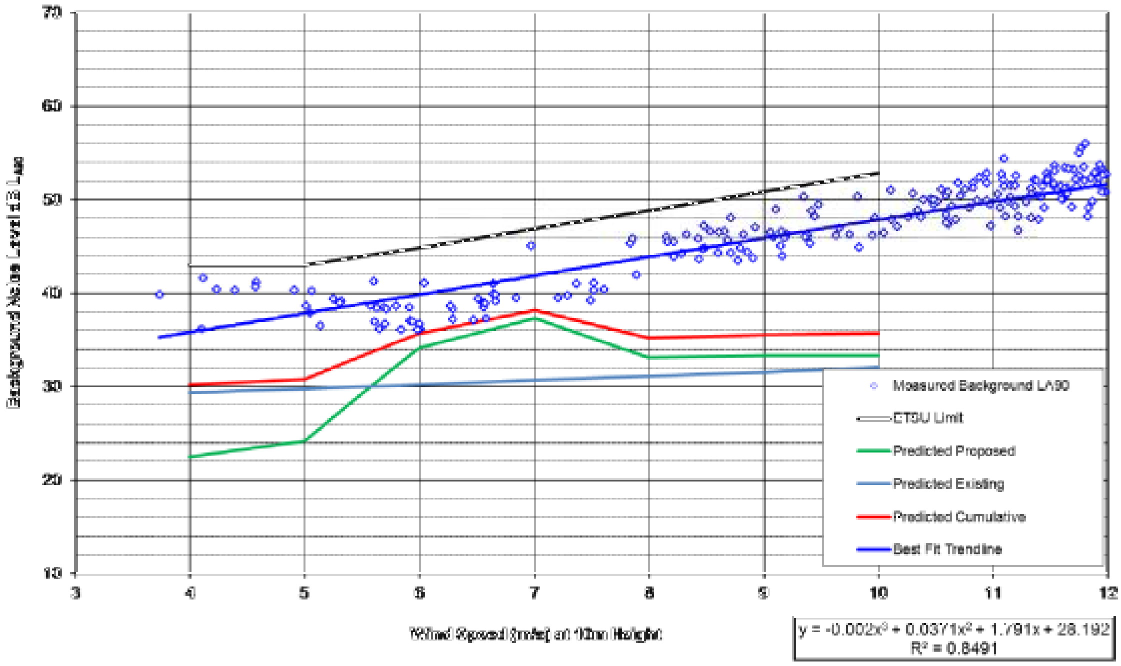
No. 2 Harrington Parks Cottages – also showing No. 1 (next door)

APPENDIX E – SCATTER PLOTS






Harrington Parks Cottages
Daytime Scatter Plot
Background Noise Level dB L_{A90}
Wind Speed (m/s) at 10m Height
Measured Background LA90
ETSU Limit
Predicted Proposed
Predicted Existing
Predicted Cumulative
Best Fit Trendline
y = -0.0083x³ + 0.2204x² + 0.1145x + 32.847
R² = 0.765


Harrington Parks Cottages
Night-time Scatter Plot
Background Noise Level dB L_{A90}
Wind Speed (m/s) at 10m Height
Measured Background LA90
ETSU Limit
Predicted Proposed
Predicted Existing
Predicted Cumulative
Best Fit Trendline
y = -0.002x³ + 0.0371x² + 1.791x + 28.192
R² = 0.8491

Sound Power Level

of the

ENERCON E-33

Operational Mode I

(Data Sheet)

Imprint

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Revision

Revision: 1.0

Department: ENERCON GmbH / Site Assessment

Glossary

WEC means an ENERCON wind energy converter.

WECs means more than one ENERCON wind energy converter.

