



Balgray Wind Farm

Chapter 10: Noise

June 2025

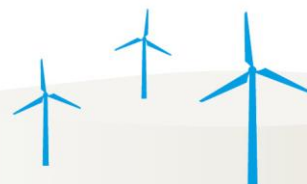


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Abbreviation	Description
AM	Amplitude Modulation
BESS	Battery Energy Storage System
BS	British Standard
CEMP	Construction Environmental Management Plan
ECU	Energy Consents Unit
EIA	Environmental Impact Assessment
ETSU	Energy Technology Support Unit
GPG	Good Practice Guide
IoA	Institute of Acoustics
ISO	International Organisation for Standardisation
OAM	Other Amplitude Modulation
PAN	Planning Advice Note
WHO	World Health Organisation



10. Noise

10.1 Introduction

- 10.1.1 This chapter provides an assessment of the noise and vibration impact of the Proposed Development. The operational noise assessment for the wind turbines has been carried out according to the Energy Technology Support Unit (ETSU) report ETSU-R-97 and the Institute of Acoustics Good Practice Guide. This is the approved assessment method stated in Scottish Government guidance for onshore wind turbines. The ETSU guidance advises on noise limits for wind turbines which are thought to *“offer a reasonable degree of protection to wind farm neighbours, without placing unreasonable restrictions on wind farm development”*.
- 10.1.2 This chapter has been prepared by Gavin Irvine from Ion Acoustics Ltd for Fred. Olsen Renewables. Gavin Irvine is a Member of the Institute of Acoustics and has worked on wind turbine noise assessment for 30 years.
- 10.1.3 Noise predictions for operation of the Proposed Development are presented here based on noise data for Vestas V162 7.2MW wind turbines with a 119m hub height (200m to blade tip). The predictions have been carried out according to ISO 9613-2 with input parameters and limitations specified in the Institute of Acoustic’s Good Practice Guide (IoA GPG).
- 10.1.4 The predicted noise levels are compared with the lower daytime noise limit of 35 dB L_{A90} or 5 dB(A) above the background noise, whichever is the greater. A baseline noise survey has been carried out to determine the prevailing background noise levels in the area.
- 10.1.5 Various electrical equipment associated with the Battery Energy Storage System (BESS) can also make a noise including transformers and inverters. However, this noise is rarely audible beyond the site boundary. Noise predictions for the BESS are also presented here with the results compared to a fixed limit of 35 dB L_{Aeq} .
- 10.1.6 Noise can also be generated during the construction period from the excavation of the turbine foundations and trenches for cables, the construction of new access tracks and hard standings and from the erection of the turbines themselves. Most of these activities will occur within the main site far from residential properties. Noise from the transportation of construction materials and turbine and BESS components will also occur on local roads.
- 10.1.7 In view of its remote location, and the fact that construction noise is temporary, occurring generally during the working day only, a formal numerical construction noise assessment is not included here. However, a Construction Environmental Management Plan (CEMP) will be prepared for agreement with the local authority. This will detail how construction noise and vibration can be controlled using best practicable means. It will also provide details of the normal



working hours. Best practicable means involves using all measures to reduce noise subject to practicality and cost. It is expected that a suitably worded Planning Condition will be applied to any consent for the Proposed Development requiring the CEMP to be prepared and approved by Dumfries and Galloway Council post consent and prior to the commencement of construction works.

- 10.1.8 Noise during the decommissioning phase will be similar to the construction phase and again no numerical assessment is proposed.
- 10.1.9 The scheme is close to (but outside) the 15km exclusion which has been proposed to protect the seismic monitoring station at Eskdalemuir from extraneous vibration. Vibration from wind turbines is not an issue for people as the levels are below human perception thresholds even within the Site. However, the vibration can be detected by highly sensitive seismic equipment near to the turbines, hence the exclusion zone. This issue, and established mitigation principles are discussed separately in Section 15, Other Issues.

10.2 Policy and Guidance

Dumfries and Galloway Guidance

- 10.2.1 Dumfries and Galloway Council's Supplementary Guidance specifically Wind Energy Development from February 2020 requires consideration of noise impacts from the construction and operation of wind farms. Paragraph E11 states:

“Generally schemes can be sited with sufficient distance from noise sensitive development to ensure ambient noise levels are acceptable. For all large and medium turbines a full site-specific noise impact assessment following ETSU-R-97 and Institute of Acoustics methodology (or subsequent accepted national guidelines), which includes cumulative impact, would be required for all appropriate noise sensitive properties as agreed with Environmental Health. Manufacturer's noise information data should be provided for all schemes which include turbines below 50m in height to blade tip.”

Scottish Government Guidance

- 10.2.2 Scottish Government advice on noise issues for planning is provided in Planning Advice Note (PAN) 1/2011 'Planning and Noise'¹. In relation to wind turbines, the document states: *“Good acoustical design and siting of turbines is essential to minimise the potential to generate noise.”* PAN 1/2011 then refers to online planning advice for renewable energy technologies.

¹ <https://www.gov.scot/publications/planning-advice-note-1-2011-planning-noise/>



10.2.3 Scottish Government information and planning advice on the technologies for renewable energy is available in the form of a series of online advice documents. The document Onshore Wind Turbines: planning advice² from May 2014 is applicable.

10.2.4 In respect the noise, the guidance refers to ETSU-R-97 and the Institute of Acoustics Good Practice Guide as well as online technical guidance on noise impact assessment.

ETSU-R-97

10.2.5 The assessment methodology for operational noise is described in ETSU-R-97 'The Assessment and Rating of Noise from Windfarms'³. The basic aim of ETSU-R-97 is to provide:

"Indicative noise levels thought 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 local authorities".

