Mid Moile Wind Farm

Environmental Statement
Chapter 10: Noise

December 2021

CONTENTS

10 NOISE **1**
Introduction 1
Planning Policy & Relevant Information 1
Operational Noise Assessment Methodology & Significance Criteria 9
Baseline Conditions 16
Potential Effects 16
Cumulative Operational Assessment....18
Mitigation....19
Residual Effects 20
Summary 20
References....21

TABLES

Table 10.1: Assessment Locations
Table 10.2: Turbine Locations, Dimensions & Model
Table 10.3: Turbine Source Sound Power Levels, dB L_{WA}
Table 10.4: Atmospheric Absorption Coefficients
Table 10.5: Predicted Mid Moile Wind Farm Noise Levels, dB L_{A90}
Table 10.6: Construction Plant Details for Track Works
Table 10.7: Predicted Cumulative Wind Farm Noise Levels, dB L_{A90}

APPENDICES

Appendix 10.1: Noise Contour Plots

10 NOISE

Introduction

10.1 Hayes McKenzie Partnership Limited (HMPL) have undertaken an assessment of the potential noise levels resulting from the introduction of the proposed Mid Moile Wind Farm ('the Proposed Development), located in Dumfries and Galloway, on behalf of EnergieKontor UK Ltd (EKUK).

10.2 The operational assessment has been carried out according to the recommendations of ETSU-R-97, *The Assessment and Rating of Noise from Wind Farms*, and the good practice guidance published by 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* (GPG) and its associated Supplementary Guidance documents. These documents are referred to within web-based planning guidance provided by the Scottish Government.

10.3 Predictions of the noise levels associated with the operation of the Proposed Development in isolation, based on the installation of Siemens-Gamesa SG155 AM 6.6 MW wind turbines, have been compared with the noise limits prescribed in ETSU-R-97.

10.4 The cumulative impact of the Proposed Development operating in combination with the operational Glen App and recently consented Stranoch 2 wind farm, (ECU Reference ECU00000710), has also been assessed.

10.5 A discussion of the potential impacts relating to the construction of the Proposed Development, including from possible blasting within the proposed borrow pits, is provided in terms of relevant guidance; BS5228 *Code of Practice for Noise and Vibration Control on Construction & Open Sites*. However, a detailed assessment is not provided as the distances from turbine construction activities and neighbouring properties will mean that potential noise levels are well within typical planning limits in this regard.

Planning Policy & Relevant Information

PAN1/2011, Planning and Noise

10.6 *Planning Advise Note PAN1/2011* (Scottish Government, 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". It refers to the "web based planning advice" on renewables technologies for onshore wind turbines.

10.7 The accompanying Technical Advice Note to PAN1/2011, Assessment of Noise, lists BS 5228, *Noise and Vibration Control on Construction and Open Sites* (BSI, 2009 + 2014) as being applicable for Environmental Impact Assessment (EIA) and planning purposes.

Web Based Planning Advice, Onshore Wind Turbines

10.8 The web-based planning advice on onshore wind turbines (Scottish Government, 2014) states that the sources of noise are *"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"* and that *"there has been significant reduction in the mechanical noise generated by wind turbines through improved turbine design"*. 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 windfarm 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"*. 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"*.

10.9 It 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 (GPG), and states that *"The Scottish Government accepts that the guide represents current industry good practice"*.

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

10.10 ETSU-R-97, *The Assessment and Rating of Noise from Wind Farms* (DTI, 1996), 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.

10.11 ETSU-R-97 recommends that noise limits should be set relative to existing background noise levels 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"*.

10.12 For day-time periods, the noise limit is 35-40 decibel (dB) $L_{A90,t}$ or 5 dB above the 'quiet daytime hours' prevailing background noise, whichever is the greater. The actual value within the 35-40 dB L_{A90} range depends on the number of dwellings in the vicinity; the effect of the limit on the number of kWh generated; and the duration of the level of exposure. The $L_{A90,t}$ is the noise level which is exceeded for 90% of the measurement period 't'.

10.13 For night-time periods the noise limit is 43 dB L_{A90} or 5 dB above the prevailing night-time hours background noise, whichever is the greater. The 43 dB L_{A90} lower limit is based on a sleep disturbance criterion of 35 dB(A) with an allowance of 10 dB for attenuation through an open window and 2 dB subtracted to account for the use of L_{A90} rather the L_{Aeq} (see Paragraph 10.17).

10.14 Where the occupier of a property has some financial involvement with the proposal, the day and night-time lower noise limits are increased to 45 dB L_{A90} and consideration can be given to increasing the permissible margin above background. These limits would be applicable up to a wind speed of 12 m/s measured at 10 m height on the site.

10.15 Quiet day-time periods are defined as evenings from 18:00-23:00 plus Saturday afternoons from 13:00-18:00 and Sundays from 07:00-18:00. Night-time is defined as 23:00-07:00. The prevailing background noise level is set by calculation of a best fit curve through values of background noise plotted against wind speed as measured during the relevant time period with background noise measured in terms of $L_{A90,t}$. It is recommended that at least 1 weeks' worth of measurement is required.

10.16 Where predicted noise levels are low at the nearest residential properties, a simplified noise limit can be applied, such that noise is restricted to a level of 35 dB L_{A90} 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.

10.17 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 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 noise level. Use of the L_{A90} descriptor, the level exceeded for 90% of the measurement period, for wind farm noise allows reliable measurements to be made without corruption from relatively loud, transitory noise events from other sources.

10.18 ETSU-R-97 also specifies that a penalty should be added to the predicted noise levels, where any audible tone is present. The level of this penalty, as shown on page 10 of the executive summary, is described and varies according to the level by which any tonal components exceed audibility.

10.19 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 effect 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 be considered as part of the prevailing background noise.

A Good Practice Guide to the Application of ETSU-R-97

10.20 In May 2013, the Institute of Acoustics published *A Good Practice Guide to the Application of ETSU-R-97 for the Assessment and Rating of Wind Turbine Noise* (IOA, 2013). This was subsequently endorsed by the Scottish Government. The publication of the Good Practice Guide followed a review of current practice carried out for the Department of Energy and

Climate Change (DECC, 2011) and an IOA discussion document which preceded the GPG (IOA, 2012).

