12 Noise

12.1 Scope of Assessment

12.1.1 This chapter assesses the noise effects arising from the proposed development and considers its construction, operational and decommissioning phases.

12.1.2 Operational wind turbines generate noise by two mechanisms: mechanical noise from the gearbox and generator in the nacelle, and aerodynamic noise caused by wind passing over the turbine blades. The wind turbines are designed in such a manner as to minimise mechanical noise, and properly maintained wind turbines perform well in terms of any mechanical noise such that it is possible to concentrate on aerodynamic noise in this assessment. Aerodynamic noise is minimised by the design of the turbine blade, however, some aerodynamic noise is unavoidable, and will increase with wind speed.

12.1.3 The assessment of operational noise is undertaken in accordance with relevant policy and guidance as set out below. Predictions of operational noise are based on turbine output data provided by manufacturers. The design parameters for the proposed development have been developed for a turbine with maximum blade tip height of 125 m. The Vestas V90 3.0 MW turbine meets this parameter, and will result in the highest predicted noise levels at noise sensitive receptors for the range of candidate turbines considered by the Applicant. This model of turbine has been used in this noise assessment, although it may not be the installed model of turbine. The turbine selected for the proposed development will however meet the noise limits proposed in this assessment.

12.1.4 The effects of noise generated during the construction and decommissioning phases of the proposed development are considered in relation to established guidance and noise limit values (see paragraph 12.5 below).

12.2 Noise Terminology

12.2.1 In this chapter a number of technical terms are referred to in relation to noise. The terminology is described below.

12.2.2 Noise is detected in the ear by changes in sound pressure. The range between the quietest audible sound and loudest tolerable sound is a million to one in terms of the change in sound pressure. Consequently, a logarithmic scale, known as the decibel scale is used to describe noise.

12.2.3 The human ear will perceive 'loudness' of a noise differently depending of the pitch or frequency of the noise. As microphones do not distinguish noise in the same way as the human ear a weighting is applied to noise levels to approximate to human response. The correction factor is known as the A-weighting and is denoted by the letter A applied to noise indices where appropriate.

12.2.4 The following noise terms are also used in the assessment:

$L_{A90,t}$: the A-weighted noise level exceed for 90% of the measurement period "t". This noise index is widely accepted as a descriptor of 'background' noise levels.

$L_{Aeq,t}$: the equivalent continuous sound level, which conveys the same acoustic energy over a specified measurement period as a time varying source.

SPL: Sound pressure level, dB L_{Aeq} (re 20 μPa)

SWL: Sound power level, dB L_{WA} (re 1 pW)

12.3 Policy Context

12.3.1 Chapter 6 of the ES sets out the planning policy framework that is relevant to the EIA. The policies set out include those from TAYplan (the Strategic Development Plan), the Highland Area Local plan, those relevant aspects of Scottish Planning Policy (SPP), Planning Advice Notes and other relevant guidance. Of relevance to the noise assessment, regard has been had to the policy and guidance documents discussed below.

Scottish Planning Policy

12.3.2 Scottish Planning Policy[1] identifies wind power as being one of the main sources of renewable electricity generation. Paragraph 187 of the policy identifies a number of factors, including noise, which should be considered in determining the suitability of sites for wind farm developments.

12.3.3 Specific guidance in relation to onshore wind is provided by the Scottish Government as follows:

"The Report, *'The Assessment and Rating of Noise from Wind Farms'* (Final Report, Sept 1996, DTI), (ETSU-R-97[2], (hereafter referred to as ETSU) describes a framework for the measurement of wind farm noise, which should be followed by applicants and consultees, and used by planning authorities to asses and rate noise from wind energy developments, until such time as an update is available. 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".

"Circular 10/1999 sets out Government policy on the role of the planning system in controlling noise and the Planning Advice Note (PAN)[3] on Planning and Noise provides advice on the role of the planning system in helping to prevent and limit the adverse effects of noise".

[1] Scottish Government (2010) *Scottish Planning Policy*
[2] DTI (1996) *ETSU-R-97 The Assessment and Rating of Noise from Wind Farms*
[3] Scottish Government (2011) Planning Advice Note *PAN 1/2011 Planning and Noise*

Scottish Government Specific Advice – Onshore Wind Turbines

12.3.4 The Scottish Government has published a specific advice sheet in connection with onshore wind turbines which includes which includes the following advice in relation to infrasound and low frequency noise. "The most conclusive summary of the implications of low frequency wind farm noise for planning policy is given by the UK Government's statement regarding the findings of the Salford University report into Aerodynamic Modulation of Wind Turbine Noise. The report concludes that there is no evidence of health effects arising from infrasound or low frequency noise generated by wind turbines".