10.2.6 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 'background noise', that is the underlying noise level in the absence of short-term events. This unit was chosen to assess turbine noise, which is fairly steady, because extraneous short-term events such as discrete car passes, and aircraft do not usually affect the L_{A90} value. For wind turbine noise, the L_{A90} is typically 2 dB less than the L_{Aeq} parameter. The L_{Aeq} is defined as the equivalent steady-state noise level with the same energy as the fluctuating noise level over a time period.

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

- relative to the background noise (L_{A90} dB); or
- fixed at an absolute limit when background noise levels are otherwise very low.

10.2.8 The background noise depends on the wind speed. 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

² <https://www.gov.scot/publications/onshore-wind-turbines-planning-advice/>

³

https://assets.publishing.service.gov.uk/media/5a798b42ed915d07d35b655a/ETSU_Full_copy__Searchable_.pdf



and is often sufficient to mask the sound of wind turbines. Therefore, it is often at lower wind speeds that the turbines could be audible.

10.2.9 The ETSU-R-97 limits are set relative to the prevailing background noise. The prevailing background is 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).

10.2.10 For the daytime (which applies from 07.00 to 23.00 hours), the suggested noise limits are 35 to 40 dB L_{A90} or 5 dB above the prevailing amenity hours daytime 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.

10.2.11 For night-time periods, the ETSU noise limit is 43 dB L_{A90} or 5 dB above the background, whichever is the greater. The 43 dB L_{A90} limit was derived from 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} .

10.2.12 The ETSU-R-97 night-time limit was partly based on the previous World Health Organisation (WHO) internal noise standard of 35dB L_{Aeq} . Since the publication of ETSU-R-97, a later WHO document 'Guidelines for Community Noise'⁴ reduced the internal night-time noise standard to 30dB L_{Aeq} "*to avoid negative effects on sleep*". The same WHO guidelines recommend that "*at night-time, outside sound levels approx. 1 metre from facades of living spaces should not exceed 45dB L_{Aeq} , so that people may sleep with bedroom windows open*". This was based on a reduction of 15dB for the sound level difference between the inside and outside with an open window. The WHO 45dB L_{Aeq} external noise limit at 1m from a façade translates to a limit of 42dB L_{Aeq} in free-field conditions, away from the façade, or 40dB L_{A90} when applied to wind turbine noise.

⁴ WHO Task Group on Environmental Health Criteria for Noise (1980). World Health Organization.
<https://apps.who.int/iris/handle/10665/39458>



Therefore, there is an argument for reducing the ETSU-R-97 external noise limit to 40 dB L_{A90} to protect sleep.

- 10.2.13 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 35 dB(A) up to wind speeds of 10 m/s at 10 m height, then this condition alone would offer sufficient protection of amenity and background noise surveys would be unnecessary”.

- 10.2.14 ETSU-R-97 allows for a higher limit at properties where the occupiers are ‘financially involved’ with the wind turbine development. The suggested limit is 45 dB L_{A90} , or 5 dB above the background noise, whichever is the greater, for both the daytime and night-time periods. It is understood that the property Balgray Hill is owned by the landowner associated with the Proposed Development. However, it is occupied by tenant farmers and therefore would not be considered financially involved. The standard limit of 35 dB L_{A90} or the background noise dB $L_{A90} + 5dB$ (whichever is the greater) would apply and can be met at this location in any case.

- 10.2.15 Where audible tones are present in the noise spectrum, ETSU-R-97 stipulates that a tonal penalty of up to 5 dB be added to the turbine noise levels. The magnitude of the tonal penalty depends on the audibility of the tone.

Institute of Acoustics Good Practice Guide

- 10.2.16 In May 2013, the Institute of Acoustics (IoA) published the ‘Good Practice Guide to the Application of ETSU-R-97 for the Assessment and Rating of Wind Turbine Noise’⁵. The document was prepared with the purpose of agreeing current good practice in the application of the ETSU-R-97 methodology and predicted turbine noise levels (which was not addressed in ETSU-R-97). The document was prepared by a specialist working group and reviewed by a peer group of professionals working in a variety of relevant disciplines. A discussion of ETSU-R-97 noise limits was excluded from the remit of the working group as these are a matter of UK Government policy.
- 10.2.17 The Scottish Government has formally endorsed the IoA Good Practice Guide (GPG) and accepts that the guide represents current industry good practice. Since May 2013, a number of supplementary guidance notes have also been published providing further detail. The IoA GPG and the supplementary guidance notes should be regarded as a refinement of the ETSU-R-97 guidance to ensure consistency, and the noise assessment will follow the guidelines stated therein.

⁵ Institute of Acoustics (2013) A Good Practice Guide to the application of ETSU-R-97 for the assessment and rating of wind farm noise <https://www.ioa.org.uk/publications/wind-turbine-noise>



10.2.18 The GPG provides general advice on noise monitoring and data processing for noise surveys. It also clarifies a number of issues including the following:

