8. Noise

8.1 Non-Technical Summary

8.1.1 During construction, noise disturbance may result from the use of plant and machinery to carry out construction activities. Due to the substantial separation distance between the Proposed Development and nearby residential dwellings, no significant effects are anticipated. Notwithstanding this, Best Practice mitigation measures will be adopted to manage noise emissions, including restrictions on working hours during the construction of the Proposed Development.

8.1.2 During operation, wind turbines can generate noise from the machinery housed within the turbine and from the movement of blades through the air. Modern turbines are designed to minimise noise and planning conditions are used to ensure compliance with specified noise limits.

8.1.3 The operational assessment has been undertaken in accordance with the recommendations of ETSU R-97, the method of assessing wind turbine noise recommended by Government guidance, and following the current best practice methods described in the Good Practice Guide (GPG), as endorsed by the Scottish Government. It has been shown that noise due to the Proposed Development would comply with the requirements of both ETSU R-97 and The Highland Council ('THC') at the closest, and therefore all receptor locations.

8.1.4 A cumulative assessment has also been undertaken in conjunction with the Operational Scheme, the existing Moy Wind Farm, and the proposed Lethen Wind Farm. Worst-case operational noise levels are below the identified noise limits, and the impact of operational noise has therefore been shown to be acceptable.

8.1.5 Noise produced during decommissioning of the Proposed Development is likely to be of a similar nature to that during construction, although the duration of decommissioning will be shorter than that of construction. Any legislation, guidance or best practice relevant at the time of decommissioning would be complied with.

8.2 Introduction

8.2.1 This Chapter of the Environmental Impact Assessment Report ('EIA Report') evaluates the noise impacts associated with the proposed extension to the Tom na Clach Wind Farm (hereafter known as 'the Proposed Development'). This assessment was undertaken by Wood Resilient Environments International ('Wood').

8.2.2 The operational noise assessment has been undertaken by comparing the predicted noise levels of both the Proposed Development in isolation, and cumulatively with the existing Tom na Clach Wind Farm the 'Operational Scheme'), Moy Wind Farm, and the proposed Lethen Wind Farm, with cumulative noise levels assessed against noise limits detailed within ETSU-R-97, *The Assessment and Rating of Noise from Wind Farms*, as referred to within the Scottish 'web based planning guidance', which is in turn referred to in PAN1/2011.

8.2.3 The assessment has been performed with reference to the guidance contained within the Institute of Acoustics document, *A Good Practice Guide to the Application of ETSU-R-97 for the Assessment and Rating of Wind Turbine Noise*, which is endorsed by the Scottish Government.

8.2.4 Construction and decommissioning noise on-site has been assessed with reference to BS:5228:2009, *Code of practice for noise and vibration control on construction and open sites*.

8.3 Statement of Competency

8.3.1 All acoustic consultants involved with the production of this chapter are associate or corporate members of the UK Institute of Acoustics (IOA). Wood is a member of the UK Association of Noise Consultants (ANC). All work is carried out in line with recognised industry standards, and best practice recommendations of the IOA and ANC.

8.4 Potential Noise Effects

8.4.1 Noise and vibration would occur during the construction, operation and decommissioning of the Proposed Development. The extent to which this is significant depends on the noise sources, in each case, and the distance of each of the noise sources to potential receptors.

8.4.2 Potential receptors in this case are considered to be residential properties. During the construction and de-commissioning phases, the effects can be divided into noise and vibration from on-site activities and from construction traffic accessing the site. During operation, noise is generated by the turbines as they rotate with noise output depending on wind speed.

8.4.3 For on-site construction noise, and operational noise at different wind speeds, the levels received at residential properties would depend on wind direction. Vibration from on-site construction activities and during operation would not be perceptible at residential properties. Vibration from construction vehicles accessing the site may be perceptible at roadside properties but would be no greater than from other heavy good vehicles and would not be significant. Vibration has therefore been scoped out of the assessment.

8.4.4 Noise arising during decommissioning would typically include removal of the turbine structures, and breaking up of the concrete foundations, and removal of access tracks.

8.5 Planning Policy

Planning Advice Note PAN1/2011, Planning and Noise

8.5.1 PAN1/2011 identifies two sources of noise from wind turbines; mechanical noise and aerodynamic noise. It states that "*good acoustical design and siting of turbines is essential to minimise the potential to generate noise*" (Scottish Government 2011). It refers to the "*web-based planning advice*" (Scottish Government 2011) on renewables technologies for onshore wind turbines.

Scottish Government 2014, Web Based Planning Advice, Onshore Wind Turbines

8.5.2 The web-based planning advice on onshore wind turbines re-iterates the sources of noise as "*the mechanical noise produced by the gearbox, generator and other parts of the drive train and the aerodynamic noise produced by the passage of the blades through the air*" (Scottish Government 2014) and that "*there has been significant reduction in the mechanical noise generated by wind turbines through improved turbine design*" (Scottish Government 2014). It states that "the Report, "*The Assessment and Rating of Noise from Wind Farms*" *(Final Report, Sept 1996, DTI), (ETSU-R-97), describes a framework for the measurement of wind farm noise, which should be followed by applicants and consultees, and used by planning authorities to assess and rate noise from wind energy developments, until such time as an update is available*" (Scottish Government 2014). It notes that "*this gives indicative noise levels thought to offer a reasonable degree of protection to wind farm neighbours, without placing unreasonable burdens on wind farm developers, and suggests appropriate noise conditions*" (Scottish Government 2014).