Planning Advice Note: Planning and Noise

12.3.5 Planning Advice Note PAN 1/2011 sets out a series of noise issues that planning authorities must be aware of when formulating development plans and making decisions on planning applications in order to preserve environmental quality. In relation to wind farm noise the PAN references Scottish Government guidance as detailed above.

12.3.6 A Technical Advice Note (TAN) on Assessment of Noise[4] has been published to accompany PAN 1/2011. Appendix 1 of the TAN includes codes of practice for the assessment of various sources of noise. In relation to wind farm noise the TAN references ETSU as the appropriate guidance on assessing wind warm noise and also sets out the appropriate parameters to be applied in undertaking noise propagation calculations.

12.3.7 The TAN on Assessment of Noise also identifies BS 5228[5] for guidance on construction site noise control, and as a method of prediction of noise from construction sites.

ETSU-R-97

12.3.8 ETSU is the recommended method of assessment for operational wind farm noise. ETSU sets out a method of assessing operational noise levels from a wind farm and calculating appropriate evaluation criteria. The Institute of Acoustics has published a Good Practice Guide[6] to the application of ETSU. This assessment has followed the methods, guidance and advice set out in these publications.

Perth & Kinross Council Supplementary Planning Guidance

12.3.9 Supplementary Planning Guidance[7] (SPG) provides PKC's interpretation of the national planning guidance for wind energy developments and sets out areas of high sensitivity, within which there is a presumption against development. The SPG also sets out guideline background noise levels for rural areas across a range of wind speeds to be used in the absence of measured site-specific values. Further information on these background levels is provided in the 'existing environment' section below.

[4] Scottish Government (2011) *Technical Advice Note on Assessment of Noise*
[5] British Standards Institute (2009) *BS 5228 Code of practice for noise and vibration control on construction and open sites*.
[6] Institute of Acoustics (2013) *A Good Practice Guide to the Application of ETSU-R-97 for the Assessment and Rating of Wind Turbine Noise.*
[7] Perth and Kinross Council (2005) *Supplementary Planning Guidance for Wind Energy Proposals in Perth and Kinross.*

12.3.10 Existing Environment

12.3.11 The site of the proposed development is located in an upland setting, remote from centres of population. The closest receptors to the development are situated to the south of The site, a minimum of approximately 3.8 km from the nearest turbine. The existing noise environment at receptors surrounding the development site is quiet, as would be expected in a typically rural setting.

12.3.12 The principal noise sources in the area are naturally occurring, including wind induced noise through vegetation, and noise from the various watercourses in the area. Anthropogenic noise sources are mainly related to agricultural activities, with the occasional overflying aircraft (including military low flying) contributing to short term increases in ambient noise levels, however background (L_{90}) noise levels are expected not to be affected by these short-term noise events.

12.3.13 The measurement of background noise levels has not been conducted as part of this assessment due to the separation distance between the turbines and nearest receptors. It has therefore been assumed that the noise levels for rural areas published by PKC in its SPG will apply at each of the identified noise sensitive receptors. These are provided below in Table 12.1.

Table 12.1: Assumed Background Noise Levels, dB L_{A90}

Wind Speed (Ms^{-1})	4	5	6	7	8	9	10
Background dB L_{A90}	24	25	27	29	31	33	35

Operational Noise

12.3.14 Operational noise limits have been established for two separate periods based on the measured background noise levels. ETSU defines these periods as follows:

Quiet Daytime: All evenings from 18:00 - 23:00 hrs plus Saturday afternoons from 13:00 - 18:00hrs; plus all day Sunday 07:00 - 18:00 hrs

Night-time: 23:00 - 07:00 hrs

12.3.15 Whilst ETSU refers to Quiet Daytime period only the limits derived for the Quiet Daytime are applied across the entire daytime period (07:00-23:00).

12.3.16 The noise limits have been established for both the Quiet Daytime and Night-time periods in accordance with ETSU in the following terms:

"In low noise environments the day-time level of the $L_{A90,10min}$ of the wind farm noise should be limited to an absolute level within the range of 35-40 dB(A). The actual value chosen within this range should depend upon a number of factors:

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

12.3.17 The Noise Working Group recommends that the fixed limit for night-time is 43 dB(A)".

12.3.18 ETSU also advises that where the background noise level exceeds a certain level, the basis of the rating is measured background noise level plus 5 dB. In the circumstances, and since it has not been necessary to carry out background noise measurements, the proposed rating limit for all times of the day and night is 35 dB L_{A90}.