- The background noise survey should be of sufficient duration that no fewer than 200 valid data points are obtained for each of the amenity hours and night-time periods with no fewer than five valid points in any 1 m/s wind speed bin.
- The background noise measurements (and thereby noise limits) should preferably be corrected for wind shear by correlating the background noise measurements with the standardised wind speed at 10 m height. The standardised wind speed is defined as the wind speed at 10 m height which is derived from the hub height wind speed using a standard equation.
- That ISO 9613-2 is to be used for wind turbine noise predictions, with certain stipulations and limitations as follows:
 - The turbine sound power levels should be stated, and information provided on whether these are measured levels, measured levels with an allowance for measurement uncertainty, warranted levels or generic levels;
 - Downwind propagation should normally be considered to represent the worst case;
 - The atmospheric conditions assumed should be stated, with 10°C and 70 per cent Relative Humidity preferred;
 - The ground factor assumed should be either (i) $G = 0$ (hard ground), together with measured sound power levels; or (ii) $G = 0.5$ (mixed ground); together with a receiver height of 4.0 m and either manufacturer's warranted sound power levels or measured sound power levels plus an allowance for measurement uncertainty;
 - Barrier attenuation (where applicable) should be limited to 2 dB; and
 - The predicted noise levels ($L_{Aeq,t}$) may be converted to the required $L_{A90,10min}$ by subtracting 2 decibels (dB).
- Consideration of cumulative noise issues including:
 - How noise impacts from existing and consented wind farm schemes must be assessed; and
 - The use of directivity corrections for specific situations so that the effect of wind direction on noise propagation can be accounted for.



This is important in respect of cumulative noise level as some receptor location which cannot be downwind of all turbines at the same time.

ISO 9613-2

- 10.2.19 ETSU-R-97 does not prescribe a calculation method for predicting wind turbine noise. However, in accordance with the Institute of Acoustics Good Practice Guide described above, this study has used ISO 9613-2 ‘Attenuation of sound during propagation outdoors’⁶. The standard has recently been revised and adopted as a British Standard (BS EN ISO 9613-2: 2024) but it should be noted that the Institute of Acoustics Good Practice Guide uses the older standard with specified input parameters and refinements and therefore ISO 9613-2: 1996 and the IoA GPG will be used in this assessment in accordance with Scottish Government advice.
- 10.2.20 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 scenario. When the wind is blowing in the opposite direction, that is when a house is upwind of the turbine, noise levels will be reduced by as much as 10dB.
- 10.2.21 Noise from wind turbines is reduced by distance, atmospheric losses, screening effects 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:
- $$\text{Predicted Noise Level } L_{90} = L_{W (eq)} + D - A_{geo} - A_{atm} - A_{gr} - A_{bar} - A_{misc} - 2\text{dB}$$
- 10.2.22 The calculation is carried out for each octave frequency band and then the predicted octave band levels are summed together to give the overall A-weighted predicted sound level. Distance loss (or A_{geo} in the equation above) is the most significant factor. The correction of 2 dB 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. Further detail on the attenuation factors and the ISO 9613-2 calculation is provided in Appendix 10.1.
- 10.2.23 The basic ISO 9613-2 calculation formula described above has been shown to underestimate noise levels for propagation across valleys or for terrain with a concave ground profile. This is because multiple ground reflections can occur

⁶ International Standards Organisation (ISO) ISO 9613-2: 1996 Attenuation of sound during propagation outdoors – Part 2: General method of calculation



which combine at the receptor location to increase noise levels as shown in Figure 10.1 below.

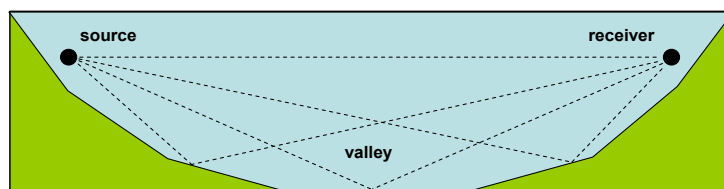


Figure 10.1: Multiple reflection paths for sound propagation across concave ground

- 10.2.24 To compensate for this, the GPG recommends a +3dB valley correction be applied to the noise level of a turbine when a certain criterion is met, defined below:

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

Where h_m is the mean height above the ground of the direct line of sight from the receiver to the source, and h_s and h_r are the heights above local ground level of the source and receiver respectively.

British Standard BS 4142: 2014+A1:2019

- 10.2.25 Specific guidance on the assessment of wind turbines is described above. However, the battery energy storage scheme would be assessed differently. In this case, it is envisaged that an assessment would be made according to British Standard BS 4142 “Method for rating and assessing industrial and commercial sound” as this is the usual way of assessing commercial, plant or industrial noise affecting housing. A BS 4142 assessment is typically made by determining the difference between the industrial noise under consideration and the background sound level as represented by the L_{A90} parameter, determined in the absence of the industrial noise. The L_{A90} parameter is defined as the level exceeded for 90% of the measurement time, representing the underlying noise in the absence of short duration noise events such as dog barks or individual cars passing.
- 10.2.26 The industrial noise under consideration is assessed in terms of the ambient noise level, L_{Aeq} , but a character correction penalty can be applied where the noise exhibits certain characteristics such as distinguishable tones, impulsiveness or, if the noise is distinctively intermittent. The ambient noise level, L_{Aeq} is defined as the steady-state noise level with the same energy as the actual fluctuating sound over the same time period. It is effectively the average noise level during the period. The industrial noise level (L_{Aeq}) with the character correction (if necessary) is known as rating level, L_{Ar} , and the difference between the background noise and the rating level is determined to make the BS 4142 assessment. The standard then states:



- a) *“Typically, the greater the difference, the greater the magnitude of the impact.*
- b) *A difference of around +10dB or more is likely to be an indication of a significant adverse impact, depending on the context.*
- c) *A difference of around +5dB is likely to be an indication of an adverse impact, depending on the context.*
- d) *The lower the rating level is relative to the measured background sound level, the less likely it is that the specific sound will have an adverse impact or a significant adverse impact. Where the rating level does not exceed the background sound level, this is an indication of the specific sound source having a low impact, depending on the context.”*

10.2.27 With regard to the quantification of the background noise level L_{A90} , BS 4142: 2014 states:

In using the background sound level in the method for rating and assessing industrial and commercial sound, it is important to ensure that values are reliable and suitably represent both the particular circumstances and periods of interest. For this purpose, the objective is not simply to ascertain a lowest measured background sound level, but rather to quantify what is typical during particular time periods.