8.5.3 The advice introduces the Institute of Acoustics (IOA) A Good Practice Guide to the Application of ETSU-R-97 for the Assessment and Rating of Wind Turbine Noise (Institute of Acoustics, 2013), and states that "The Scottish Government accepts that the guide represents current *industry good practice*" (Scottish Government 2014).

8.5.4 The accompanying Technical Advice Note (Scottish Government, 2011) to PAN1/2011, Assessment of Noise, lists BS 5228, Noise and Vibration Control on Construction and Open Sites (British Standards Institution, 2014). as being applicable for Environmental Impact Assessment (EIA) and planning purposes.

The Assessment and Rating of Noise from Wind Farms: ETSU-R-97

8.5.5 ETSU-R-97, The Assessment and Rating of Noise from Wind Farms (ETSU-R-97), presents the recommendations of the Working Group on Noise from Wind Turbines, set up in 1993 by the Department of Trade and Industry (DTI) as a result of difficulties experienced in applying the noise guidelines existing at the time to wind farm noise assessments. The group comprised independent experts on wind turbine noise, wind farm developers, DTI personnel and local authority Environmental Health Officers. In September 1996 the Working Group published its findings by way of report ETSU-R-97. This document describes a framework for the measurement of wind farm noise and contains suggested noise limits, which were derived with reference to existing standards and guidance relating to noise emission from various sources.

8.5.6 ETSU-R-97 recommends that, although noise limits should be set relative to existing background and should reflect the variation of both turbine and background noise with wind speed; this can imply very low noise limits in particularly quiet areas, in which case, "*it is not necessary to use a margin above background in such low-noise environments. This would be unduly restrictive on developments which are recognised as having wider global benefits. Such low limits are, in any event, not necessary in order to offer a reasonable degree of protection to the wind farm neighbour*" (DTI 1996).

8.5.7 For day-time periods, the noise limit is 35 dB – 40 dB L_{A90} or 5 dB(A) above the 'quiet day-time hours' prevailing background noise, whichever is the greater. The actual value within the 35 dB – 40 dB(A) range depends on the number of

dwellings in the vicinity; the impact of the limit on the number of kWh generated; and the duration of the level of exposure.

8.5.8 For night-time periods the noise limit is 43 dB L_{A90} or 5 dB(A) above the relevant night-time hours background noise, whichever is the greater. The 43 dB(A) lower limit is based on an internal sleep disturbance criteria of 5 dB(A) with an allowance of 10 dB(A) for attenuation through an open window and 2 dB(A) subtracted to account for the use of L_{A90} rather the L_{Aeq}.

8.5.9 Where predicted noise levels are low at the nearest residential properties a simplified noise limit can be applied, such that noise is restricted to the minimum ETSU-R-97 level of 35 dB LA90 for wind speeds up to 10 m/s at 10 m height. This removes the need for extensive background noise measurements for smaller or more remote schemes.

8.5.10 It is stated that the $L_{A90,10min}$ noise descriptor should be adopted for both background and wind farm noise levels and that, for the wind farm noise, this is likely to be between 1.5 dB and 2.5 dB less than the L_{Aeq} measured over the same period. The L_{Aeq},t is the equivalent continuous 'A' weighted sound pressure level occurring over the measurement period 't'. It is often used as a description of the average ambient noise level. Use of the L_{A90} descriptor for wind farm noise allows reliable measurements to be made without corruption from relatively loud, transitory noise events from other sources.

8.5.11 ETSU-R-97 also specifies that a penalty should be added to the predicted noise levels, where any tonal component is present. The level of this penalty is described and is related to the level by which any tonal components exceed the threshold of audibility.

8.5.12 With regard to multiple wind farms in a given area, ETSU-R-97 specifies that the absolute noise limits and margins above background should relate to the cumulative impact of all wind turbines in the area contributing to the noise received at the properties in question. Existing wind farms should therefore be included in cumulative predictions of noise level for proposed wind turbines and not considered as part of the prevailing background noise.

A Good Practice Guide to the Application of ETSU-R-97 for the Assessment and Rating of Wind Turbine Noise

8.5.13 In May 2013, the Institute of Acoustics (IOA) published A Good Practice Guide to the Application of ETSU-R-97 for the Assessment and Rating of Wind Turbine Noise (GPG), as referred to in the Web Based Planning Advice. This was subsequently endorsed by the Secretary of State for Energy and Climate Change and by the Scottish Ministers. The publication of the GPG followed a review of current practice (Department of Energy and Climate Change, 2011) carried out for the Department of Energy and Climate Change (DECC) and an IOA discussion document (Institute of Acoustics, 2012) which preceded the GPG.

8.5.14 The GPG includes sections on Context; Background Data Collection; Data Analysis and Noise Limit Derivation; Noise Predictions; Cumulative Issues; Reporting; and Other Matters including Planning Conditions, Amplitude Modulation, Post Completion Measurements and Supplementary Guidance Notes. The Context section states that the guide "*presents current good practice*

in the application of the ETSU-R-97 assessment methodology for all wind turbine development above 50 kW, reflecting the original principles within ETSU-R-97, and the results of research carried out and experience gained since ETSU-R-97 was published" (IOA 2013). It adds that "*the noise limits in ETSUR- 7 have not been examined as these are a matter for Government*" (IOA 2013).