10.21 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*". It adds that "*the noise limits in ETSU-R-97 have not been examined as these are a matter for Government*".

10.22 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 a preferred methodology for dealing with wind shear.

BS 8233 Guidance on Sound Insulation and Noise Reduction for Buildings

10.23 British Standard (BS) 8233 (BSI, 2014) advises the use of ETSU-R-97 when assessing wind farm noise impact and states that reliable estimates of wind farm noise levels can be made by implementing the procedures set out in the IOA GPG. It draws particular attention to the issues of amplitude modulation (AM); however, it goes on to state that such adverse effects cannot be predicted at the planning stage.

BS 5228 Code of Practice for Noise and Vibration Control on Construction and Open Sites

10.24 BS 5228:2009 + A1:2014 (BSI, 2009 + 2014) 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.

10.25 The first is based on the use of criteria defined in Department of the Environment Advisory Leaflet (AL) 72, *Noise Control On Building Sites* (DoE, 1976), 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 façade L_{Aeq} values with free-field levels taken to be 3 dB lower giving an equivalent noise criterion of 67 dB L_{Aeq}.

10.26 The second is based on noise change but applies minimum criteria of 45, 55 and 65 dB L_{Aeq} for night-time (23:00-07:00), evening and weekends (19:00-23:00 weekdays, 13:00-23:00 Saturdays and 07:00-23:00 Sundays), and daytime (07:00-19:00) including Saturdays (07:00-13:00) respectively. These limits are applicable when existing noise levels are low and for construction activities having a duration of one month or more. It should be noted that the time period to which each limit applies also defines the time averaging period for the calculated L_{Aeq}.

Blade Swish (Amplitude Modulation of Aerodynamic Noise)

10.27 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) and is an inherent feature of wind turbine noise. This affect is identified within ETSU-R-97, where it is envisaged that '*… modulation of blade noise may result in variation of the overall A-Weighted noise level by as much as 3 dB(A) (peak to trough) when measured close to a wind turbine... '* 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)'*.

10.28 It has been noted that complaints about wind farm noise to planning authorities in the UK, where they have occurred, have often been specifically concerned with amplitude modulation. This is also apparent from ETSU-R-97, where it is noted that '*it is the regular variation of the noise with time that, in some circumstances, enables the listener to distinguish the noise of the turbines from the surrounding noise'*. The modulation of noise may affect perceived annoyance for sounds with the same overall sound pressure level.

10.29 RenewableUK (RUK), the main renewable energy trade association in the UK, completed research into the causes and subjective effects of AM (RUK, 2013) following various reports of increased levels of AM being experienced at dwellings neighbouring some wind turbine sites. This has concluded that the predominant cause is likely to be from individual blades going in and out of stall as they pass through regions of higher wind speed at the top of their rotation under high wind shear conditions. Subjective tests carried out by Salford University, using loudness matching techniques, have demonstrated the extent to which higher levels of modulation depth result in increased perceived loudness.

10.30 This resulted in the inclusion of a mechanism to assess and regulate AM effects in the standard form of a condition (RUK, 2013), frequently applied to wind farm developments as included in the IOA GPG. The IOA reviewed this mechanism and released a discussion document (IOA, 2015) which reviews several different methods for rating amplitude modulation in wind turbine noise and subsequently released a recommended method (IOA, 2016) by which to characterise the peak to trough level in any given 10 minute period.

10.31 Although this document provides a definitive approach for the quantification of amplitude modulation, it does not provide any comment on what could be defined as an unacceptable level of AM nor any kind of penalty scheme, such as for tonal content, by which the overall turbine noise level should be corrected to account for its presence. This has subsequently been covered by a Department of Energy & Climate Change (DECC) commissioned project looking at human response to the amplitude modulated component of wind turbine noise (DECC, 2016).

10.32 The combination of these documents provides both a method of quantification of the level of amplitude modulation over a given 10 minute period and the appropriate penalty to apply where necessary. This is in addition to any penalty for tonal noise.

10.33 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 can be covered by a suitably worded planning condition. One proposed wording for such a condition can be seen in an article jointly authored by a number of prominent consultants in the November/December 2017 issue of the Institute of Acoustics' Acoustics Bulletin magazine (McKenzie et al., 2017). However, there is still on-going debate as to the specifics of how potential penalties in respect of AM should be applied in practice and, rather than applying planning conditions relating to AM which could be considered ambiguous, many councils in Scotland refer to statutory nuisance powers in this respect. This enables flexibility in the interim as the situation develops.

10.34 There are no standard or agreed methods by which to predict, with any certainty, the likelihood of amplitude modulation occurring at a level requiring a penalty at a particular development, only some indicators such as relatively high wind shear conditions under certain circumstances or particular turbine designs and/or dimensions for example.

Wind Shear

10.35 Wind shear, or more specifically vertical wind shear, is the rate at which wind speed increases with height above ground level. This has particular significance to wind turbine noise assessment where background noise measurements are referenced to measurements of wind speed at 10 metres height, which is suggested as appropriate by ETSU-R-97, but which is not representative of wind at hub-height, which is what affects the noise generated by the turbines.

10.36 The preferred method of accounting for wind shear in noise assessments is by referencing background noise measurements to hub height wind speed. Hub height wind speed may be determined directly by using a tall mast or remote sensing technology (i.e. LiDAR or SoDAR) or indirectly from measurements at a number of heights below hub height in order to calculate the hub height wind speed during the background noise survey period, as described in the GPG referred to at Paragraphs 10.20 to 10.22. The hub height wind speeds are then converted to 'standardised 10 m wind speeds', assuming standardised conditions as used by turbine manufacturers when specifying turbine sound power levels.

Tonal Noise

10.37 ETSU-R-97 notes that, at the time the report was written, where complaints had been made over noise from existing wind farms, the tonal character of the noise from machinery in the nacelle had been the feature that had caused greatest annoyance. The recommendation was, therefore, that any assessment carried out should include a correction to the predicted noise levels according to the level of any tonal components in the noise. A specific tonal assessment methodology is described in the report which is based on the well-established Joint Nordic Method for the Evaluation of Tones in Broadband Noise (DMoE, 1984) which has now been superseded by a revised version (Pederson et al., 1999) although this revision makes no substantive difference to the ETSU-R-97 methodology. A scale of corrections for tonal noise is included where the penalty is increased as the tone level increases above audibility to a maximum of 5 dB. The necessity of minimising tonal components in the noise output from the turbines is well understood by the turbine manufacturers and a guarantee should always be sought that any tonal noise will be below that requiring a penalty under the ETSU-R-97 scheme.