10.2.28 The standard outlines a number of methods for defining appropriate ‘character corrections’ to determine the rating levels to account for tonal qualities, impulsive qualities, other sound characteristics and/or intermittency.

10.2.29 The standard also highlights the importance of considering the context in which a sound occurs. The standard indicates that factors including the absolute sound level, the character of the sound, the sensitivity of the receptor and the existing acoustic character of the area should be considered when assessing the noise impact.

10.2.30 The absolute sound level is of particular importance where the measured background sound levels are low, which is typically taken as L_{A90} 30dB and below. In regard to low sound levels, the standard states:

“Where background sound levels and rating levels are low, absolute levels might be as, or more, relevant than the margin by which the rating level exceeds the background. This is especially true at night.”

10.2.31 For the Proposed Development, where background noise levels are expected to be fairly low, it is proposed to adopt a fixed level of 35 dB L_{Aeq} as an absolute noise limit. This is 10dB below World Health Organisation guidance to prevent sleep disturbance. This limit would be defined as the BS 4142 rating level including any character corrections, that is 35 dB L_{Ar} .



10.3 Consultation

- 10.3.1 The Applicant submitted an Environmental Impact Assessment (EIA) Scoping Report to the Energy Consents Unit in December 2023 and received an EIA Scoping Opinion in April 2024. The Proposed Development and assessment methodology has been discussed with William Jackson, an Environment Health Officer with Dumfries and Galloway Council.
- 10.3.2 Mr Jackson confirmed that the Council would seek to impose the lower ETSU noise limits on the development (35 dB(A) or 5 dB(A) above the background noise whichever was the greater. This is accepted. Further consultation was carried out to agree the noise monitoring positions.

10.4 Baseline Noise Levels

- 10.4.1 The Proposed Development is in a rural area and the nearest locations are either farms or isolated properties. As such noise levels are likely to be dominated by natural sources including streams and the wind blowing in the trees and other vegetation. There would be some distant traffic noise from the roads to the west including the M74 motorway and noise from Steven's Croft Power Station is also heard at some locations. Agricultural activity would also be expected to be heard occasionally.
- 10.4.2 A noise survey at the Site was carried out by others in respect of a previous (refused) proposal (Newfield Wind Farm) during December 2006 to January 2007 but the noise data is not available on the planning portal and in any case the survey predates the Institute of Acoustics Good Practice Guide and therefore the data would need reanalysed.
- 10.4.3 A new noise survey was carried out by Ion Acoustics from 15th November 2024 to 17th December 2024 to enable ETSU-R-97 limits to be set for the scheme based on the background noise. Dumfries and Galloway Council were consulted with regard to the noise monitoring positions and methodology.

Measurement Details

- 10.4.4 The agreed noise monitoring positions were as follows:
- Hutton Lodge to the north
 - Corsehill to the north-east.
 - Balgray Hill Farm to the south (and closest to the BESS area).
- 10.4.5 The equipment used and the measurement positions are described in more detail in Table 10.1 below together with the approximate grid location. The locations are shown also shown on the Noise Contour Plot in Technical Appendix 10.5.



Table 10.1: Details of the Noise Monitoring Positions

Location	Easting	Northing	Meter	Comments
Hutton Lodge	316488	589731	Rion NL-52	The meter was set up in the rear garden. Noises heard in this location included birds, distant traffic noise and aircraft noise. A tipping bucket rain gauge was also set up in this location.
Corsehill	317822,	589615	01dB Duo	The meter was set up at the back of the property. The area was fairly quiet although cows in the field across the road were heard at set-up. It is possible that distant road traffic was audible as a low rumble.
Balgray Hill Farm	315478	586315	Larson-Davis LD-820	The meter was set up in the garden of the property. The dogs around the farm were barking during our visits. Noise from the A74(M) was audible and the resident reported that the Stephen's Croft Wood Chip power station is usually audible.

10.4.6 The sound level meters were set-up to log various noise levels (dB L_{Aeq}, dB L_{A90}, etc) in 10-minute periods. The microphones were fitted with double-skin windshields in accordance with the recommendations of the Institute of Acoustics Good Practice Guide and mounted on tripods at a height of 1.2-1.5m above ground level. The time clocks of the sound level meters were synchronised with UTC.

10.4.7 The equipment was calibrated using a Brüel & Kjær Type 4231 sound level calibrator. The meters and calibrator are calibrated to national standards biennially and annually respectively in line with the recommendations of the IoA GPG. The difference in calibration levels did not exceed 0.1 dB at any location which is within accepted tolerances. Calibration charts for the equipment are available on request.

10.4.8 Photos of the measurement locations are provided in Appendix 10.2.

10.4.9 For the noise survey, wind speed and direction measurements were made using a ZX300 Lidar unit installed on the Site at approximate Ordnance Survey grid reference 316352, 587929.