Sound Power Level for the E-33 with 330 kW rated power

in relation to standardized wind speed v_S at 10 m height					
hub height / v_s at 10 m height	37 m	44 m	49 m	50 m	
5 m/s	90.9 dB(A)	91.0 dB(A)	91.3 dB(A)	91.3 dB(A)	
6 m/s	95.1 dB(A)	96.0 dB(A)	96.5 dB(A)	96.5 dB(A)	
7 m/s	98.6 dB(A)	98.9 dB(A)	99.0 dB(A)	99.0 dB(A)	
8 m/s	99.7 dB(A)	99.8 dB(A)	99.9 dB(A)	99.9 dB(A)	
9 m/s	100.0 dB(A)	100.0 dB(A)	100.0 dB(A)	100.0 dB(A)	
10 m/s	100.0 dB(A)	100.0 dB(A)	100.0 dB(A)	100.0 dB(A)	
95% rated power	100.0 dB(A)	100.0 dB(A)	100.0 dB(A)	100.0 dB(A)	

Measured value at 95% rated power				***100.8 dB(A)*** *CarlBroEng. P8.008.04*	

1. The relation between the sound power level and the standardized wind speed v_S in 10 m height as shown above is valid on the premise of a logarithmic wind profile with a roughness length of 0.05 m.

2. A tonal penalty of 5 dB according to (ETSU97) has to be taken into account (valid in the near vicinity of the turbine according to IEC 61 400 -11 ed. 2).

3. The sound power level values given in the table are valid for the **Operational Mode I** (defined via the rotational speed range of 18 – 43 rpm). The respective power curve is the calculated power curve E-33 dated Febuary 2004 (Rev. 2.x).

4. The values displayed in the tables above are based on official and internal measurements of the sound power level. If available the official measured values are given in this document as a reference (in italic print). The extracts of the official measurements can be made available upon request. The values given in the measurement extracts do not replace the values given in this document. All measurements have been carried out according to the recommended German and international standards and guidelines as defined in the measurement reports, respectively.

5. Due to the typical measurement uncertainties, if the sound power level is measured according to one of the accepted methods the measured values can differ from the values shown in this document in the range of +/- 1 dB.

   Accepted measurement methods are:

   a) IEC 61400-11 ed. 2 („Wind turbine generator systems – Part 11: Acoustic noise measurement techniques; Second edition"), and

b) the FGW-Guidelines („Technische Richtlinie für Windenergieanlagen – Teil 1: Bestimmung der Schallemissionswerte“, published by the association “Fördergesellschaft für Windenergie e.V.”, 18th revision).

If the difference between total noise and background noise during a measurement is less than 6 dB a higher uncertainty must be considered.

6. The sound power level of a wind turbine depends on several factors such as but not limited to regular maintenance and day-to-day operation in compliance with the manufacturer’s operating instructions. Therefore, this data sheet can not, and is not intended to, constitute an express or implied warranty towards the customer that the E-33 WEC will meet the exact sound power level values as shown in this document at any project specific site.

6.1 Apparent sound power levels

The apparent sound power levels $L_{WA,k}$ are calculated using 4th order regression analysis of data pairs (total noise and background noise separately).

Table 6. Apparent sound power levels at integer wind speeds

Standardized wind speed V_s [m/s]	6	7	8	9	10*
Apparent sound power level $L_{WA,k}$ [dB]	98,0	100,0	100,9	100,8	-

* 10 m/s corresponds to more than 95% of rated power. No data is available.