Infra-sound

10.38 Infra-sound is noise occurring at frequencies below that at which sound is normally audible, i.e. at less than about 20 Hz, due to the significantly reduced sensitivity of the ear at such frequencies. In this frequency range, for sound to be perceptible, it has to be of very high amplitude and it is generally considered that when such sounds are perceptible then they can cause considerable annoyance.

10.39 Wind turbines have been cited by some as producers of infra-sound. This has, however, been due to the high levels of such noise, as well as audible low frequency thumping noise, occurring on older 'downwind' turbines of which many were installed in the USA prior to the large scale take up of wind power production in the UK. Downwind turbines are configured with the blades downwind of the tower such that the blades pass through the wake left in the wind stream by the tower resulting in a regular audible thump, with infra-sonic components, each time a blade passes the tower. Virtually all modern larger turbines are of the upwind design; that is with the blades upwind of the tower, such that this effect is eliminated.

10.40 A study into low frequency noise from wind farms (ETSU/DTI, 2006) concluded that "*infrasound noise emissions from wind turbines are significantly below the recognised threshold of perception for acoustic energy within this frequency range. Even assuming that the most sensitive members of the population have a hearing threshold which is 12 dB lower than the median hearing threshold, measured infrasound levels are well below this criterion*". It goes on to state that, based on information from the World Health Organisation, "*there is no reliable evidence that infrasound below the hearing threshold produce physiological or psychological effects*" and that "*it may therefore be concluded that infrasound associated with modern wind turbines is not a source which may be injurious to the health of a wind farm neighbour*".

10.41 A considerable amount of research has been conducted in regards to the levels of infrasound that wind turbines emit over the years (ETSU/DTI, 1997) (Styles et al., 2005) (Turnball et al., 2012). Further reliable evidence (LUBW, 2016) (VN TEAS, 2020) suggests that at typical residential distances (e.g. at 500 m or more), the levels of infrasound from a windfarm are significantly below accepted thresholds of perception. Even when measured in close proximity to a wind turbine, the measured levels of infrasound are still below accepted thresholds of perception. This suggests that infrasound is not an issue for neighbours in the vicinity of wind turbines.

Low Frequency Noise

10.42 Noise from modern wind turbines is essentially broad band in nature in that it contains similar amounts of noise energy in all frequency bands from low to high frequency. As distance from a wind farm site increases, the noise level decreases as a result of the spreading out of the sound energy and also due to air absorption which increases with increasing sound frequency. This means that, although the energy across the whole frequency range is reduced, higher frequencies are reduced more than lower frequencies with the effect that as distance from the site increases the ratio of low to high frequencies also increases. This effect is not specific to wind turbines and may be observed with road traffic noise or natural sources, such as the sea, where higher frequency components are diminished relative to lower frequency components at long distances. At such distances, where residential properties are typically located in relation to wind farm developments, the overall noise level is so low, such that any bias in the frequency spectrum is insignificant in terms of typical noise criteria (Moorhouse et al, 2005) in this regard.

Vibration

10.43 The ETSU study referenced at Paragraph 10.41 (ETSU/DTI, 1997) found that vibration from wind turbines, as measured at 100 m from the nearest machine, was well below the criteria recommended for human exposure in critical working areas such as precision laboratories (BSI, 2008). At greater distances from turbines vibration levels are even lower. This has been confirmed by the Keele University study (Styles et al., 2005), which showed vibration levels of around 10-8 m.s-2 at a distance of 2.4 km from the Dun Law Windfarm site under high wind conditions, orders of magnitude lower than the criteria referred to above which specify levels in the region of 0.005 m.s-2. The LUBW report (LUBW, 2016), also referenced at Paragraph 10.41, provides further evidence that levels of vibration associated with the operation of larger wind turbines are insignificant.

Audibility

10.44 The potential audibility of noise from proposed wind turbines depends to a large extent on the amount by which the predicted turbine noise level exceeds the noise from other sources (the baseline or background noise level) and the presence of any acoustical 'features' which distinguish it. Other background noise may be steady and unchanging, but is more likely to be continuously variable depending on the time of day and other factors including, particularly in rural areas, wind speed.

10.45 In instances where baseline noise measurements are carried out for development proposals, the potential audibility of wind turbine noise can be determined by comparing the predicted turbine noise with the measured background noise. Where predicted noise levels are around the same level as the background noise this suggests that the noise source may be just audible, with audibility increasing with margin above background and also when taking into account any significant acoustic features such as tonality or amplitude modulation. Similarly, where predicted noise levels are lower than the existing background noise levels, audibility decreases as the margin below background noise becomes greater. Where background noise is very low, audibility becomes more dependant absolute noise level, reducing and becoming less intrusive as noise level decreases. Where predicted noise levels are below 35 dB L_{A90}, as discussed in Paragraph 10.16, a comparison against background noise level is not required by ETSU-R-97, and potential audibility falls off below this level.

Sleep Disturbance

10.46 The potential for sleep disturbance depends on the average and maximum levels of noise in sleeping areas during the night time period. The night-time noise limits in ETSU-R-97 aim to protect against sleep disturbance by limiting the amount of turbine noise external to dwellings assuming a worst case of inhabitants sleeping with the windows open for ventilation. The internal noise levels in such circumstances can be calculated by assuming a 10-15 dB reduction in noise from outside to inside. The World Health Organisation (WHO) published recommendations in 1999 to the effect that average night-time noise levels in sleeping areas should not exceed 30 dB L_{Aeq} (WHO, 1999). Although this figure relates to overall noise level in sleeping areas, the potential for sleep disturbance specifically from turbine noise, for worst case downwind propagation with windows open, can be evaluated for each dwelling by subtracting 10-15 dB from the predicted turbine noise level and comparing with this criterion, after also adding 2 dB to convert the predicted turbine noise level to an L_{Aeq} value.