12.3.19 ETSU allows for a simplified method of assessment such that:

"..with very large separation distances between the turbines and nearest properties a simplified noise condition may be suitable....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".

12.3.20 Properties with financial involvement in the development are granted higher permissible noise levels within ETSU as detailed below:

"...both day- and night-time lower fixed limits can be increased to 45 dB(A) and that consideration should be given to increasing the permissible margin above background where the occupier of the property has some financial involvement in the wind farm".

12.4 Evaluation Criteria

Construction and Decommissioning Noise

12.4.1 BS5228-1:2009 sets out example criteria for the assessment of the significance of noise effects from construction and decommissioning activities. Several example criteria are given, based on both fixed noise limits and in relation to prevailing ambient noise levels. In this assessment it is considered that the most appropriate criteria are those detailed as the 'ABC method', which combines both fixed limits and an allowance for prevailing background noise levels.

12.4.2 The assessment categories and periods are reproduced below in Table 12.2.

Table 12.2: Construction noise assessment periods and lower thresholds, dB L_{Aeq}

Assessment Category and Threshold Value Period	Category A Threshold Value	Category B Threshold Value,	Category C Threshold Value
Evenings and Weekends 1900-2300 Weekdays 1300-2300 Saturdays 0700-2300 Sundays	55	60	65
Daytime 0700-1900 Weekdays 0700-1300 Saturdays	65	70	75

12.4.3 The category of threshold values to be applied is dependent on the existing ambient noise level. It is anticipated that the ambient noise level at receptors surrounding The site will be relatively low, therefore the Category A threshold values are applied to construction noise. No night-time construction work is proposed, therefore the assessment considers only Daytime and Evenings and weekend periods.

Operational Noise

12.4.4 The SPG proposes the following criteria for the evaluation of predicted noise levels against background noise levels:

- A difference of 3 dB or less - insignificant;
- Difference of 4 to 6 dB - marginal loss of amenity;
- A difference of 7 to 9 dB - significant loss of amenity; and
- A difference of 10 dB or more - major loss of amenity.

12.4.5 The property at Ardlarach (the closest residential property to the proposed development) is in the ownership of the developer, therefore its occupiers are considered by ETSU to have a financial involvement in the proposed development. In accordance with ETSU guidance, a fixed noise limit of 45 dBL_{A90} has been applied to this property in this assessment.

12.5 Method of Prediction of Change and Results

Construction Noise

12.5.1 The assessment of construction noise has been undertaken in accordance with BS5228 as recommended by PAN 1/2011. Calculations have been made in accordance with BS5228:1-2009, Annexes E and F.

12.5.2 Predictions of construction noise levels were undertaken in accordance with the method set out in BS5228. Noise data for each anticipated item of plant (as described in Chapter 4.6) have been obtained from the sound level data tables in BS5228. Items of plant have been intentionally selected with worst case source levels and have been assumed to be operating continuously with a 100% on-time. Consequently, the noise level predictions are those that could not be exceeded in practice.

12.5.3 The Calculation of Road Traffic Noise (Department of Transport, 1988) (CRTN) describes the required method for calculating road traffic noise. It addresses 'low' flow' scenarios and advises that that a daily traffic flow of less than 50 vehicles per hour, calculations are unreliable and measurement should be used.

Operational noise

12.5.4 The assessment of operational noise has been undertaken in accordance with ETSU and TAN on Assessment of Noise. In accordance with the ETSU method this assessment has been undertaken in the following stages:

- Identification of the nearest noise-sensitive receptors (NSRs);
- A screening exercise to confirm that expected levels of wind farm noise will not exceed 35 dBL_{A90} for wind speeds up to 10 m/s at 10 m height, and therefore that it is appropriate to carry out a simplified assessment;
- Derivation of noise limits for each property from PKC assumed background noise levels;
- Prediction of received noise levels at receptors, by means of a noise model, appropriately corrected for tonal emissions;
- Evaluation of predicted levels with derived noise limits; and
- Identification of mitigation measures where considered necessary.

12.5.5 Prediction of operational noise levels at each of the receptor locations was undertaken in accordance with international standards and TAN on Assessment of Noise based on sound power data provided for the candidate wind turbines.

12.5.6 Predictions of operational noise levels have been undertaken in accordance with the method described in ISO 9613-2[8]. The propagation model described in this standard provides for the prediction of sound pressure levels based on downwind (i.e. worst-case) conditions. When the wind is blowing in the opposite direction noise levels will be significantly lower, therefore the propagation model is inherently conservative.