8.5.15 As well as expanding on and, in some areas, clarifying issues which are already referred to in ETSU-R-97, additional guidance is provided on noise prediction and preferred methodology for dealing with wind shear. The guidance within the GPG has been considered and generally followed for this assessment.

The Highland Council Noise Limits

8.5.16 It should be noted that THC have provided guidance on their own recommended wind farm noise limits which depart from the ETSU-R-97 noise limits. They specify night time and daytime noise lower limiting values of 38 and 35 dB L_{A90} respectively, thereby setting the night-time lower limiting value at 5 dB below that specified by ETSU-R-97, and setting the daytime noise limit at the lowest end of the range of lower and upper daytime lower limiting values range specified by ETSU-R-97.

8.6 Cumulative Noise

8.6.1 Section 5.1 of the IOA GPG deals with cumulative noise, and re-iterates the position set out in ETSU-R-97 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*" (IOA 2013).

8.6.2 The IOA GPG defines when a cumulative noise assessment is necessary and states that, "*if the proposed wind farm produces noise levels within 10 dB of any existing wind farm/s at the same receptor location, then a cumulative noise impact assessment is necessary*" (IOA 2013). This is because if the predicted noise is more than 10 dB below that already existing (or the applicable noise limit) its contribution to the overall noise level is negligible.

8.7 Other Potential Operational Wind Farm Noise Impacts

Tonal Noise

8.7.1 If tonal noise is associated with a sound source it is generally then more noticeable, and in line with other noise guidance that penalises noise which is tonal, a penalty is added to wind turbine noise if there is tonal noise which is audible at residential properties. In this case, it has been assumed that there would be no tonal noise associated with the operation of the Proposed Development which would give rise to a tonal penalty as set out in ETSU-R-97. A penalty is usually included with the planning conditions for wind farms that can be used to ensure that noise levels, including a tonal penalty, do not exceed acceptable levels in practice.

Low Frequency and Infrasound

8.7.2 Work carried out in 2006 to investigate the extent of low frequency and infrasonic noise from three UK wind farms (Department of Trade and Industry, 2006) concluded that "*the common cause of complaints associated with noise at all three wind farms is not associated with low frequency noise, but is the audible modulation of the aerodynamic noise, especially at night*" (DTI 2006). It is

therefore considered that low frequency and infrasound can be scoped out of the assessment, but modulation of aerodynamic noise is considered in more detail below.

Amplitude Modulation

8.7.3 The variation in noise level associated with turbine operation, at the rate at which turbine blades pass any fixed point of their rotation (the blade passing frequency), is often referred to as blade swish and amplitude or aerodynamic modulation (AM). This effect is identified within ETSU-R-97 where it is envisaged that *"… modulation of blade noise may result in variation of the overall AWeighted noise level by as much as 3 dB(A) (peak to trough) when measured close to a wind turbine…"* (DTI 1996) and that at distances further from the turbine where there are *"… more than two hard, reflective surfaces, then the increase in modulation depth may be as much as 6 dB(A) (peak to trough)*" (DTI 1996). There have been instances where levels of AM are higher than this, which results in the noise being perceived as more intrusive (in the same way as tonal content makes the noise more intrusive).

8.7.4 The Government released a Wind Turbine AM Review (Department of Energy and Climate Change, 2016) report in October 2016 (although the Phase 2 report is dated August 2016). Phase 1 of the report sets out its approach and methodology, and the Phase 2 report includes a literature review, its research into human response to AM, and recommends how excessive AM might be controlled through the use of a planning condition. The report includes recommendations on how AM should be addressed when quantified according to the recommendations of an IOA Amplitude Modulation Working Group (AMWG) document, A Method for Rating Amplitude Modulation in Wind Turbine Noise (Institute of Acoustics, 2016).

8.7.5 The AM Review reports recommend a two-tier approach whereby the first tier would be to seek a reduction in the depth and/or occurrence of AM with a rating level (according to the IOA AMWG method) ≥3 dB. Whether remedial action is required depends on the prevalence of any complaints, and how often AM rating levels ≥3 dB occur. The second tier is that if AM is deemed to be a significant issue, and, if nothing can be done to reduce the level of AM, then a penalty scheme is proposed whereby a penalty ranging from 3 dB (for a rating level of 3 dB) up to a maximum of 5 dB (for a rating level of 10 dB and above) should be added to the measured level before measured levels are compared with the relevant noise limits.

8.7.6 It should be noted that most wind farms operate without significant AM, and that it is not possible to predict the likely occurrence of AM, but, like tonal noise, AM could be covered by a suitably worded planning condition.

8.8 Construction Noise

8.8.1 The Scottish Government's Technical Advice Note, Assessment of Noise, states that, for planning purposes, construction noise should be assessed according to BS 5228, Noise and Vibration Control on Construction and Open Sites. The standard provides example criteria for the assessment of the significance of construction noise effects and a method for the prediction of noise levels from

construction activities. Two example methods are provided for assessing significance.