10.47 It should be noted that guidance from the WHO on night noise levels, in the form of the Night Noise Guidelines for Europe (WHO, 2009), recommends that the population is not exposed to average external night-time noise levels, over a whole year, of more than 40 dB L_{Aeq}. This average yearly noise level will depend on the variation in wind speed, wind direction and noise from other sources over each year period.

.1 Further to the above, the latest guidance from the WHO (WHO, 2018) conditionally recommends that turbine noise should not exceed an L_{den} of 45 dB. L_{den} is the average noise level over one year, where noise during evening and night-time periods is penalised with a 5 and 10 dB correction respectively. However, the WHO report makes it clear that reference should be made to relevant country or district guidance in this respect. Under typical circumstances in the UK, the ETSU-R-97 guidance results in noise levels that would be below 45 dB L_{den}.

10.48 It should also be noted that potential difficulty in getting to sleep, either at the start of the night or once awoken by other sources, may be more related to audibility indoors under specific circumstances than by average noise level.

Operational Noise Assessment Methodology & Significance Criteria

Assessment Methodology

10.49 The assessment of operational noise levels associated with the Proposed Development have been undertaken in accordance with ETSU-R-97 and the GPG for both the scheme operating in isolation and cumulatively with the existing Glen App and consented Stranoch wind farms. There are no other wind farms in the vicinity of the Proposed Development that are expected to result in combined operational noise effects of any relevance.

10.50 The closest relevant residential dwellings located in the vicinity of the wind farm sites have been considered as part of the assessment and are listed at Table 10.1 and shown at Technical Appendix 10.1

10.51 Construction noise is discussed in general terms and with regard to national planning guidance.

Table 10.1 Assessment Locations

Location	Easting	Northing
High Mark	213399	570642
Dalnigap	213383	570997
Shennas	212568	572014
White Cairn	207516	574626
Drumbo	206528	573843
Meikle Laight	206851	570096
House at Penwhirn Dam	213388	569454

Noise Prediction Methodology

10.52 Noise predictions have been carried out using International Standard ISO 9613, *Acoustics - Attenuation of Sound During Propagation Outdoors*. The propagation model described in Part 2 of this standard (ISO, 1996) provides for the prediction of sound pressure levels based on either short-term downwind (i.e. worst case) conditions or long-term overall averages. The predictions provided here correspond to short-term downwind conditions except where wind direction effects have been taken into account.

10.53 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:

$$\text{Predicted Octave Band Noise Level} = L_W + D - A_{geo} - A_{atm} - A_{gr} - A_{bar} - A_{misc}$$

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

10.55 The turbine co-ordinates used for the assessment, as provided by EnergieKontor, are shown at Table 10.2.

Table 10.2 Turbine Locations, Dimensions & Model

Turbine	Easting	Northing	Hub-Height	Tip Height	Turbine Model
Mid Moile					
M1	208348	571355	122.5	200	SG155 AM 6.6 MW
M2	209065	570903	122.5	200	SG155 AM 6.6 MW
M3	209480	570658	122.5	200	SG155 AM 6.6 MW
M4	209737	570202	122.5	200	SG155 AM 6.6 MW
M5	209923	569750	122.5	200	SG155 AM 6.6 MW
M6	209002	572057	122.5	200	SG155 AM 6.6 MW
M7	209231	571655	122.5	200	SG155 AM 6.6 MW
M8	209628	571366	152.5	230	SG155 AM 6.6 MW
M9	210093	571136	152.5	230	SG155 AM 6.6 MW
M10	210309	570661	152.5	230	SG155 AM 6.6 MW

Turbine	Easting	Northing	Hub-Height	Tip Height	Turbine Model
M11	210547	570198	152.5	230	SG155 AM 6.6 MW
M12	209630	572192	152.5	230	SG155 AM 6.6 MW
M13	210149	571930	152.5	230	SG155 AM 6.6 MW
M14	210798	571418	152.5	230	SG155 AM 6.6 MW
M15	211206	570377	152.5	230	SG155 AM 6.6 MW
Glen App					
G1	207869	572346	80	125	G90 2 MW
G2	208342	572472	80	125	G90 2 MW
G3	208734	572486	80	125	G90 2 MW
G5	208455	573734	80	125	G90 2 MW
G6	208044	573744	80	125	G90 2 MW
G7	207730	573247	80	125	G90 2 MW
G8	208311	572321	80	125	G90 2 MW
G9	208867	573409	80	125	G90 2 MW
G10	208651	572903	80	125	G90 2 MW
G11	209149	572851	80	125	G90 2 MW
G12	207878	572794	80	125	G90 2 MW
Stranoch					
S1	216669	574716	100	175	V150
S2	217110	574524	100	175	V150
S3	215781	574112	100	175	V150
S4	216355	574135	100	175	V150
S5	216815	573966	100	175	V150
S6	217421	574247	84	142.5	V117
S7	215831	573597	100	175	V150
S8	216285	573472	100	175	V150
S9	217172	573667	84	142.5	V117
S10	215948	572962	100	175	V150
S11	216326	572832	100	175	V150
S12	216649	573251	82	150	V136
S13	215313	571187	82	150	V136
S14	214916	570605	82	150	V136
S15	215672	570870	84	142.5	V117
S16	214812	570068	82	150	V136
S17	215337	570083	82	150	V136
S18	215166	570407	82	150	V136
S19	215165	569538	82	150	V136

Turbine	Easting	Northing	Hub-Height	Tip Height	Turbine Model
S20	215689	569802	84	142.5	V117

L_W - Source Sound Power Level

10.56 The sound power level of a noise source is normally expressed in dB re:1pW. Noise predictions for the proposed Mid Moile turbines are based on the maximum sound power level for a Siemens-Gamesa SG155 AM 6.6 MW turbine with a hub-heights of 125 and 152.5 m and with serrated trailing edges (STEs) installed on the blades, as provided by the turbine manufacturer.

10.57 The maximum source noise levels for the Gamesa G90 2 MW turbine with a hub-height of 80 m installed at the neighbouring Glen App Wind Farm been used to inform the predictions herein. Since this particular turbine is known to be installed at the site it is considered that the GPG prediction methodology and associated assumptions represents a realistic conservative estimate of the actual noise levels resulting from the Glen App development will be without any further account for what the planning consent documents may allow for.