12.5.7 The ISO propagation model calculates the predicted 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 – Ageo - Aatm – Agr - Abar

12.5.8 The geometric divergence (Ageo) attenuation factor represents the reduction in noise levels with distance from the source. The attenuation factor is directly related to the distance from the source.

12.5.9 Atmospheric absorption (Aatm) is the attenuation of noise in the atmosphere as sound energy is converted to heat. The level of absorption varies depending on the distance from sources and atmospheric conditions (temperature

[8] ISO (1996) *ISO 9613-2 Acoustics - Attenuation of Sound During Propagation Outdoors: Part 2 - General method of calculation*

and humidity). ISO 9613-1[9] provides appropriate air attenuation factors for differing atmospheric conditions. Calculations were undertaken assuming atmospheric conditions of 70°C and 10% relative humidity.

12.5.10 The ground attenuation factor (Agr) represents the reduction in noise levels due to the absorption and reflection of sound energy by ground cover. The ground attenuation will vary significantly depending on the absorptive qualities of the ground cover. ISO 9613-1 provides advice on appropriate ground attenuation factors based on ground cover ranging from hard ground (concrete) to soft absorbent ground. Test levels have been used as source noise terms in this assessment, therefore a ground absorption factor of G=0.5 has been used in the noise predictions, in accordance with the IoA *Good Practice Guide*.

12.5.11 The attenuation due to barriers (Abar) accounts for the screening and reflection effects provided by obstacles between the source and the receiver. The level of attenuation will vary depending on the degree by which the line of sight between source and receiver is affected and the frequency considered. In relation to wind farms, local topography will provide the largest influence on barrier effects. The noise TAN allows a barrier attenuation factor of 2 dB to applied in the calculations where no line of sight is determined between the rotor and the receiver, however no barrier corrections were applied in the assessment. The predicted octave band levels from each of the turbines are summed to give the overall 'A' weighted predicted sound level from all the turbines operating simultaneously.

Other operational noise effects

12.5.12 The assessment of other operation noise effects or phenomena i.e. infrasound, low frequency noise, amplitude or aerodynamic modulation (AM) is based upon a review of relevant literature and is discussed in more detail later in this chapter.

Model Input Data

Construction and Decommissioning Phases

12.5.13 The construction activities are programmed over a period of approximately 15 months. The majority of activities will be located within and close to the turbine development area. The separation distances between the turbine development area and the nearest receptors are such that construction noise levels are unlikely to be audible at these receptors. The assessment of construction noise has therefore focussed on the construction of the lower stretch of the access track to its junction with the B846. Activities and plant items during decommissioning are expected to be similar to the construction phase, hence noise levels are also anticipated to be similar.

12.5.14 The input noise levels and plant used for construction and decommissioning at the lower stretch of the access track are presented in Table 12.3.

Table 12.3: Assumed plant data for construction & decommissioning activities at the lower stretch of access track

Equipment	Size (tonnes)	L_{Aeq} @ 10 m
Wheelwash Water Pump	N/A	99

[9] ISO (1996) *ISO 9613-1 Acoustics - Attenuation of Sound during Propagation Outdoors: Part 1 - Method of calculation of the attenuation of sound by atmospheric absorption*.

Equipment	Size (tonnes)	L_{Aeq} @ 10 m
Excavator trenching	25	102
Dump Truck	25	109
Dozer	11	110
Roller	12	108

12.5.15 Predictions of noise levels at each of the receptors were undertaken assuming construction activities were occurring at the closest point of the access track. The noise propagation calculations were undertaken assuming mixed ground attenuation in accordance with BS5228.

Operational noise

12.5.16 The following input parameters were applied to the model:

- Turbine sound power levels used as listed in Table 12.4;
- The atmospheric conditions of 10^{0}C and 70% RH;
- A ground attenuation factor of G=0; and
- Topographical screening as determined by the model.

12.5.17 Predictions of operational noise were undertaken for 24 Vestas V90 3 MW turbines with a blade tip height of 125 m and hub height of 80 m. Vestas V90 broadband data is published by Vestas[10], and presents test data in accordance with IEC 61400-11. In accordance with the IoA Good Practice Guide, 2 dB has been added to the predicted noise levels to account for test uncertainty. The test sound power levels, across the range 4-12 m/s are presented in Table 12.4.