8.8.2 The first is based on the use of criteria defined in Department of the Environment Advisory Leaflet (AL) 72, Noise Control on Building Sites (Department of the Environment, 1969) which sets a fixed limit of 70 dB(A) in rural suburban and urban areas away from main roads and traffic. Noise levels are generally taken as facade L_{Aeq} values with free-field levels taken to be 3 dB lower, giving an equivalent noise criterion of 67 dB L_{Aeq}.

8.8.3 The second is based on noise change, with a 5 dB increase in overall noise considered to be significant. However, when existing noise levels are low, such as at this site, and construction activities continue for more than one month, minimum criteria are applicable. These are 45 dB, 55 dB and 65 dB L_{Aeq}, for night-time (23:00-07:00), evening and weekends, and daytime (07:00-19:00) including Saturdays (07:00-13:00) respectively.

8.8.4 Road traffic noise is assessed by calculating the predicted increase in noise levels generated by road traffic associated with the Proposed Development, or where there is currently very little traffic, against the criteria for construction noise set out in BS 5228.

8.9 Noise Impact Assessment Criteria

Operational Noise Impact Assessment Criteria

8.9.1 Noise sensitive receptors (NSR) have been identified from the previous noise impact assessment of the Operational Scheme. The assessed locations are as follows: Ballachrochin, Balvraid Lodge, Daless, Guilichan, and Ruthven. Where predicted cumulative sound levels from the wind farms fall below 25 dB(A), the properties have been scoped out of the noise impact assessment.

8.9.2 A further cumulative noise assessment has been carried out by predicting noise levels from the Operational Scheme, the neighbouring operational Moy Wind Farm, and the proposed Lethen Wind Farm acting together with the Proposed Development. These predicted cumulative noise levels have been compared with predicted noise levels from wind farms that are already consented, and the noise limits either set by the existing planning consents or derived from baseline noise measurements in accordance with ETSU-R-97.

Construction and Decommissioning Noise Impact Assessment Criteria

8.9.3 Construction and decommissioning activities would be undertaken during the daytime and, for activities of a duration of one month or longer, the adopted criterion is 65 dB L_{Aeq}, and if noise levels from predicted construction activities are below this then no significant noise impacts are predicted. Where construction activities have a duration of less than one month, noise levels above 65 dB L_{Aeq} are considered to be acceptable as long as mitigation is implemented to reduce the impact as much as practicable.

8.9.4 Due to the low levels of existing and proposed traffic which is likely for the construction of the Proposed Development, an assessment comparison between the baseline and proposed traffic would not be possible to predict. Therefore, traffic noise will be discussed in terms of absolute noise levels from lorry pass-bys and using the same construction noise criteria of 65 dB.

8.10 Baseline Noise Levels

8.10.1 Normally baseline noise levels are measured over a period of time sufficient to capture data at wind speeds from 4 – 12 m/s. In accordance with ETSU-R-97 and the IOA Guidance, this data is used to form a criteria dependent background noise levels, wind speed and the minimum limits described in paragraphs 8.57-8.58. This process was undertaken for the 2009 Environmental Statement (Infinergy, 2009) for the Operational Scheme, and this criteria would be used if required for the assessment of the Proposed Development (if cumulative levels exceed 35 dB at residential receptors). It is considered that this existing measurement data still reasonably represents the baseline at residences excluding any turbine noise as per IOA Guidance (any new survey data could potentially be contaminated by the existing turbine noise and not compliant with the assessment process).

8.11 Predictions

Operational Noise Prediction Methodology

8.11.1 Operational Noise levels have been predicted using SoundPLAN v8.2 noise modelling software. The software has been used on several onshore wind farm projects and predict worst-case sound levels at receptors.

8.11.2 The noise predictions have been calculated using International Standard ISO 9613, *Acoustics - Attenuation of Sound during Propagation Outdoors* (International Organization for Standardization, 1996).) The propagation model described in Part 2 of this standard provides for the prediction of sound pressure levels based on either short-term downwind (i.e. worst case) conditions or long-term overall averages. When the wind is blowing in the opposite direction, noise levels may be significantly lower, especially if there is any shielding between the site and the houses. Only the 'worst case' downwind short-term predictions are carried out here, such that the long-term average predicted noise levels would be lower.

8.11.3 The GPG suggests that ISO 9613-2 can be applied to obtain realistic predictions of noise from on-shore wind turbines during worst case propagation conditions, provided that the appropriate choice of input parameters are made.

8.11.4 The ISO 9613-2 standard is used for predicting sound pressure level by taking the source sound power level for each turbine in separate octave bands and subtracting a number of attenuation factors according to the following:

Predicted Octave Band Noise Level = LW + D - Ageo - Aatm - Agr – Abar – Amisc

8.11.5 These factors are discussed in detail below. The predicted octave band levels from each turbine are summed together to give the overall 'A' weighted predicted sound level.

<u>LW - Source Sound Power Level</u>

8.11.6 The sound power level of a noise source is normally expressed in dB re: 1pW. Noise predictions are based on the maximum sound power and octave band levels detailed in Table 8.1.

8.11.7 For the Proposed Development, the potential candidate turbines considered to be typical of the dimensions proposed is the Vestas V136 3.6 MW turbine or the Vestas V136 4.5 MW turbine with a hub height of 82 m. As the 3.6 MW variant has the higher potential sound power, this variant has been used in the assessment to constitute as conservative, worst-case assessment. Other variants of the Vestas 136 turbine quote equal or lower sound power levels.