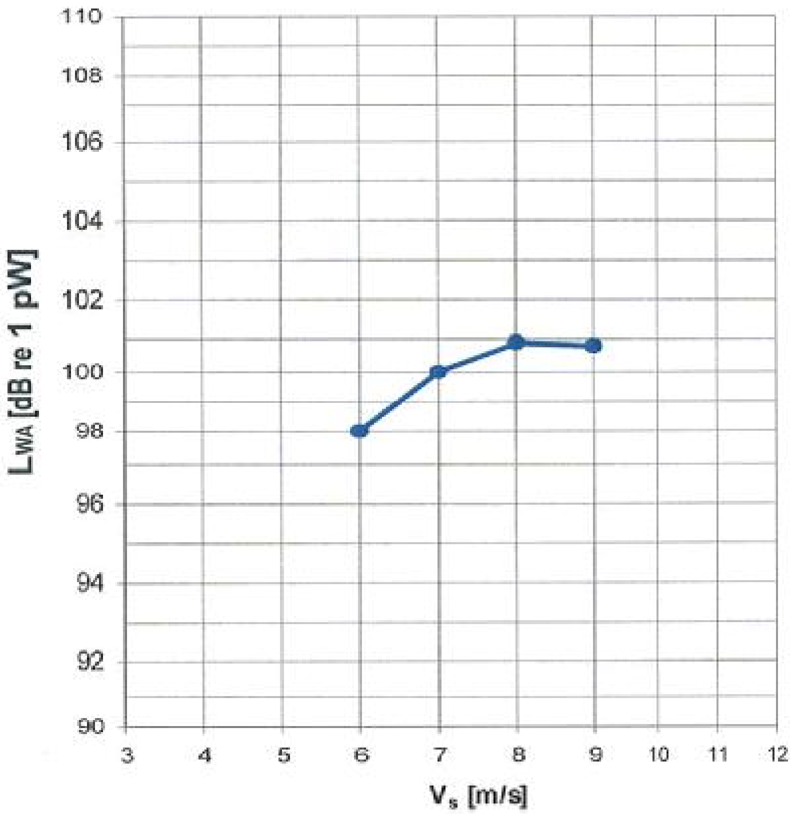


Figure 5. Apparent sound power levels at integer wind speeds

6.2 Third octave spectra

All sound power levels are A-weighted and corrected for the influence of the background noise.