10.4.10 The Institute of Acoustics' Good Practice Guide requires that wind shear on the Site be taken into account in noise assessments. Therefore, the use of the standardised wind speed at 10m height is required. This can be derived from the hub height wind speed according to the log law equation describing the variation in wind speed with height above ground (see the equation below) and with the ground roughness set at 0.05m.



$$v_{10} = v_{hh} \times \left(\frac{\ln \left[\frac{10}{z_0} \right]}{\ln \left[\frac{hh}{z_0} \right]} \right)$$

- 10.4.11 Where v_{10} and v_{hh} are wind speeds at heights of 10m and hub height (119m) respectively, and z_0 is the standard ground roughness length (0.05m).
- 10.4.12 The Lidar provides measurements of wind speeds at various heights including 119m. For this site, the wind speed at the hub height (119m) was taken directly from the Lidar data and corrected to the standardised wind speed at 10m height using the equation above.
- 10.4.13 The use of the standardised wind speed ensures that both the background noise measurements and predicted wind turbine sound levels are described with the same wind speed reference, i.e. at 10m height but derived from the hub height wind speed using the same equation. This method allows for wind shear to be factored directly into the background noise measurements to reduce the uncertainties due to the wind shear experienced on site as recommended by the Institute of Acoustics' Good Practice Guide. The wind speed and direction during the survey is shown in Appendix 10.3.
- 10.4.14 The Lidar wind data was subject to a quality control procedure to remove potentially invalid samples; this is the reason why occasionally no wind speed data is shown. Sometimes this occurs due to rain when the readings are less reliable. Noise data with rain is excluded in any case for the ETSU-R-97 analysis.

Data Processing

- 10.4.15 The measured noise level, standardised wind speed and rain data have been correlated to obtain time history plots showing the daily variation of noise, wind speed and rain fall. Further inspections of the data have been carried out and in some cases the audio data has been used to identify and exclude spurious noises which are not regarded as typical. There were few such periods identified. The time history plots are available in electronic form on request.
- 10.4.16 The data from the time history plots has been sorted into data sets and then plotted to obtain scatter plots showing the variation of background noise versus the standardised wind speed for the ETSU-R-97 daytime amenity hours (AH) and night periods. These scatter plots are shown in Appendix 10.4. Best fit trendlines are plotted for background noise values. The predicted noise level for the property is also shown. The background noise values (L_{A90} dB) calculated from the derived trendlines are presented in Table 10.2 for standardised wind speeds from 3 to 10 m/s at 10m height.



Table 10.2: Prevailing Background Noise Levels Derived from the Survey

Location	Period	Prevailing Background Noise Level dB L _{A90} at Standardised Wind Speeds (m/s) at 10m Height							
		3	4	5	6	7	8	9	10
Hutton Lodge	AH Day	27.3	28.0	29.6	32.0	34.9	38.0	41.3	44.3
	Night	26.9	27.8	29.4	31.6	34.3	37.2	40.4	43.5
Corsehill	AH Day	23.6	24.9	26.6	28.8	31.3	34.0	36.9	39.7
	Night	21.8	23.0	25.0	27.6	30.6	33.9	37.4	40.7
Balgray Hill Farm	AH Day	32.4	33.1	34.1	35.6	37.3	39.2	41.2	43.1
	Night	31.3	32.1	33.2	34.6	36.2	38.0	39.9	41.9

10.4.17 There is some variation between the positions, Corsehill has the lowest noise levels as it is furthest from the roads to the west and is on the leese of the Balgray site. Balgray Hill farm has the highest noise levels as the motorway and the power station are visible to the west and contribute to the background noise and because the property is also a working farm.

10.4.18 Noise limits will be set in relation to these results in accordance with ETSU-R-97. The lower daytime limit is adopted in accordance with the Dumfries and Galloway requirements. (35 dB L_{A90} or the background noise level +5dB(A) whichever is the higher. The ETSU-R-97 night-time limit will apply in respect of night-time noise levels (43 dB L_{A90} or the background noise +5dB) although it is not proposed to increase turbine noise levels at night.

10.5 Predicted Operational Effects – Wind Turbine Noise

Prediction Methodology

10.5.1 Computer noise modelling software (IMMI) implementing the ISO 9613-2 methodology described above has been used to predict noise levels from the wind turbines. The following modelling assumptions have been made in line with the current agreed best practice described in the Institute of Acoustics Good Practice Guide:

- Downwind propagation to reflect the worst case in terms of propagation;
- A +2dB margin is applied to the turbine sound power data to account for uncertainty;
- mixed ground absorption (G=0.5) is assumed with a receiver height of 4 metres;
- ambient air temperature of 10 °C and 70% relative humidity;



- barrier attenuation is limited to 2 dB;
- Predictions to key receptors have been checked to determine whether the valley correction applies.

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

10.5.3 The predictions have not included any allowance for a tonal penalty. Therefore, it will be necessary to procure turbines which are free from tones which could incur a penalty. The turbine supply agreement should ensure that there is an appropriate warranty in respect of tones.

Turbine Sound Levels

10.5.4 A candidate turbine for this site is a Vestas V162 7.2 MW wind turbine with a 119m hub height. The turbine blades are fitted with Serrated Trailing Edges (STE) to reduce noise levels.

10.5.5 At the time of writing noise data is not available for this turbine but noise levels for the 6.2MW variant have been used. The variation in noise with the standardised wind speed at 10m height is set out below in Table 10.3.