10.58 The source noise levels for the turbines installed at the Stranoch development are taken from the most recent Further Environmental Information (FEI) Chapter associated with the consented Stranoch 2 proposal. The development is expected to consist of various Vestas turbine models (see Table 10.2) and the maximum level from each has been used to inform the cumulative assessment. The Stranoch site already has planning consent for which conditions are attached in respect of operational noise. The planning consent for Stranoch 2 includes the same operational noise limits, as previously consented for the original Stranoch scheme. At this point it is not possible to determine what the actual turbine to be procured for the Stranoch site will be. However, the latest FEI published for the site indicates that the assumptions made for its assessment are provided on a conservative basis, including the need for some minor curtailment in wind directions which are not relevant for the properties considered here. This curtailment has, in any case, not been factored in here so that it is assessed on a worst-case basis. In practice,, overall turbine noise levels associated with this development would not differ substantially from that presented within the FEI for the dwellings of interest here. As a result, no further correction for what the consent documents (as existing and recently approved) may allow for in terms of operational noise has been accounted for here.

10.59 All sound power levels are taken from specification documents provided by the respective turbine manufacturers with 2 dB added to account for uncertainty. As such, the assumed sound power levels are likely to be comparable to a declared sound power level i.e. derived according to the methodology detailed within IEC 61400-14 (IEC, 2005).

10.60 Table 10.3 provides the overall source noise levels used for the noise predictions for the various turbine models, including for the uncertainty explained above.

Table 10.3 Turbine Source Sound Power Levels, dB L_{WA}

Turbine	Overall, dB L_{WA}	Octave Band Centre Frequency (Hz)							
		63	125	250	500	1k	2k	4k	8k
SG155 AM 6.6 MW	107.0	86.6	94.0	98.6	100.9	100.7	101.0	94.4	79.4
G90 2 MW	107.5	88.5	96.1	101.1	102.9	100.7	96.2	91.1	92.7
V150	106.9	87.9	95.6	100.2	102.0	100.9	96.8	89.9	80.0
V136	105.9	86.8	94.5	99.2	101.0	99.9	95.8	88.9	78.8
V117	108.0	88.3	95.5	100.3	102.6	102.4	99.7	94.5	86.8

10.61 The ETSU-R-97 noise limits require a tone correction to be applied to any derived turbine noise levels resulting from noise measurements of the operational turbines which depends on the amount by which the tone exceeds the audibility threshold. 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. A warranty will be sought from the supplier of the turbines to be installed at the site to ensure that no tonal penalty would be required in practice.

D - Directivity Factor

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

A_{geo} - Geometrical Divergence

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

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

where, d = distance from the turbine

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

A_{atm} - Atmospheric Absorption

10.65 The atmospheric absorption accounts for the frequency dependant linear attenuation with distance over the frequency spectrum according to:

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

where, a = the atmospheric absorption coefficient for the relevant frequency band

10.66 Published values of 'a' from ISO9613 Part 1 (ISO, 1992) have been used, corresponding to a temperature of 10°C and a relative humidity of 70%, which give relatively low levels of atmospheric attenuation, as given at Table 10.4. This provides a conservative basis for assessment.

Table 10.4 Atmospheric Absorption Coefficients

Octave Band Centre Frequency (Hz)	63	125	250	500	1k	2k	4k	8k
Atmospheric Absorption Coefficient (dB/m)	0.0001	0.0004	0.0010	0.0019	0.0037	0.0097	0.0328	0.1170

A_{gr} - Ground Effect

10.67 Ground effect is the interference of sound reflected by the ground interfering 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 (includes paving, water, ice, concrete and any sites with low porosity) and 1 for 'soft' ground (includes ground covered by grass, trees or other vegetation). The GPG recommends that the use of G = 0.5 and a receptor height of 4 m in rural areas are appropriate assumptions for the determination of noise emission levels at receptor locations downwind of wind turbines, provided that an appropriate margin for uncertainty has been included within the source levels for the proposed turbine. Accordingly, predictions provided here are based on G = 0.5 with a receptor height of 4 m.

A_{bar} - Barrier Attenuation

10.68 The effect of any barrier between the noise source and the receiver position is that noise will 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 results of a study of propagation of noise from wind farm sites carried out for ETSU (DTI, 2000), concludes 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 and that 10 dB(A) should be allowed where a barrier lies within 5 m of a receiver and provides a significant interruption to the line of site. The effect of barrier attenuation, including the effects of increased distance from the turbine to surrounding dwellings as a result of the surrounding topography as compared with a 'flat-earth' model, has been included within the prediction model.

10.69 The potential attenuation of noise due to the topography of the site has been determined through the inclusion of a terrain map within the prediction model. The resultant attenuation due to the topographical barriers has been calculated using VDI 2720 *Noise Control by Barriers Outdoors* (VDI, 1997). The relevant inputs, C_1, C_2 and C_3, account for the proportional attenuation effects associated with line of sight between the source and receiver, the relative path difference and the presence of any localised reflections near the barrier respectively. These factors have been calibrated, minimising the overall effect of each such that the resultant attenuation due to topography at neighbouring residences is limited to approximately 2 dB where there is clearly no line of site between a turbine and the receptor, 5 dB in situations where there is a significant topographical barrier between a particular turbine and a receptor and 10 dB in exceptional situations where receptors are located relatively close to particularly large barriers such as tall cliff faces that obstruct any view from the wind farm site.

A_{misc} - Miscellaneous Other Effects

10.70 ISO 9613 includes effects of propagation through foliage and industrial plants as additional attenuation effects. The attenuation due to foliage has not been included here and any such effects are unlikely to significantly reduce noise levels below those predicted.

Concave Ground Profile

10.71 Studies have shown that sound propagation across a valley or 'concave ground profile' can result in noise levels which are higher than predicted due to a reduced ground effect and/or the focussing effect of the ground shape. Calculating the precise effect of this phenomenon is particularly difficult. However, a simplified approach to allow for it has been suggested in the GPG. Paragraph 4.3.9 in the GPG states that 'A further correction of +3 dB (or +1.5 dB if using G=0.0) should be added to the calculated overall A-weighted noise level for propagation "across a valley", i.e. a concave ground profile, or where the ground falls away significantly, between the turbine and the receiver location. The following criterion of application is recommended:

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

where, h_m is the mean height above the ground of the direct line of sight from the receiver to the source (as defined in ISO 9613-2, Figure 3), and h_s and h_r are the heights above local ground level of the source and receiver respectively.'