8.11.8 The turbines of the existing Tom na Clach Wind Farm are Vestas V112 3.45 MW turbines with a hub height of 69 m. The predictions provided here assume that each of these turbines have regular trailing edges fitted to the blades, which is the standard fit option offered by the manufacturer. The Sound power levels used in the calculation, derived from manufacturer's provided hub height data is detailed at Table 8.1 below.

Table 8.1 Sound Power Levels (dB LWA)

Turbine Model	Hub Height (m)	Standardised 10 m height Wind Speed (m/s)									
		3	4	5	6	7	8	9	10	11	12
V136	82	93.2	93.6	96.5	100.0	103.2	105.9	106.9	106.9	106.9	106.9
V112	69	84.7	86.4	91.3	95.8	99.7	102.9	104.7	105.3	105.3	105.2
Nordex N100	80	95.5	96.5	98.5	102.8	104.4	105.0	105.5	105.5	105.5	105.5

8.11.9 The overall sound power levels have had an appropriate amount of uncertainty added, depending on the data supplied or available in line with the IOA GPG. In this case 2 dB has been added to the sound power levels for each turbine as this data is provided by the turbine manufacturers and is likely to be warranted in practice, and the data shown in Table 8.1 includes this uncertainty. The octave band spectra assumed for each turbine type, normalised to the required sound power level at each integer wind speed, as taken from the manufacturer's documentation, is provided at Table 8.2 below.

Table 8.2 Octave Band Spectra (dB LWA)

Turbine Model	Octave Band Centre Frequency (Hz)							
	63	125	250	500	1000	2000	4000	8000
Vestas V136	85	93	98	101	101	100	96	90
Vestas V112	87	96	98	100	99	96	91	78
Nordex N100	84	80	93	97	101	101	95	80

8.11.10 The turbine coordinates used in the assessment are detailed at Table 8.3 below.

Table 8.3 Wind Turbine Coordinates

Wind Farm	Easting	Northing	Hub Height (m)	Tip Height (m)	Turbine Type
Proposed Development	287046	835418	82	149.9	Vestas V136
	287546	835407	82	149.9	Vestas V136
	287203	834826	82	149.9	Vestas V136
	286951	834149	82	149.9	Vestas V136
	287341	833716	82	149.9	Vestas V136
	287624	834318	82	149.9	Vestas V136
	287070	833723	82	149.9	Vestas V136
Existing Tom na Clach Wind Farm	285732	834288	69	125	Vestas V112
	286320	834173	69	125	Vestas V112
	285833	834735	69	125	Vestas V112
	286218	834594	69	125	Vestas V112
	286730	834448	69	125	Vestas V112
	285540	835514	69	125	Vestas V112
	285592	834103	69	125	Vestas V112
	286393	835045	69	125	Vestas V112
	286752	834904	69	125	Vestas V112
	285856	835862	69	125	Vestas V112
	286054	835529	69	125	Vestas V112
	286660	835721	69	125	Vestas V112
	286317	835948	69	125	Vestas V112
Moy Wind Farm	277866	836659	80	126.5	Nordex N100
	278118	836398	80	126.5	Nordex N100

Wind Farm	Easting	Northing	Hub Height (m)	Tip Height (m)	Turbine Type
	278303	836298	80	126.5	**Nordex N100**
	278414	836918	80	126.5	**Nordex N100**
	278645	836838	80	126.5	**Nordex N100**
	278813	836501	80	126.5	**Nordex N100**
	278922	837255	80	126.5	**Nordex N100**
	279026	836328	80	126.5	**Nordex N100**
	279082	836960	80	126.5	**Nordex N100**
	279348	836664	80	126.5	**Nordex N100**
	279397	837843	80	126.5	**Nordex N100**
	279368	837558	80	126.5	**Nordex N100**
	279575	836524	80	126.5	**Nordex N100**
	279585	837230	80	126.5	**Nordex N100**
	279810	837928	80	126.5	**Nordex N100**
	279899	837706	80	126.5	**Nordex N100**
	279902	836991	80	126.5	**Nordex N100**
	280009	837340	80	126.5	**Nordex N100**
	280232	836916	80	126.5	**Nordex N100**
	280375	837351	80	126.5	**Nordex N100**
Lethen Wind Farm	291856	838024	105	185	**Vestas V136 (for calculation purposes)**
	292499	837877	105	185	**Vestas V136 (for calculation purposes)**
	292963	837730	105	185	**Vestas V136 (for calculation purposes)**
	293585	837485	105	185	**Vestas V136 (for calculation purposes)**

Wind Farm	Easting	Northing	Hub Height (m)	Tip Height (m)	Turbine Type
	292060	837270	105	185	**Vestas V136 (for calculation purposes)**
	292591	837119	105	185	**Vestas V136 (for calculation purposes)**
	293063	836934	105	185	**Vestas V136 (for calculation purposes)**
	293470	836691	105	185	**Vestas V136 (for calculation purposes)**
	291987	836688	105	185	**Vestas V136 (for calculation purposes)**
	292454	836523	105	185	**Vestas V136 (for calculation purposes)**
	292753	836128	105	185	**Vestas V136 (for calculation purposes)**
	292147	835122	105	185	**Vestas V136 (for calculation purposes)**
	292761	835281	105	185	**Vestas V136 (for calculation purposes)**
	293366	835423	105	185	**Vestas V136 (for calculation purposes)**
	292841	834628	105	185	**Vestas V136 (for calculation purposes)**
	293724	834930	105	185	**Vestas V136 (for calculation purposes)**
	291714	833928	105	185	**Vestas V136 (for calculation purposes)**