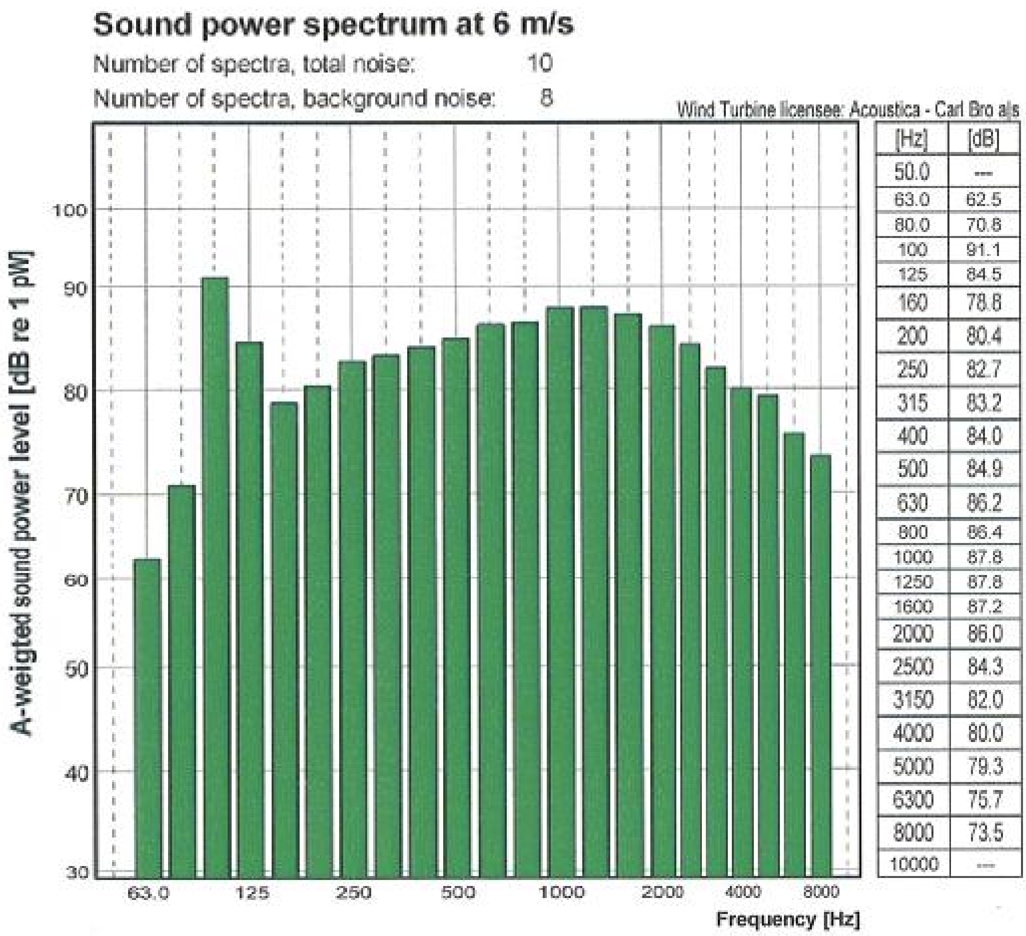
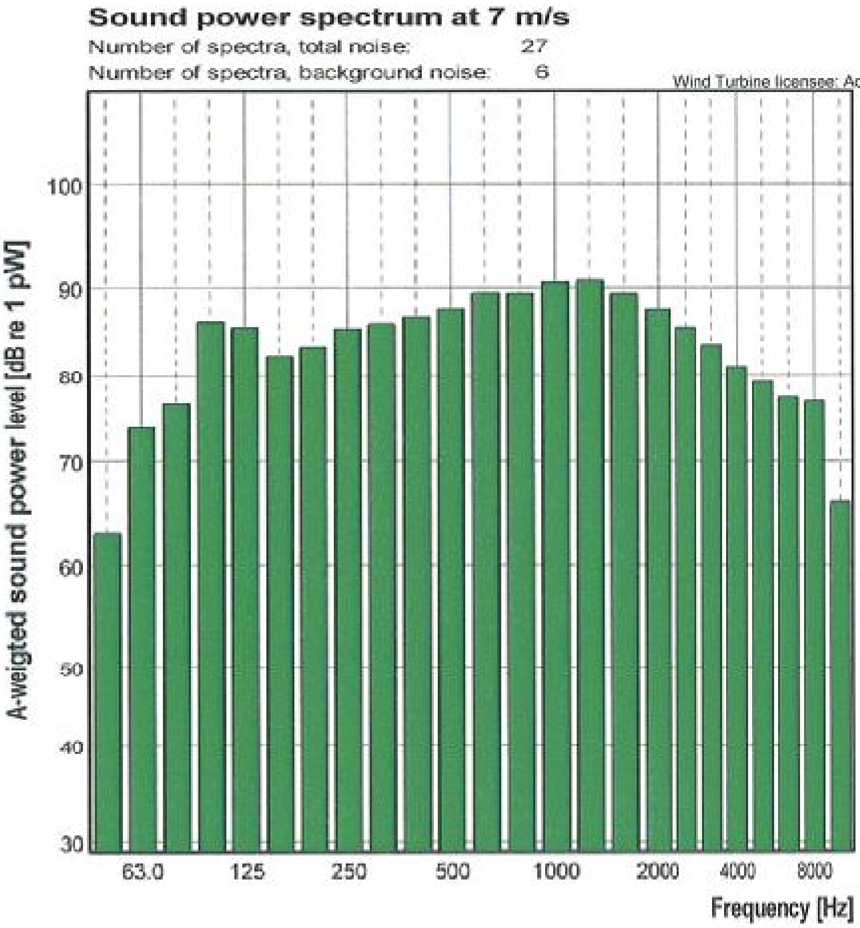
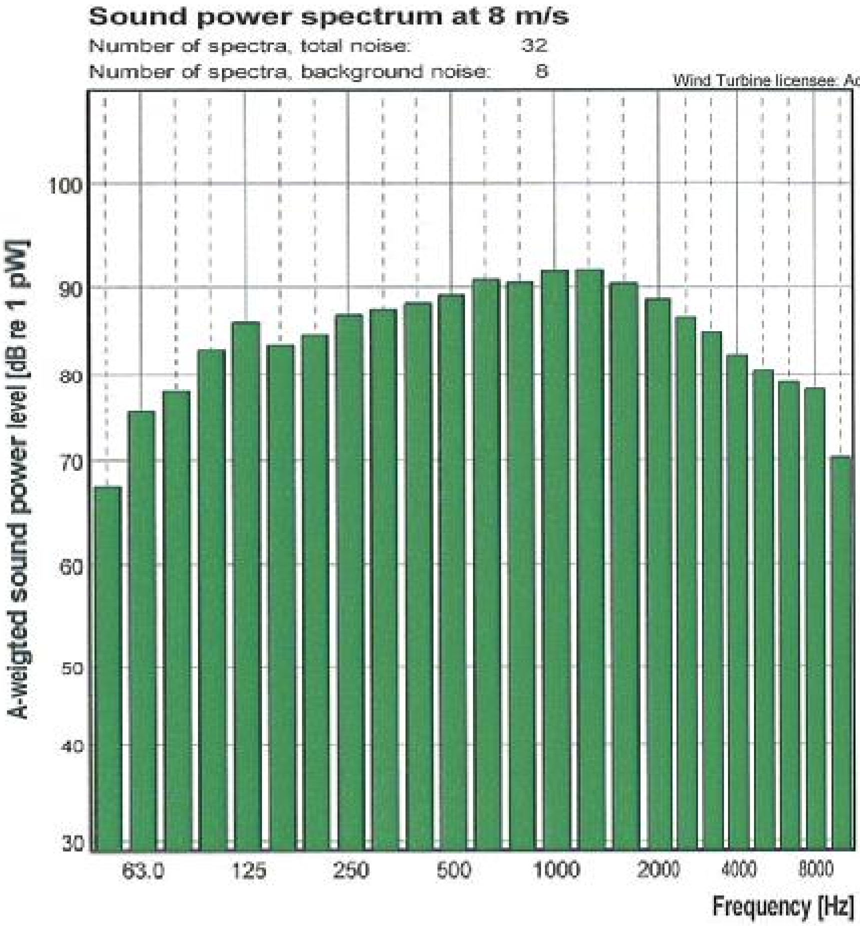