10.72 The GPG states that *'Care needs to be exercised when evaluating this condition, as small changes in distances and height may trigger (or not) the criterion when the actual situation has not changed significantly'*. It is also evident that the criterion may also be triggered in situations where there is more than one valley between a particular source and receiver, where, in reality, the stated causes of the 'concave ground profile' effect could not occur.

10.73 The topography between the turbines and surroundings considered here has been incorporated into the noise model. A 3 dB correction has been applied in all instances where the above criterion is fulfilled, except where there is no line-of-sight between a turbine and a relevant location (i.e. one of the possible instances where the criterion may be triggered but the stated effect could not occur in practice). This is still expected to be a particularly conservative basis for assessment as it is considered that the full extent of the corrections applied here will not occur in practice.

Significance Criteria

10.74 There are no formal significance criteria for assessing operational noise from wind farms. However, for the purposes of this assessment the noise impact is considered to be not significant in EIA terms if the limits discussed at Paragraphs 10.10-10.19 above are met and significant if not.

10.75 Construction noise is assessed against an adopted daytime criterion of 65 dB L_{Aeq} and the impact is therefore judged to be not significant if this criterion is met (see Paragraphs 10.24 to 10.26).

Baseline Conditions

10.76 Baseline/background noise levels in rural areas are generally low but become increasingly affected by wind induced noise sources such as the rustling or trees and foliage as wind speed increases. Various other sources such as water flow, localised traffic movements and dawn chorus can also influence the background noise environment to varying degrees.

10.77 ETSU-R-97 recommends that measurements of the existing background noise levels are not necessary for smaller or remote schemes where it can be shown that noise levels associated with a particular development does not exceed 35 dB L_{A90} at high wind speeds (see Paragraph 10.16). In this instance, the proposed Development has predicted noise levels that are well below this criterion.

Potential Effects

Operational Noise

10.78 Appendix 10.1 shows the maximum noise level from the Proposed Development acting in isolation in the form of noise contours.

10.79 The predicted turbine noise L_{Aeq} has been adjusted by subtracting 2 dB to give the equivalent L_{A90} as suggested in ETSU-R-97 and reaffirmed within the GPG. The predictions assume that all the dwellings considered here are downwind of all turbines simultaneously, which cannot occur in practice at some locations, and that all the turbines are operating unrestricted and at their maximum sound power level.

10.80 Table 10.5 shows the predicted noise levels in tabular form for the properties identified in Table 10.1.

Table 10.5 Predicted Mid Moile Wind Farm Noise Levels, dB L_{A90}

Location	Easting	Northing	Noise Level, dB L_{A90}
High Mark	213399	570642	28.7
Dalnigap	213383	570997	27.9
Shennas	212568	572014	31.2
White Cairn	207516	574626	24.4
Drumbo	206528	573843	24.2
Meikle Laight	206851	570096	30.4
House at Penwhirn Dam	213388	569454	27.7

10.81 The maximum operational noise levels presented within Table 10.5 for the site operating in isolation are well below the minimum requirements of ETSU-R-97 (see Paragraph 10.79). As a result, operational noise is considered not significant (see Paragraph 10.74).

Construction Noise

10.82 The construction of the proposed turbines will occur at distances that are highly unlikely to breach typical construction noise limits prescribed within relevant guidance such as BS 5228 Code of Practice for Noise and Vibration Control on Construction & Open Sites (see Paragraphs 10.24 to 10.26). This combined with the temporary nature of the works means that a detailed assessment of the construction noise impacts is not considered necessary.

Construction of New Access Track

10.83 The proposed new access track to the site, leading from the A77 just north of Cairnryan, passes 3 residential properties slightly further away than the existing minor road. This proposed access does not use the existing minor road used by residents and is slightly further from the properties at 50 metres from Bonny Braes and 155 metres from Lairds Hill and Little Laight. Construction noise predictions have therefore been carried out as follow to quantify the temporary noise impact at these properties during the construction of this new track and in the following months when it is used by HGVs accessing the main construction site.

10.84 Construction plant has been assumed as follows for the proposed track construction works with the highest relevant levels taken from the tables of noise levels provided in BS5228 Appendix C as a worst case.

Table 10.6 – Construction Plant Details for Track Works

Plant Item	BS5228 Table Ref	BS5228 Item in Table	Number of Items	A-Weighted 10 m noise level (dB $_{LAeq}$)
Road Lorry	C2	34	3	80
Dozer	C5	14	1	86
Vibratory Roller	C5	24	1	84

10.85 Noise predictions for this plant at the closest point to the three properties have been carried out using the methodology specified in BS5228 Appendix F, assuming 50% soft ground and 100% on-time for the plant. This shows predicted maximum noise levels of 74 dB L_{Aeq} at Bonny Braes and 63 dB L_{Aeq} at Laird's Hill and Little Laight. This can be compared with the criteria outlined at Paragraph 10.24 - 10.26 (above) and it can be seen that, at Bonny Braes, the 65 dB L_{Aeq} noise criterion, applicable for day-time working, would be exceeded. At Laird's Hill it will be just below that level. It should be noted, however, that these criteria apply where existing noise levels are low and for construction activity of duration of one month or more. In this case, existing noise level would be raised by traffic on the A77, above that normally found in rural areas, and by a greater extent at Bonny Braes than at the other two properties. It is estimated that the track works will progress at a rate of 100 metres per day and, based on that, the 65 dB L_{Aeq} criterion is predicted to be exceeded for 4 days as the construction plant passes Bonny Braes.

HGV Traffic Accessing Site

10.86 The peak number of HGV traffic accessing the site is predicted to occur in Month 4 with 69 HGV movements predicted per day over this period. This is insignificant for properties along the A77 in the context of existing traffic flow of 3573 daily vehicles with 27% HGVs (A77 North) and 4862 daily vehicles with 31% HGVs (A77 South) resulting in increases in noise level, also taking account of 80 non-HGV construction vehicles per day, of less than 0.5 dB in both cases.