Wind Farm	Easting	Northing	Hub Height (m)	Tip Height (m)	Turbine Type
	292242	833934	105	185	**Vestas V136 (for calculation purposes)**
	292873	834052	105	185	**Vestas V136 (for calculation purposes)**
	293705	834293	105	185	**Vestas V136 (for calculation purposes)**

D – Directivity Factor

8.11.11 The directivity factor allows for an adjustment to be made whereby the sound radiated in the direction of interest is higher than that for which the sound power level is specified. For wind turbines, the sound power level is measured in a down wind direction, corresponding to the worst-case propagation conditions considered here and needs no further adjustment.

A_{geo} – Geometrical Divergence

8.11.12 The geometrical divergence accounts for spherical spreading in the free-field from a point sound source, resulting in an attenuation depending on distance according to:

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

where d = distance from the turbine

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

A_{atm} - Atmospheric Absorption

8.11.14 Sound propagation through the atmosphere is attenuated by the conversion of the sound energy into heat. This attenuation is dependent on the temperature and relative humidity of the air through which the sound is travelling and is frequency dependent with increasing attenuation towards higher frequencies. The attenuation depends on distance according to:

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

where d = distance from the turbine

a = atmospheric absorption coefficient in dB/m

8.11.15 Values of 'α' from ISO 9613 Part 1 corresponding to a temperature of 10°C and a relative humidity of 70% has been used. These are the values specified in the IOA GPG. These give relatively low levels of atmospheric attenuation and correspondingly conservative noise predictions, and the values were used are given below at Table 8.4.

Table 8.4 Frequency Dependant Atmospheric Absorption Coefficients

	Octave Band Centre Frequency (Hz)							
	63	**125**	**250**	**500**	**1000**	**2000**	**4000**	**8000**
Atmospheric Absorption Coefficient (dB/m)	0.000122	0.000411	0.00104	0.00193	0.0037	0.00966	0.0328	0.117

A_{gr} Ground Effect

8.11.16 Ground effect is the interference of sound reflected by the ground with the sound propagating directly from source to receiver. The prediction of ground effects are inherently complex and depend on the source height, receiver height, propagation height between the source and receiver and the ground conditions. The ground conditions are described according to a variable G which varies between 0 for 'hard' ground (including paving, water, ice, concrete & any sites with low porosity) and 1 for 'soft' ground (includes ground covered by grass, trees or other vegetation). The IOA GPG states that where wind turbine source noise data includes a suitable allowance for uncertainty, as is the case here, a ground factor of G = 0.5 and a receptor height of 4 m should be used.

A_{bar} - Barrier Attenuation

8.11.17 The effect of any barrier between the noise source and the receiver position is that noise would be reduced according to the relative heights of the source, receiver and barrier and the frequency spectrum of the noise. The barrier attenuations predicted by the ISO 9613 model have, however, been shown to be significantly greater than that measured in practice under downwind conditions. The IOA GPG states that an attenuation of just 2 dB(A) should be allowed where the direct line of site between the source and receiver is just interrupted. There are no significant topographical features here that would significantly interrupt line of site to the tip of the turbines and therefore no barrier corrections have been applied.

A_{misc} – Miscellaneous Other Effects

8.11.18 ISO 9613 includes effects of propagation through foliage, industrial plant and housing as additional attenuation effects. These have not been included here and any such effects are unlikely to significantly reduce noise levels below those predicted.

Concave Valley

8.11.19 The IOA GPG states that sound propagation across a concave ground profile, for example valleys or where the ground falls away significantly between the turbine and the receptor should incur an additional correction of +3 dB(A) to the overall A-weighted noise levels. This correction is implemented in order to take account

of the reduced ground effects and, under some rare circumstances, the potential for multiple reflection paths caused by the concave profile.

8.11.20 A condition is recommended in the IOA GPG for indicating where this correction should be applied:

hm≥1.5×("abs" (hs-hr)/2)

where hm is the mean height above ground along the direct path between the source and the receptor, hs is the absolute source height above ground level and hr is the absolute receptor height above ground level.

8.11.21 Whilst this condition is useful at highlighting where the ground profile beneath a source to receptor path may be concave, it is inherently non-robust and can produce false positives. It should therefore be used in conjunction with a visual assessment of the ground profile when determining whether a correction should be applied.

8.11.22 A computer program has been used to generate the ground profiles beneath each source – receptor path. From these plots it is possible to determine where a correction is appropriate. In this case there are no significant concave ground profiles between any turbines and receptor locations that would require a correction.