Table 12.4: Vestas V90 3.0 MW Test Sound Power Levels, dB L_{WA}

Turbine Model	Wind Speed (m/s)								
	4	5	6	7	8	9	10	11	12
Vestas V90 3.0 MW	97.9	100.9	104.2	106.1	107.0	106.9	105.6	105.2	105.3

12.5.18 Noise levels have been predicted using octave band data, which characterises the sound energy content in terms of its frequency, in accordance with ISO 9613-2. The assumed sound power level spectrum for the various operational wind speeds are presented in Table 12.5.

[10] Vestas (2010) *0005-5233 V01 – 1/1 Octaves According to General Specification V90-3.0 MW*

Table 12.5: Vestas V90 3MW turbine sound power level octave band spectra, dB L_{WA}

Wind Speed (m/s)	Octave Band Centre Frequency / Hz							
	63	125	250	500	1K	2K	4K	8K
4	76.6	84.6	89.3	91.7	92.3	91.1	86.8	75.2
5	82.1	86.9	91.5	93.5	95.9	94.6	90.5	79.1
6	85.7	90.9	94.0	96.5	99.1	98.2	94.3	83.7
7	89.7	93.3	96.1	98.3	100.8	100.1	96.2	85.7
8	91.8	94.0	97.3	99.6	101.8	100.5	96.7	86.7
9	92.3	94.2	96.9	99.5	101.7	100.4	96.4	86.6
10	91.3	93.0	95.5	98.2	100.4	99.2	94.9	85.0
11	91.0	92.6	95.2	97.9	100.1	98.6	94.2	84.2
12	91.1	92.7	95.3	98.0	100.2	98.7	94.3	84.3

12.5.19 The method for application of ground attenuation set out in ISO 9613-2 advises that the method of calculating ground effect is applicable only for ground which is approximately flat or has a constant slope. This assessment therefore considers mixed ground (G=0.5) with a receptor height of 4.0 m.

12.5.20 The L_{Aeq} noise levels have been converted into the L_{A90} required for the assessment following the procedure stated within ETSU, where:

$$L_{A90,\ (10\ mins)} = L_{Aeq} - 2\ dB$$

12.6 Study Area and Sensitive Receptors

12.6.1 The nearest properties to the proposed turbine locations are a minimum of approximately 3.8 km from the turbines, therefore it is proposed to consider these nearest properties in the noise assessment, together with other properties located near to the point where The site is accessed from the public road network. The nearest representative noise-sensitive receptors are listed in Table 12.6 and illustrated on Figure 12.1.

Table 12.6: Noise Sensitive Receptor Locations

Receptor Name	Coordinates		Distance from Nearest Turbine (km)
	Easting	Northing	
Lochview Cottages	253632	758195	3.9
Tighnabruiach	252225	758339	4.0
Ghillies Cottage	250638	757439	5.1
Tighnalinn	250220	756672	6.0
Finnart	251619	757060	5.3
Finnart Lodge	252462	757372	4.9
Croiscrag Lodge	254654	756667	5.5
Ardlarach	252801	758416	3.8

Predicted Noise Levels

Construction noise

12.6.2 The predicted noise levels at each of the specified receptors for each construction phase are presented in Table 12.7.

Table 12.7: Predicted construction noise levels, dB L_{Aeq}

Receptor	Predicted Noise Level
Lochview Cottages	37.3
Tighnabruiach	59.1
Ghillies Cottage	33.7
Tighnalinn	29.3
Finnart	36.8
Finnart Lodge	40.9
Croiscrag Lodge	28.0
Ardlarach	46.5

12.6.3 The predicted levels of construction noise exceed Category A Daytime noise criterion at Tighnabruiach during evening and weekend periods. Predicted levels of construction noise at all other receptors are below daytime, evening and weekend criteria.

12.6.4 The maximum level of construction traffic is predicted to peak in month 7. The maximum level is 49 vehicle movements per day, or approximately 6 vehicles per hour in both directions (assuming an 8-hour working day). This number of vehicle movements is below the lower limit of reliability for calculation advocated by CRTN. The predicted change in the levels of traffic flow (refer Chapter 14) on the B846 and A889 are 213% and 12.8% respectively.

Operational noise

12.6.5 The predicted operational noise levels for the range of operational wind speeds, at each of the identified sensitive receptors, are presented in Table 12.8. Comparison of the predicted noise level with the assumed background noise level at each receptor is presented in Table 12.9.