Figure 6. Third octave spectrum at the standardised wind speed 6 m/s.



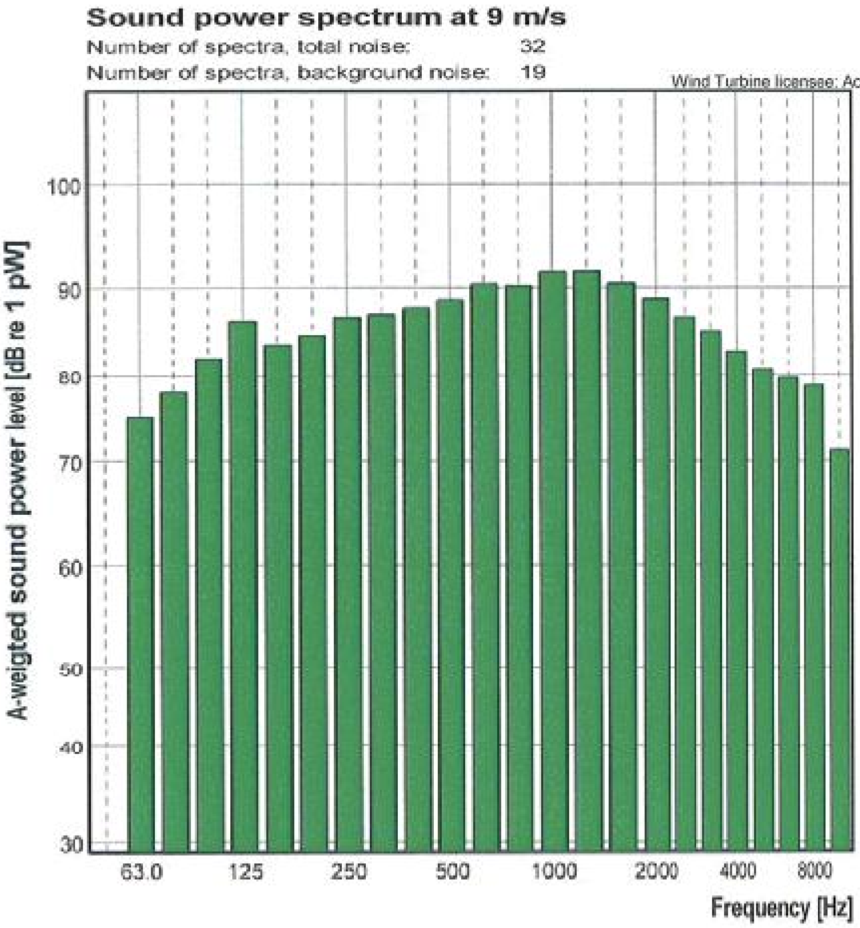
[Hz]	[dB]
50.0	63.1
63.0	73.3
80.0	76.4
100	86.8
125	86.1
160	82.4
200	83.6
250	85.9
315	86.5
400	87.2
500	88.0
630	89.5
800	89.4
1000	90.6
1250	90.7
1600	89.5
2000	87.9
2500	86.1
3150	83.9
4000	81.0
5000	79.3
6300	77.2
8000	76.7
10000	66.1