10.87 Specific predictions have, however, been carried out for the properties of Bonny Braes, Laird's Hill and Little Laight using the same noise data for lorries accessing the site as assumed for the track construction work (see Table 10.6) but travelling with a speed of 50 km per hour following the prediction methodology for mobile plant in BS5228 Appendix F. This results in predicted noise levels of 49 dB L_{Aeq} at Bonny Braes and 44 dB L_{Aeq} at Laird's Hill and Little Laight which is below the 65 dB L_{Aeq} criteria for day-time working identified above and would not be significantly increased by factoring in the 80 non-HGV vehicles noted above.

Cumulative Operational Assessment

Operational Noise

10.88 Appendix 10.1 also shows the maximum noise level from the Proposed Development, Glen App & Stranoch 2 operating at the same time in the form of contours for the cumulative scenario and for each site individually.

10.89 As for the noise contours for the site operating in isolation, the predicted turbine noise L_{Aeq} has been adjusted by subtracting 2 dB to give the equivalent L_{A90} as suggested in ETSU-R-97 and reaffirmed within the GPG. The predictions assume that all dwellings considered here are downwind of all turbines simultaneously, which cannot occur in practice, and that all the turbines are operating unrestricted and at their maximum sound power level.

10.90 Table 10.6 shows the predicted noise levels, associated with the Proposed Development operating at the same time as Glen App and Stranoch 2, in tabular form for the properties identified in Table 10.1. It also includes the predicted increase in noise levels due to the introduction of the proposed Development although in practice this would depend on wind direction.

Table 10.7 Predicted Cumulative Noise Levels, dB L_{A90}

Location	Glen App	Stranoch	Total Existing	Mid Moile	Total Cumulative	Increase
High Mark	21.4	34.4	34.6	28.7	35.6	1.0
Dalnigap	21.8	34.0	34.3	27.9	35.2	0.9
Shennas	24.8	31.3	32.2	31.2	34.7	2.5
White Cairn	36.1	16.1	36.1	24.4	36.4	0.3
Drumbo	34.3	14.9	34.3	24.2	34.7	0.4
Meikle Laight	30.3	15.4	30.4	30.4	33.4	3

Location	Glen App	Stranoch	Total Existing	Mid Moile	Total Cumulative	Increase
House at Penwhirn Dam	20	33.4	33.6	27.7	34.6	1

10.91 It can be seen that the contribution made by Mid-Moile is insignificant (<1 dB) at Dalnigap, White Cairn and Drumbo. At Shennas, Meikle Laight and the House at Penwhirn Dam the total cumulative noise level is less than the ETSU-R-97 simplified limit of 35 dB L_{A90}. At High Mark the cumulative noise level exceeds the 35 dB L_{A90} limit by 0.6 dB but in practice it will be less than this because of wind direction effects whereby, for westerly winds the Stranoch site will be upwind of this property, with levels for that site reduced by around 10 dB. For easterly winds, Mid Moile will be upwind, correspondingly with levels reduced for that site by 10 dB. For winds from the north or south noise levels from both sites will be approximately 2 dB lower. As a result, cumulative operational noise is considered not significant (see Paragraph 10.74).

10.92 Any potential variations to the Stranoch scheme in terms of the potential turbine to be installed or the adopted condition limits (see Paragraph 10.58) are highly unlikely to change the conclusions presented here.

Construction Noise

10.93 There are no cumulative effects anticipated in respect of construction noise. As a result, this is considered not significant.

Mitigation

Operational Noise

10.94 No noise mitigation/curtailment is expected to be required in order for operational turbine noise to meet the ETSU-R-97 simplified noise limit.

Construction Noise

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

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

10.97 The construction 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 BS 5228: 2009; and
- Section 61 of the Control of Pollution Act 1974 and Section 80 of the Environmental Protection Act.

10.98 A noise control plan would be produced that includes:

- procedures for ensuring compliance with statutory or other identified noise control limits;
- procedures for minimising noise from construction related traffic on the existing road network;
- procedures for ensuring that all works are carried out in accordance with the principle of "Best Practicable Means" as defined in the Control of Pollution Act 1974; and
- general induction training for site operatives, and specific training for staff having responsibility for particular aspects of controlling noise from the site.

10.99 In terms of any potential blasting required as part of the Proposed Development, the most appropriate mechanism is for a pre-blasting noise management programme to be prepared which would identify the most sensitive receptors that could be potentially affected by blasting noise. The programme 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 programme would also contain contact details which would be provided to local residents should concerns arise regarding construction and blasting activities. In addition, each blast will be designed carefully to maximise its efficiency and to reduce the transmission of noise.

Residual Effects

Operational Noise

10.100 No significant residual operational effects are expected as cumulative predicted operational noise levels are expected meet the relevant noise limits without the need for any mitigation to be applied.

10.101 Operational noise would, in practice, be controlled via planning conditions which set out noise limits for the Proposed Development.

Construction Noise

10.102 A very temporary construction noise impact will occur as the proposed access track construction track works pass the Property of Bonny Braes, where it leaves the A77 just to the north of Cairnryan. This is expected to occur for no longer than 4 days. No further significant construction effects are expected as, other than this, construction noise levels will be below the adopted noise limits, although it is possible that noise from construction activities could be audible at receptor locations at times, particularly from the track works in the vicinity of Bonny Braes, Laird's Hill and Little Laight.

Summary

10.103 A noise assessment was carried out in order to determine whether the site meets typical planning requirements in respect of operational noise from wind turbines. The assessment takes in to account the methodologies set out within ETSU-R-97, *The Assessment and Rating of Noise from Wind Farms* (1996) and the Institute of Acoustic document, *A Good Practice Guide to the Application of ETSU-R-97 for the Assessment and Rating of Wind Turbine Noise*.

10.104 The results of the operational noise assessment indicate that noise levels meet the relevant noise limit and no specific mitigation is required. The noise impact is, therefore, determined to be not significant.

10.105 Construction noise levels at neighbouring dwellings are expected to meet typical requirements in this regard, except for a temporary period of about 4 days when new track construction work passes the property of Bonny Braes. No specific mitigation measures are considered to be required in respect of this, or for any other effects, other than that deemed necessary under normal best practice.