Table 12.8: Predicted operational noise levels, dB L_{A90}

	Wind Speed (m/s)						
Receptor	4	5	6	7	8	9	10
Lochview Cottages	18.6	21.3	24.6	27.3	25.3	23.3	27.7
Tighnabruiach	18.8	21.5	24.8	27.4	25.4	23.4	27.9
Ghillies Cottage	15.4	18.3	21.7	24.6	22.6	20.6	25.2
Tighnalinn	13.6	16.6	20.1	23.0	21.0	19.0	23.7
Finnart	15.3	18.2	21.6	24.5	22.5	20.5	25.1
Finnart Lodge	16.4	19.2	22.6	25.4	23.4	21.4	26.0
Croiscrag Lodge	14.6	17.6	21.0	23.9	21.9	19.9	24.6
Ardlarach	19.2	21.9	25.2	27.8	25.8	23.8	28.2

Table 12.9: Comparison of predicted operational noise levels with assumed background noise levels, dB

	Wind Speed (m/s)						
Receptor	4	5	6	7	8	9	10
Lochview Cottages	-5.4	-3.7	-2.4	-1.7	-5.7	-9.7	-7.3
Tighnabruiach	-5.2	-3.5	-2.2	-1.6	-5.6	-9.6	-7.1
Ghillies Cottage	-8.6	-6.7	-5.3	-4.4	-8.4	-12.4	-9.8
Tighnalinn	-10.4	-8.4	-6.9	-6.0	-10.0	-14.0	-11.3
Finnart	-8.7	-6.8	-5.4	-4.5	-8.5	-12.5	-9.9
Finnart Lodge	-7.6	-5.8	-4.4	-3.6	-7.6	-11.6	-9.0
Croiscrag Lodge	-9.4	-7.4	-6.0	-5.1	-9.1	-13.1	-10.4
Ardlarach*	-25.8	-23.1	-19.8	-17.2	-19.2	-21.2	-16.8

Compared with 45 dBLA90 limit for properties with financial involvement

12.7 Evaluation of Effects

Construction and decommissioning phases

12.7.1 The predicted construction and decommissioning noise level of 59 dBL_{Aeq} at Tighnabruiach during works on the lower stretch of the access track exceeds the 55 dBL_{Aeq} threshold for evening and weekend working, and is less than the 65 dBL_{Aeq} threshold for normal daytime working. Predicted construction and decommissioning noise levels during works on the lower stretch of the access track at all other receptors during all phases of construction and decommissioning are substantially below the noise criteria adopted for the daytime and evening/weekend periods.

12.7.2 The percentage changes are based on an exceptionally low baseline level of traffic flow, typical of a rural area. In this context, the change in noise level arising from a maximum of additional 6 vehicles per hour is considered negligible.

Operational phase

12.7.3 Predicted noise levels at all wind speeds and at all receptors are below the PKC assumed background noise levels. According to the PKC evaluation criteria, the loss of amenity at all receptors at all wind speeds will be insignificant. The predicted operational noise levels at Ardlarach are substantially below the recommended limit for properties that have a financial involvement in the proposed development.

Other Operational Noise Effects

Low frequency noise

12.7.4 Low frequency noise was a feature of early wind turbine designs, where the blades were down-wind of the tower. Modern turbines, and the turbines that will be used in this development, have their blades upwind of the tower, thus reducing the low frequency noise to below the threshold of human perception.

12.7.5 Leventhall[11, 12] assessed the likely levels of low frequency noise at receptor locations 600 m from a proposed site of five 1.3 MW turbines. The 2004 study reported: "It is concluded that noise from the proposed installation in the low frequency (10 Hz to 200 Hz) range is unlikely to be a problem".

[11] Leventhall et al (2003) *A Review of Published Research on Low Frequency Noise and its Effects*.

12.7.6 Measurements of the emissions from larger turbines have shown noise levels at frequencies below 20 Hz, known as infrasound, to be below audibility. Klug[13] reported the results of measurements of a Vestas V66-1750 turbine, comparing the measured levels with the German DIN45680 standard concluded: "Wind turbines are radiating sound at extremely low levels in the infrasound range (below 20 Hz). This sound is far below the detection threshold ……….. Measurements on a turbine in the megawatt class at the DEWI Test Site showed levels of 58 dB at a distance of 100 m to the turbine in the one-third octave band level at 10 Hz, which means more than 30 dB below the hearing threshold at this frequency".

12.7.7 Physic Gmbh[14] reports the results of 1/3 octave band and 'G' weighted measurements of a Nordex N80 2.5 MW turbine at 200 m. The measured values were also compared with the audibility thresholds from DIN45680 and were found to be below perceptible levels. In each case where measurements were made, low frequency noise was not considered to be of a level likely to be a cause for concern. At the proposed development site, the turbines will be very much further from properties than was the case in these studies, therefore it is concluded that low frequency noise will not result in perceptible effects from the proposed development site.