Tonality

8.11.23 The ETSU-R-97 noise limits assume that the wind turbine noise contains no audible tones. Where tones are present, a correction should be added to the measured or predicted noise level before comparison with the recommended limits. The audibility of any tones can be assessed by comparing the narrow band level of such tones with the masking level contained in a band of frequencies around the tone called the critical band. The ETSU-R-97 recommendations suggest a tone correction, which depends on the amount by which the tone exceeds the audibility threshold. It has been assumed that the existing turbines do not exhibit tonal noise that would require a penalty under ETSU-R-97 or their planning conditions. No tonal penalties have been added to the predicted noise levels and it is recommended that a warranty is sought from the supplier of turbines for this site to ensure that no tonal penalty would be required in practice.

8.12 Operational Noise Prediction Results

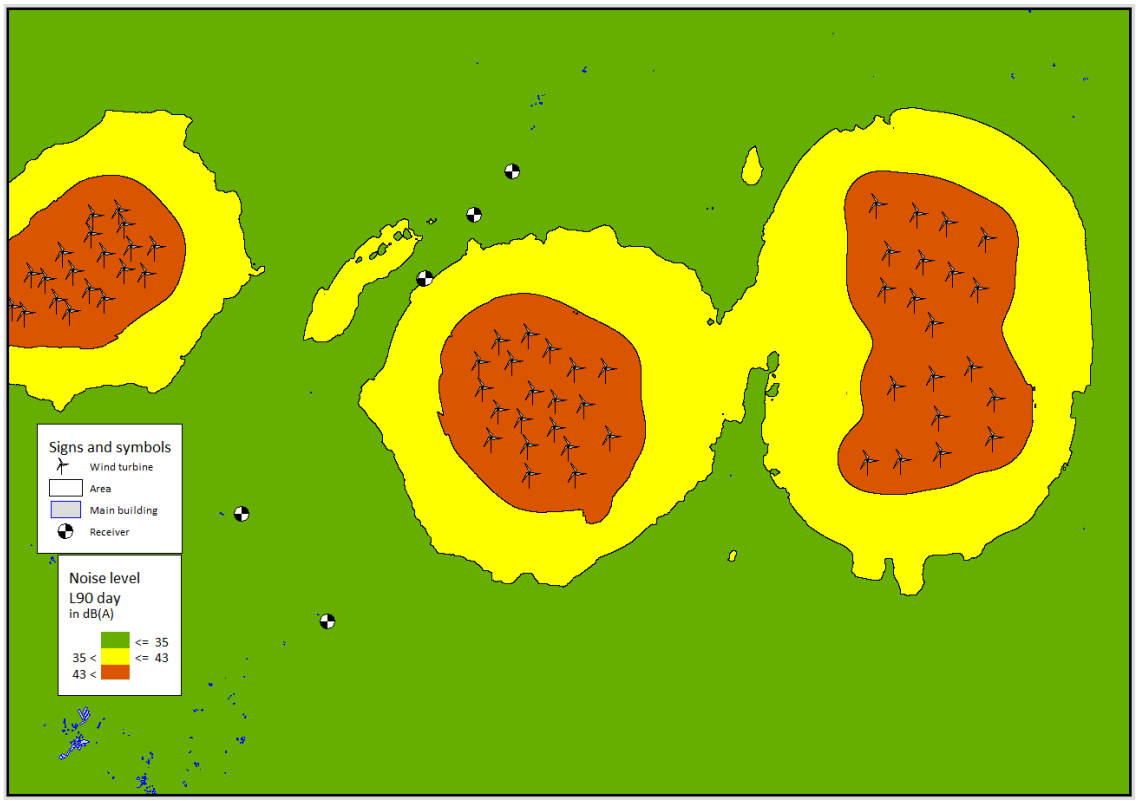
8.12.1 The nearest residential receptors to the Proposed Development have been identified, and predicted noise levels have been calculated for both the Proposed Development at rated power operating in isolation and cumulatively with other proposed and existing developments. Table 8.5 shows the results of these predictions, and **Figure 8.1** and **Figure 8.2** show the results as noise contours for the Proposed Development in isolation and cumulatively with existing wind farms.

Table 8.5 Predicted Noise Levels for the Proposed Development and the Operational Development for 10 m/s standardised 10 m height wind speed

Location	Easting	Northing	Predicted Noise Level (dB L_{A90})	
			Proposed	Cumulative
Ballachrochin	284705	836821	25	35
Balvraid Lodge	282934	831420	21	27
Daless	286062	838501	24	32
Quilichan	285458	837820	24	33
Ruthven	281700	833091	19	27

Figure 8.1 Predicted Noise Contours for the Proposed Development for 10 m/s standardised 10 m height wind speed

Figure 8.2 Predicted Noise Contours for the Proposed Development and existing wind farms for 10 m/s standardised 10 m height wind speed



8.12.2 As can be seen from **Figure 8.1** and Table 8.5 predicted operational noise levels from the Proposed Development acting together with the Operational Development and other identified existing or proposed wind farms are below or equal to the lowest noise limit of 35 dB L_{A90} and therefore a detailed assessment referencing baseline noise levels and criteria are not required.

8.13 Construction Noise Predictions

8.13.1 Detailed construction noise predictions have not been carried out due to the large separation distances between on-site construction activities and sensitive residential receptors. The closest works would be on-site track construction at their closest 200 m from residential properties. At this distance, construction plant such as tracked excavators could result in noise levels of around 55-60 dB, below the criterion for significance of effect. With the exception of blasting, the activity likely to result in the highest noise levels on site is piling for turbine foundations, but the noise levels for this activity are likely to be below the 65 dB criterion 300 m from the works and given the turbine locations, this would not result in significant effects at residential locations.