Table 10.3: Vestas V162 6.2MW STE Turbine A-weighted Sound Power Levels + 2dB uncertainty

Turbine	A-Weighted Sound Power Levels dB $L_{WA(eq)}$ at Standardised Wind Speeds (m/s) at 10m Height							
	3	4	5	6	7	8	9	10
V162 6.2MW with Serrated Trailing Edges	96.2	98.0	102.1	106.3	106.8	106.8	106.8	106.8

10.5.6 To carry out the predictions, a frequency spectrum must be used. The octave band frequency spectrum of the V162 6.2MW with serrated trailing edges has been obtained from a Vestas data sheet. This has been corrected to a maximum sound power level of 106.8 dB including +2dB uncertainty. The spectrum used in the calculations is shown in Table 10.4 below

Table 10.4: Vestas V162 6.2MW STE Turbine Octave Band Sound Power Levels at Rated Power + 2dB uncertainty

Turbine	Overall Sound Power dB L_{WA}	A-Weighted Sound Power Levels dB $L_{WA(eq)}$ at Octave Band Centre Frequencies, Hz							
		63	125	250	500	1000	2000	4000	8000
V162 6.2MW	106.8	88.8	96.6	101.5	102.0	99.4	95.1	88.0	77.7



10.5.7 For commercial reasons, it is not possible to state which turbine will definitely be used at this stage. The final choice of turbine will depend on many factors, including the noise output. The options will be studied carefully by the developer and turbine supplier when the turbines are procured and will be selected to be compliant with the planning noise limits. In addition, a tonal warranty should be obtained to ensure that the turbines are free from tonal components which would result in a tonal penalty.

Predicted Noise Levels

10.5.8 The nearest noise-sensitive receptors have been identified from scoping inspection of various mapping sources. These are stated below together with the distance from the nearest turbine and the approximate Ordnance Survey grid reference.

10.5.9 The noise predictions have been carried out in the first instance as a noise contour plot for the Vestas V162 turbine. The contour plot is shown in Technical Appendix 10.5. It can be seen that all locations are outwith the 35 dB L_{A90} contour except for Hutton Lodge where the predicted noise level is 35.1 dB L_{A90} . This is deemed compliant as the 35 dB L_{A90} simplified limit is expressed as an integer value.

10.5.10 Predictions have also been carried out to the individual receptors. The results are shown in Table 10.5.

Table 10.5: Balgray Wind Farm – Predicted Noise Levels at Rated Power

Location	Easting	Northing	Noise Level at Rated Power dB L_{A90}	Distance (m) to nearest Turbine
Corsehill	317802	589661	33.2	1560m (T5)
Heithatpark	318094	589467	33.2	1576m (T5)
Cumstone	318472	586109	31.1	1760m (T1)
Cumstone Cottage	318465	585769	29.5	2038m (T1)
Rockhillflat Farm	314882	587191	32.4	1725m (T2)
Balgray Home Farm Cottages	314625	586768	30.0	2073m (T2)
Unknown Name	314807	588404	30.6	1626m (T3)
West and East Lodge	314590	588621	30.3	1893m (T3)
Mid Cottage	314744	586421	29.7	2104m (T2)
Nether Hutton	316221	589794	34.1	1210m (T6)
Hutton Lodge	316475	589731	35.1	1090m (T6)
River House	315943	589936	30.7	1451m (T6)



Location	Easting	Northing	Noise Level at Rated Power dB L _{A90}	Distance (m) to nearest Turbine
Croftfoot	315468	589911	31.4	1704m (T6)
Hallhill Farm	314947	587978	33.7	1446m (T3)
Hallhills Cottage	314913	588006	33.4	1479m (T3)
Barnsdale	315723	590083	31.2	1687m (T6)
Trelawney Cottage	314674	588796	29.9	1877m (T3)
River Cottage	314671	588782	29.9	1874m (T3)
Bundhill Bush	315231	589947	30.5	1896m (T6)
Cocklets Cottage	314598	588977	30.7	2024m (T3)
Whitegates	314572	588947	30.6	2033m (T3)
Cocklets	314560	588944	30.6	2043m (T3)
Kirkcroft	314832	587768	31.0	1583m (T3)
The Hewke	314552	588577	30.2	1917m (T3)
Stobohill	318775	587778	33.0	1394m (T1)
Balgray Hill	315501	586318	32.5	1556m (T2)
Hewkemill	314484	588665	30.0	2008m (T3)
Old School House	314659	587683	29.8	1769m (T3)
Top Cottages	314883	586293	29.8	2051m (T2)
Stobohill Cottage	318723	588513	33.3	1654m (T1)
Gillenbie Cottage	318081	585595	29.9	2031m (T1)
Gall Farm	316977	590083	32.9	1478m (T6)
The Gall	317160	590080	32.7	1531m (T6)
The Gall 2	317209	590071	32.6	1541m (T6)

10.5.11 For the properties where noise monitoring has been carried out, a more detailed analysis can be carried out to assess noise levels against the ETSU-R-97 daytime and night-time limits. This is set out in Table 10.6 to 10.8 below for the three properties.

10.5.12 For this analysis the lower ETSU-R-97 daytime limit (35 dB L_{A90}) is assumed and a night-time limit based on 40 dB L_{A90} or 5 dB above the background noise is assumed. A margin of compliance is given with a positive value indicating compliance with the limit.