12.7.8 Styles[15] undertook a study into low frequency vibration with respect to the siting of wind farms and possible effects of the operation of the UK seismological array located at Eskdalemuir in southern Scotland. The study included vibration measurements arising from the existing Dunlaw wind farm in the Scottish Borders. Contrary to some perceptions, the study did not examine human response to either low frequency noise or vibration from wind turbines. To clarify any misconceptions, the authors of the report issued a subsequent press release which advised "…The Dunlaw study was designed to measure effects of extremely low level vibration on one of the quietest sites (Eskdalemuir) in the world, and one which houses one of the most sensitive seismic installations in the world. Vibrations at this level and in this frequency range will be available from all kinds of sources such as traffic and background noise – they are not confined to wind turbines. To put the level of vibration into context, they are ground vibrations with amplitudes of about one millionth of a millimetre. There is no possibility of human beings sensing the vibration and absolutely no risk to human health".

12.7.9 The (then) DTI published a study[16] that investigated claims that infrasound or low frequency noise emitted from wind turbines was causing adverse health effects. The study concluded that there is no evidence of health effects arising from infrasound or low frequency noise from wind turbines.

12.7.10 On the basis of the published research no perceptible effects are predicted, therefore no significant effects will result.

Aerodynamic Modulation

12.7.11 The phenomenon of Aerodynamic Modulation (AM) of wind farm noise has been identified in isolated circumstances in ways not anticipated by ETSU. In response to this phenomenon the DTI commissioned Salford University to conduct a study[17] to investigate historical complaints in relation to wind farm noise across the UK to

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[12] Leventhall (2004) *Assessment of Low Frequency Noise from the Proposed West Mill Wind Farm, Watchfield.*
[13] Klug (2002) *Infraschall von Windenergieanlagen: Realität oder Mythos?* Helmut Klug, DEWI, Extract from DEWI Magazine Nr. 20 (translated).
[14] Physic Gmbh (2003) *Messung der Infraschall-Abstrahlung einer Windenergieanlage des Typs NORDEX N-80.* 10th Juni 2003. Institut für technische und angewandte Physic Gmbh (in German only).
[15] Styles et al (2006) *Low Frequency Noise & Wind Turbines*
[16] Department of Trade and Industry (2006) DTI report W/45/00656/00/00, *The measurement of low frequency noise at three UK wind farms.*
[17] University of Salford (2007) DEFRA Contract Report NANR233, *Research into Aerodynamic Modulation of Wind Turbine Noise*

determine where AM was a factor. The study also determined to develop an understanding of AM and to whether AM can be predicted.

12.7.12 The Salford University study concluded that AM cannot be fully predicted, however, that the incidence of complaints relating to AM was low with less than four wind farms out of 133 operational wind farms studied experiencing problems. Of the wind farms experiencing problems remedial action has resolved the complaints in three cases with the other case still under investigation. A Government Statement[18] advises that whilst the situation will remain under review, it does not consider there to be a 'compelling case for further work into AM', however further research into AM has been commissioned by *RenewableUK* which is expected to be completed in late 2011.

12.7.13 Key outcomes from the research study findings[19] published by *RenewableUK* include the following:

- Normal AM (NAM) is a fundamental characteristic of wind turbine noise and its causal mechanisms are well understood;
- Other AM (OAM) is defined in the study as AM whose characteristics cannot be described by the normal source generation mechanisms of NAM. OAM is not simply intensified NAM, and has different causal mechanisms to NAM;
- NAM can occur with modulation depths as high as approximately 5 dBA in close proximity to a turbine. OAM tends to have modulation depths of approximately 5 dBA or higher in the far field;
- The occurrence of OAM is dependent on a number of interacting factors. However, the study reports the primary cause of OAM as being "transient stall" i.e. separation of the air flow from the upper surface of the turbine blade;
- Based on the evidence available, the study recognises that even at those wind farm sites where OAM has been reported to be an issue, its occurrence may be relatively infrequent;
- The study finds that it is not feasible to reliably predict the likelihood of OAM occurring at a particular site;
- The dominant descriptor of the human subjective response to wind turbine noise is the overall noise level, not the depth of modulation. When comparing modulated and un-modulated sounds of the same level, modulated sounds have been found to be slightly more annoying to some people, however, there is no specific level at which the onset of annoyance occurs; and
- Should OAM arise from a scheme, turbine management systems can be used to control the individual turbines responsible so that the impacts are mitigated under the particular conditions that give rise to the phenomenon on a case by case basis.