Figure 7. Third octave spectrum at the standardised wind speed 7 m/s.



[Hz]	[dB]
50.0	67.4
63.0	75.3
80.0	77.9
100	83.2
125	86.6
160	83.8
200	85.1
250	87.3
315	87.8
400	88.4
500	89.2
630	90.6
800	90.4
1000	91.5
1250	91.6
1600	90.3
2000	88.7
2500	87.0
3150	85.4
4000	82.5
5000	80.4
6300	79.0
8000	78.1
10000	70.1

Figure 8. Third octave spectrum at the standardised wind speed 8 m/s.



[Hz]	[dB]
50.0	---
63.0	74.6
80.0	77.9
100	82.1
125	86.8
160	83.9
200	85.0
250	87.1
315	87.4
400	88.1
500	88.8
630	90.4
800	90.2
1000	91.5
1250	91.6
1600	90.4
2000	88.9
2500	87.1
3150	85.6
4000	83.0
5000	80.8
6300	79.7
8000	78.8
10000	71.0

Figure 9. Third octave spectrum at the standardised wind speed 9 m/s.

6.3 Tonality

The tonality analysis was carried out using A-weighting.

The level of the background noise in the critical bands was more than 6 dB below the total noise.

Only tones with $\Delta L_{a,k} \geq -3,0$ dB are shown.

Table 7. Tonality

Integer wind speed, k [m/s]	6	7	8	9
Tone frequency [Hz]	107	109	126	126
Critical bandwidth [Hz]	101	101	101	101
Eff. noise bandwidth [Hz]	3,1	3,1	3,1	3,1
$\Delta L_{tn,j,k}$ j = 1 [dB]	13,0		-8,1	-3,2
$\Delta L_{tn,j,k}$ j = 2 [dB]	3,6	7,6	-2,2	-3,3
$\Delta L_{tn,j,k}$ j = 3 [dB]	11,1	1,1	-2,2	-6,1
$\Delta L_{tn,j,k}$ j = 4 [dB]	8,9	6,9	-8,5	-5,5
$\Delta L_{tn,j,k}$ j = 5 [dB]	15,1	6,8	-4,5	-7,4
$\Delta L_{tn,j,k}$ j = 6 [dB]	12,8	13,1	-5,3	-3,2
$\Delta L_{tn,j,k}$ j = 7 [dB]	13,0	8,6		-2,6
$\Delta L_{tn,j,k}$ j = 8 [dB]	7,5	6,8	-1,8	-2,1
$\Delta L_{tn,j,k}$ j = 9 [dB]	8,9	5,3	-5,7	-5,2
$\Delta L_{tn,j,k}$ j = 10 [dB]	9,3	2,5	-5,3	-7,0
$\Delta L_{tn,j,k}$ j = 11 [dB]	14,9	6,5	-7,6	-5,0
$\Delta L_{tn,j,k}$ j = 12 [dB]	15,1		-4,1	-5,8
ΔL_K [dB]	12,2	6,9	-4,8	-4,4
L_a [dB]	-2,9	-2,9	-2,9	-2,9
$\Delta L_{a,k}$ [dB]	15,1	9,8	-1,9	-1,5