Table 10.6: ETSU-R-97 Assessment for Hutton Lodge

Hutton Lodge	Noise Level dB L_{A90} at Standardised Wind Speeds (m/s) at 10m Height							
	3	4	5	6	7	8	9	10
Predicted Noise Level	24.5	26.3	30.4	34.6	35.1	35.1	35.1	35.1
Amenity Hours Background noise	27.3	28.0	29.6	32.0	34.9	38.0	41.3	44.3
ETSU Lower Daytime Limit (35 dB(A) or BG + 5 dB whichever is the greater)	35.0	35.0	35.0	37.0	39.9	43.0	46.3	49.3
Margin of Compliance relative to Limit	10.5	8.7	4.6	2.4	4.8	7.9	11.2	14.2
Night-time Background Noise	26.9	27.8	29.4	31.6	34.3	37.2	40.4	43.5
Night-time Limit Based on 40 dB(A) or BG + 5 dB whichever is the greater	40	40	40	40	40	42.2	45.4	48.5
Margin of Compliance relative to Limit	15.5	13.7	9.6	5.4	4.9	7.1	10.3	13.4

10.5.13 Noise levels are compliant with ETSU-R-97 noise limits based on the measured background noise with a minimum margin of compliance of 2dB. Noise levels in the range 5 to 7 m/s exceed the background noise and therefore, despite meeting the limits, it is possible that turbine noise will be audible at this location at certain times albeit at a low level.

Table 10.7: ETSU-R-97 Assessment for Corsehill

Corsehill	Noise Level dB L_{A90} at Standardised Wind Speeds (m/s) at 10m Height							
	3	4	5	6	7	8	9	10
Predicted Noise Level	22.6	24.4	28.5	32.7	33.2	33.2	33.2	33.2
Amenity Hours Background noise	23.6	24.9	26.6	28.8	31.3	34	36.9	39.7
ETSU Lower Daytime Limit (35 dB(A) or BG + 5 dB whichever is the greater)	35	35	35	35	36.3	39	41.9	44.7
Margin of Compliance relative to Limit	12.4	10.6	6.5	2.3	3.1	5.8	8.7	11.5
Night-time Background Noise	21.8	23	25	27.6	30.6	33.9	37.4	40.7
Night-time Limit Based on 40 dB(A) or BG + 5 dB whichever is the greater	40	40	40	40	40	40	42.4	45.7
Margin of Compliance relative to Limit	17.4	15.6	11.5	7.3	6.8	6.8	9.2	12.5

10.5.14 The situation at Corsehill is similar to Hutton Lodge with a minimum margin of compliance of 2dB. Noise levels also exceed the background noise and therefore turbine noise can be audible at certain times.



Table 10.8: ETSU-R-97 Assessment for Balgray Hill Farm

Balgray Hill Farm	Noise Level dB L _{A90} at Standardised Wind Speeds (m/s) at 10m Height							
	3	4	5	6	7	8	9	10
Predicted Noise Level	21.9	23.7	27.8	32.0	32.5	32.5	32.5	32.5
Amenity Hours Background noise	32.4	33.1	34.1	35.6	37.3	39.2	41.2	43.1
ETSU Lower Daytime Limit (35 dB(A) or BG + 5 dB whichever is the greater)	37.4	38.1	39.1	40.6	42.3	44.2	46.2	48.1
Margin of Compliance relative to Limit	15.5	14.4	11.3	8.6	9.8	11.7	13.7	15.6
Night-time Background Noise	31.3	32.1	33.2	34.6	36.2	38	39.9	41.9
Night-time Limit Based on 40 dB(A) or BG + 5 dB whichever is the greater	40	40	40	40	41.2	43	44.9	46.9
Margin of Compliance relative to Limit	18.1	16.3	12.2	8.0	8.7	10.5	12.4	14.4

10.5.15 Background noise levels at Balgray Hill Farm are significantly noisier than the other two locations as the farm is more exposed to road traffic noise from the A74(M) and has more noise from farming activity. The noise limits are met with a good margin of compliance.

10.5.16 Balgray Hill Farm is also potentially affected by noise from the proposed BESS for which a limit of 35 dB L_{Aeq} is proposed. The wind farm noise can be corrected to an L_{Aeq} level by adding 2dB and therefore at rated power (for the wind farm) the maximum noise level at this location would be around 38 dB L_{Aeq} (34.5 L_{Aeq} + 35 dB L_{Aeq}). This combined level is lower than the wind farm limits proposed above for wind speeds above 4 m/s. At 3 m/s and 4 m/s the wind farm noise is negligible in any case.

Other Operational Effects

Tonal Noise

10.5.17 The predictions above exclude any penalties for tonality. Modern wind turbines have been designed to reduce tones to levels below perception thresholds, even though tones are sometimes measurable. A tonal warranty should be provided when procuring the turbines.

Vibration

10.5.18 Vibration from wind turbines has 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 turbine sites. There is, therefore, no impact from vibration as a result of wind turbine developments.



- 10.5.19 The potential for the scheme to affect Eskdalemuir is considered in Section 15 Other Issues.

Low Frequency Noise and Infrasound

- 10.5.20 Infrasound, low frequency noise and vibration are often reported as noise issues in the media. Infrasound is usually defined as sound below 20Hz, whereas the frequency range for low frequency sound is often taken to be from 10Hz to 200Hz.
- 10.5.21 Infrasound and low frequency noise can be measured from wind turbines. However various studies have found no evidence of health effects from infrasound or low frequency sound.