12.8 Mitigation Measures

12.8.1 Predicted noise levels during construction associated with works on the lower stretch of the access are in excess of the evening and weekend construction noise threshold at Tighnabruiach. No construction works on the lower stretch of the access track (excluding the transportation of infrastructure components and supplies) will be undertaken during the evening and weekend period. It is proposed that no construction work be undertaken during evenings and weekends within 1 km of noise sensitive receptors to ensure compliance with noise limits.

[18] DTi (2007) *Government Statement regarding the Findings of the Salford University Report into Aerodynamic Modulation of Wind Turbine Noise* Ref: URN 07/1276.
[19] RenewableUK (2012) *Wind Turbine Amplitude Modulation: Research to Improve Understanding as to its Cause and Effect*

12.8.2 In addition, appropriate mitigation will be adopted in line with construction best practice, including:

- Appropriately locating equipment to minimise noise effects, maximising natural screening where possible;
- Appropriate phasing of the works, equipment to be employed, working hours, and use and control of blasting;
- Utilising quietest plant where possible and deploying or moving plant at appropriate times to minimise noise effects to occupied properties;
- Restricting any operations where emissions of noise may have an adverse effect on the occupants of sensitive premises to appropriate times;
- Training and supervision of operatives in proper techniques to reduce site noise, and self-monitoring of noise levels if appropriate; and
- Efficient operation of plant, including fitting and proper maintenance of silencers and/or enclosures, avoiding excessive and unnecessary revving of vehicle engines, and parking of equipment in locations which avoid possible effects on noise-sensitive properties.

12.8.3 No significant effects are predicted during the operational phase of the proposed development. A maintenance programme will be employed on the turbines to ensure efficient operation, thereby reducing mechanical noise.

12.9 Findings

12.9.1 The assessment of construction noise considered typical noise emissions from anticipated construction plant during each stage of the proposed development construction, commissioning and decommissioning. The assessment considered a pessimistic scenario of construction plant operating simultaneously at the activity point closest to noise sensitive receptors. Predicted noise levels were below derived construction noise limits for daytime period, but exceeded noise limits for evenings and weekends, and night-time. Consequently, no construction activities are proposed within 1 km of noise sensitive receptors during evenings (as defined in Table 12.6) and weekends and no activities at night. Construction traffic noise levels are anticipated to be negligible. No significant noise effects are, therefore, expected during the construction phase of the proposed development.

12.9.2 The assessment of operational noise considered noise emissions from the proposed development across a range of operational wind speeds based on manufacturer supplied warranted noise data. Predictions of operational noise levels at the nearest noise sensitive receptors were undertaken in accordance with industry best practice and with the conservative assumption of no topographic screening of noise by the natural land relief. Allowing for the conservative assumptions in the noise calculations, the predicted noise levels are below both the most stringent noise limits for the protection of outdoor amenity and those for the prevention of sleep disturbance. No significant noise effects are, therefore, expected during the operational phase of the proposed development.

12.9.3 The potential for adverse effects from low frequency noise and infrasound, or amplitude modulation from the operational turbines was also considered with reference to published research on each phenomenon. On the basis of published research it is considered that it is unlikely that any of the phenomena will occur on The site, thus no significant effects are predicted.

12.10 Future Monitoring Requirements

12.10.1 It is not anticipated that any future monitoring will be required. It is anticipated, however, that there would be a requirement to undertake noise monitoring in response to any substantiated noise complaint to the local authority during the operational lifetime of the proposed development. Where such an instance occurs, monitoring should be undertaken in accordance with the methods described in ETSU, or subsequent amendments, as would be specified in any planning conditions to be applied to the proposed development.

12.11 Noise Condition

12.11.1 The noise condition which is proposed is as follows:

"*The wind turbines noise levels at all receptors, except Ardlarach, as measured in accordance with the applicable method shall not exceed the levels in Table 12.10. These limits apply only to dwellings existing on the date of this Condition. As the occupiers of Ardlarach are considered to have a financial involvement in the project, a noise limit of 45* dBL_{A90} *shall apply at this property."*

Table 12.10: Proposed Noise Limits, dB L_{A90}

Wind Speed (Ms^{-1})	4	5	6	7	8	9	10
Turbine Noise Level dB L_{A90}	29	30	32	34	36	39	40

12.12 Future Scenario without the Proposed Development

12.12.1 Due to the rural and remote nature of the proposed development it is anticipated that there will not be a significant change in the existing noise environment in future years without the proposed development.