8.13.2 It is possible that blasting would be required at the proposed borrow pit location to extract rock. It is not possible to carry out meaningful predictions as the frequency, duration and noise levels from blasting all depend on the type of rock, depth of charge and surrounding ground conditions onsite, together with the amount of rock that is required. This type of noise does not typically fall within the assessment of normal construction noise because of the extremely high amplitude and impulsive nature of the waveform. It is very likely that blasting noise could be heard at nearby residential locations but a construction noise assessment would average noise levels across the day and is therefore not applicable to use for the assessment of blasting noise impacts. Protection of residential amenity from blasting activities should be provided via a Blasting Management Plan, which is discussed in the mitigation Section 8.15.

8.13.3 Where additional highways and cabling works are required along the route to the grid connection point, noise may be generated at times that is above the 65 dB L_{Aeq} adopted criterion, but the duration of the works is likely to be relatively short (i.e. less than one month).

Road traffic noise predictions use haul route methodology within BS5228 to predict the distance to residences when the 65 dB criterion would be exceeded. The predictions are based on one lorry per hour (a conservative worst-case estimate) emitting 80dB as a pass-by L_{AMax} noise level moving at 48 km/hour. The predictions consider haul routes on site. It is considered the local B-roads will already have sufficient lorry movements that the additional traffic from the Proposed Development would not be significant.

8.13.4 Noise predictions have not been undertaken for decommissioning activities, but the large separation distance between breaking up of the concreate foundations (likely to be the noisiest activity) and residential properties would result in noise levels at residential properties that are likely to be significantly below the adopted construction noise limit.

8.14 Assessment of Impacts

Operational Noise Assessment

Proposed Development Operating Alongside the Operational Scheme

8.14.1 The predicted noise levels at residences from the combined operation of the Operational Scheme and the Proposed Development are within the screening criterion of 35 dB. As such, the noise effects from the operation of the Proposed Development would not be significant.

Cumulative Operational Noise Assessment

8.14.2 The predicted noise levels at residences from the combined operation of the Operational Scheme, the Proposed Development and all other identified existing and proposed wind farms are within the screening criterion of 35 dB. As such, the noise effects from the cumulative assessment of the Proposed Development would not be significant.

Construction Noise Assessment

8.14.3 Noise from on-site construction activities are highly likely to be below the 65 dB L_{Aeq} criterion, and it can therefore be concluded that noise impact from on-site construction activities would be not significant.

8.14.4 Where highways upgrades and cabling between the site and grid connection is carried out close to residential properties, there may be temporary short-term noise impacts, with the level of impact dependant on the specific work required. It is likely, however, that noisy activities near residential properties would generally continue for a duration of less than one month, and therefore this short-term noise impact can be considered to be not significant.

Road Traffic Noise

8.14.5 The likely road traffic noise from the Proposed Development would not result in an exceedance of the 65 dB criterion at any distance from the road. Therefore, no significant effect is predicted from construction traffic noise.

Decommissioning Noise

8.14.6 No significant decommissioning noise effects are expected, although it should be noted that noise from decommissioning activities would be controlled as required by the guidance prevalent at the time.

8.15 Mitigation

Operational Mitigation

8.15.1 No specific operational mitigation is required as the relevant noise limits are met. It should be noted that noise reduced modes of operation are generally available for wind turbines of the scale proposed here that allow noise levels to be reduced by restricting the rotational speed of the machines. This mitigation could be employed if any noise issues arise that would require mitigation to be implemented.

Construction Noise Mitigation

8.15.2 Noise during construction works would be controlled by generally restricting works to standard working hours and exclude Sundays, unless specifically agreed otherwise.

8.15.3 BS 5228 states that the 'attitude of the contractor' is important in minimising the likelihood of complaints and therefore consultation with the local authority would be required along with providing information to residents on intended activity.

8.15.4 The construction and decommissioning works on-site would be carried out in accordance with:

- relevant EU Directives and UK Statutory Instruments that limit noise emissions from a variety of construction plant;
- the guidance set out in PAN1/2011 and BS5228: 2009; and
- Section 61 of the Control of Pollution Act 1974 and Section 80 of the Environmental Protection Act.

8.15.5 The most appropriate way to address blasting noise is through a condition requiring a pre-blasting noise management programme to be submitted and agreed in writing prior to any blasting operations taking place. This would

identify the most sensitive receptors that could be potentially affected by blasting noise. The plan would contain details of the proposed frequency of blasting and proposed monitoring procedures. The operator would inform the nearest residents of the proposed times of blasting and of any deviation from this programme in advance of the operations. The plan would also contain contact details which would be provided to local residents should concerns arise regarding construction and blasting activities. In addition, each blast would be designed carefully to maximise its efficiency and to reduce the transmission of noise.

Decommissioning Noise Mitigation

8.15.6 Noise during decommissioning would be controlled through the relevant standards and best practice available at the time. Noise generation during decommissioning is likely to be similar to during construction and similar measures proposed for noise mitigation, essentially management controls to ensure excessive noise is not generated, would be employed.

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