Amplitude Modulation

- 10.5.22 Since 2005 / 2006 a phenomenon known as Amplitude Modulation (AM) has been found to be a factor in some noise complaints in ways not anticipated by ETSU-R-97. ETSU-R-97 described blade swish, which is a form of AM, but is only heard relatively close to the turbines. The term Other Amplitude Modulation (OAM) is sometimes used to differentiate low frequency, far-field amplitude modulation from blade swish, but it is not necessary to make a distinction when considering the effect at residential properties.
- 10.5.23 AM is defined as periodic fluctuations in the level of audible noise from a wind turbine (or wind turbines), the frequency of the fluctuations being related to the blade passing frequency of the turbine rotor(s). For a three-bladed turbine rotating at 20 revolutions per minute (rpm), this equates to a fluctuation in noise once per second. The wind industry trade body, Renewable UK, in December 2013 published research into AM⁷. This included theoretical research on mechanisms causing the problem and subjective tests to determine a dose-response relationship. More recently, the IoA has published an agreed numerical rating method⁸ and a further Government-commissioned report by WSP PB⁹ has considered how the issue might be addressed in respect of planning.
- 10.5.24 The IoA AM rating method has been adopted in the WSP report, with recommendations on how a penalty mechanism might be incorporated into a planning condition. The wording of a possible planning condition was agreed

⁷ Renewable UK (2013) Amplitude Modulation Research to Improve Understanding as to its Cause and Effect

⁸ A Method for Rating Amplitude Modulation in Wind Turbine Noise 9 Aug 2016 Version 1
<https://www.ioa.org.uk/publications/wind-turbine-noise>

⁹ WSP PB Wind Turbine AM Review Phase 1 and Phase 2 <https://www.gov.uk/government/publications/review-of-the-evidence-on-the-response-to-amplitude-modulation-from-wind-turbines>



between various noise consultants and published in Acoustics Bulletin¹⁰; however, the form and application of any penalty scheme is not agreed, and the wording of a planning condition has yet to be approved in any Government guidance.

- 10.5.25 Although, at present it is not possible to assess the likelihood of AM occurring at the planning stage, the published IoA rating mechanism and the emergence of a possible planning condition provides some comfort it can be controlled.

10.6 Predicted Operational Effects – BESS

- 10.6.1 The proposed Battery Energy Storage System (BESS) will include around 78 containerised batteries with associated inverters and transformers. The cooling systems for the equipment can make low noise levels.

- 10.6.2 Initial predictions have been based on the following noise data:

- 78 No. Containerised BYD Batteries with a sound pressure level of 78 dB(A) at 1m assumed to be equivalent to a sound power level of 86 dB L_{WA} .
- 39 No. Power Electronics Gen 3 inverters with twin skid (transformers) with an equivalent sound power levels of 94 dB L_{WA} derived from the test report.

- 10.6.3 If alternative equipment is provided it should be no noisier than the units specified above.

- 10.6.4 From the noise survey, night-time background noise levels at Balgray Hill Farm, depending on wind speed, vary between 31 and 42 dB L_{A90} . BS 4142 indicates that the typical (rather than the lowest) background noise value should be used to set noise limits. Accordingly, a BS 4142 rating level of 35 dB L_{Aeq} is deemed to represent a low noise impact. This is also well below night-time threshold to protect sleep. Noise from the BESS has been modelled and it is confirmed that noise levels can meet the 35 dB L_{Aeq} noise limit at Balgray Hill Farm. Noise levels at other residential properties are well below 25 dB L_{Aeq} .

10.7 Mitigation

Wind Farm Noise

- 10.7.1 Predicted operational noise levels are very low and meet the applicable limits. The wind turbine blades can be provided with trailing edge serrations and low noise modes for the turbines are also available (albeit with a loss in electrical power). The serrated trailing edges are an example of embedded mitigation designed into the scheme. The manufacturer of the wind turbines procured for

¹⁰ McKenzie et. al. (2017) A planning condition for wind turbines Acoustics Bulletin Nov/Dec 2017 published by the Institute of Acoustics



the Site will be required to provide a warranty to ensure sound power levels will not exceed a certain value and that tones are also limited. There is no requirement for further mitigation.

BESS

- 10.7.2 On the basis of the initial predictions, no mitigation is necessary for the proposed BESS. The topography already provides a barrier effect to reduce noise levels. BESS technology is changing rapidly and therefore if a requirement for mitigation to meet the proposed 35 dB L_{Aeq} limit is identified in the future, then noise-reduced options may be available from the technology supplier. Sometimes a solid fence can be provided around the units to provide additional screening. No mitigation is proposed at present although the units to be provided must meet the proposed 35 dB L_{Aeq} noise limit.

10.8 Residual Effects

- 10.8.1 It is possible that turbine noise will be just audible under certain downwind conditions but there will be no residual significant effects.

10.9 Cumulative Effects

- 10.9.1 Cumulative noise levels from the proposed BESS and Balgray turbines have been considered above in paragraph 10.5.15. The proposed wind farm noise limits at Balgray Hill Farm can be met in combination with noise from the BESS.
- 10.9.2 There are no operational wind farms immediately adjacent to, or within the immediate area of the Proposed Development. The nearest consented scheme is Little Hartfell which is some 4.8 km to the east. This is too far to have any impact on noise levels at the receptors considered for this assessment. There are no cumulative noise effects.

10.10 Conclusions and Significance

- 10.10.1 An assessment has been made of the noise impact of the Proposed Development during the operational phases. The operational noise assessment for the wind turbines has been undertaken according to ETSU-R-97 and the IoA GPG. These are the guidance documents recommended in online Scottish Government planning advice for onshore wind turbines. In terms of operational noise, the development can meet the lower simplified limit stated in the guidance document ETSU-R-97. No significant environmental effects are identified.
- 10.10.2 Noise from the operation of the proposed BESS will also be insignificant. A fixed noise limit of 35 dB L_{Aeq} has been proposed for noise from the BESS in line with the guidance in BS4142:2014.



- 10.10.3 Noise during construction and decommissioning will be insignificant for activity on the main wind farm site. Some audible noise will occur from the transportation of construction material and wind farm components. A Construction Environmental Management Plan (CEMP) will be prepared. This will include details of the permitted working hours and measures to control noise and vibration from construction.





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