References

- British Standards Institute (2008). BS 6472-1, Guide to evaluation of human exposure to vibration in buildings. Vibration sources other than blasting. BSI
- British Standards Institute (2009 + 2014). BS 5228 + A1, Code of Practice for Noise and Vibration Control on Construction and Open Sites. BSI
- British Standards Institute (2014). BS 8233. Guidance on sound insulation and noise reduction for buildings. BSI
- Danish National Agency of Environmental Protection (1984). Measurement of Environmental Noise from Industry - The Joint Nordic Method for the Evaluation of Tones in Broadband Noise (Guideline No. 6). Danish Ministry of Environment
- Davis R A, Lower M C (1996). ETSU W/13/00386/REP, Noise Measurements in Windy Conditions, ETSU/DTI
- Department of Energy and Climate Change (2011). Report on DECC Research Contract 01.08.09.01/492A (Analysis), Analysis of How Noise Impacts are Considered in the Determination of Wind Farm Planning Applications. Available at: https://www.gov.uk/government/publications/analysis-of-how-noise-impacts-are-considered-in-the-determination-of-wind-farm-planning-applications
- Department of Energy and Climate Change (2016). Wind Turbine AM Review: Phase 1 & Phase 2 Reports. DECC. Available at: https://www.gov.uk/government/publications/review-of-the-evidence-on-the-response-to-amplitude-modulation-from-wind-turbines
- Department of Environment (1976). Advisory Leaflet 72, Noise control on building sites, DoE
- Department of Trade and Industry (1996). ETSU-R-97, The Assessment and Rating of Noise from Wind Farms. ETSU/DTI Available at: https://webarchive.nationalarchives.gov.uk/+/http:/www.berr.gov.uk/files/file20433.pdf
- Department of Trade and Industry (1997). ETSU W/13/00392/REP, Low Frequency Noise and Vibrations Measurement at a Modern Wind Farm. ETSU/DTI.
- Department of Trade and Industry (2000). ETSU W/13/00385/REP, A Critical Appraisal of Wind Farm Noise Propagation. ETSU/DTI

- Department of Trade and Industry (2006). ETSU W/45/00656/00/00, The Measurement of Low Frequency Noise at 3 UK Windfarms. ETSU/DTI.
- Institute of Acoustics (July 2012). Discussion Document on "A Good Practice Guide to the Application of ETSU-R-97 for Wind Turbine Noise Assessment". IOA
- Institute of Acoustics (May 2013). A Good Practice Guide to the Application of ETSU-R-97 for the Assessment and Rating of Wind Turbine Noise. IOA. Available at: https://www.ioa.org.uk/publications/wind-turbine-noise
- Institute of Acoustics (2015). Discussion Document on "Methods for Rating Amplitude Modulation in Wind Turbine Noise". IOA
- Institute of Acoustics (2016). A Method for Rating Amplitude Modulation in Wind Turbine Noise - Version 1. IOA. Available at: https://www.ioa.org.uk/sites/default/files/AMWG%20Final%20Report-09-08-2016_1.pdf
- International Electrotechnical Commission (1979). IEC 651-1:1979, Sound Level Meters. IEC
- International Electrotechnical Commission (2002). IEC 61672-1:2002, Sound level meters - Part 1: Specifications. IEC
- International Electrotechnical Commission (2005). IEC 61400-14, Wind turbines - Part 14: Declaration of apparent sound power level and tonality values. IEC
- International Electrotechnical Commission (2018 + A1:2018). IEC 61400-11, Wind turbine generator systems – Part 11: Acoustic noise measurement techniques. IEC
- International Organization for Standardization (1992). ISO 9613-1, Acoustics - Attenuation of sound during propagation outdoors, Part 1: Method of calculation of the attenuation of sound by atmospheric absorption. ISO.
- International Organization for Standardization (1996). ISO 9613-2, Acoustics - Attenuation of Sound During Propagation Outdoors, Part 2: General Method of Calculation. ISO
- Landesanstalt für Umwelt, Messungen und Naturschutz Baden-Württemberg (2016). Low-frequency noise incl. infrasound from wind turbines and other sources. LUBW
- McKenzie et al. (Nov/Dec 2017) Acoustics Bulletin Vol. 42 No. 6, A planning condition for wind turbines, IOA
- Moorhouse et al. (2005) NANR45, Proposed criteria for the assessment of low frequency noise disturbance, Salford University
- Pederson et al. (1999) AV 1952/99, Objective Method for Assessing the Audibility of Tones in Noise – Joint Nordic Method – Version 2. Delta.
- Perkins et al. (September 2016). A Review of Research into Human Response to the Amplitude Modulated Component on Wind Turbine Noise and Development of a Planning Control Method for Implementation in the UK. UK Proceedings of the Institute of Acoustics Vol. 38. Pt. 1.
- RenewableUK (December 2013). Wind Turbine Amplitude Modulation: Research to Improve Understanding as to its Cause and Effect. RUK Available at: https://www.renewableuk.com/page/IndustryStatementOAM/page/CommunitiesEnergy
- Renewable UK (December 2013). The Development of a Penalty Scheme for Amplitude Modulated Wind Turbine Noise: Description and Justification. RUK. Available at:

https://www.renewableuk.com/page/IndustryStatementOAM/page/CommunitiesEnergy

- Renewable UK (December 2013). Template Planning Condition on Amplitude Modulation: Noise Guidance Notes. RUK. Available at: https://www.renewableuk.com/page/IndustryStatementOAM/page/CommunitiesEnergy
- Scottish Government (March 2011). PAN1/2011. Planning and Noise. Available at: https://www.gov.scot/publications/planning-advice-note-1-2011-planning-noise/
- Scottish Government (May 2014). Onshore Wind Turbines. Available at: https://www.gov.scot/binaries/content/documents/govscot/publications/advice-and-guidance/2014/05/onshore-wind-turbines-planning-advice/documents/9bfeeca0-9a06-4bb1-bc29-306c8f675656/9bfeeca0-9a06-4bb1-bc29-306c8f675656/govscot%3Adocument[Accessed : Jan 2019]
- Styles et al. (2005) Microseismic and Infrasound Monitoring of Low Frequency Noise and Vibrations from Wind Farms. Keele University.
- Temple Group (December 2013). Summary of Research into Amplitude Modulation of Aerodynamic Noise from Wind Turbines. RUK. Available at: https://www.renewableuk.com/page/IndustryStatementOAM/page/CommunitiesEnergy
- Temple Group (December 2013). Review of RenewableUK's Research into Amplitude Modulation. RUK. Available at: https://www.renewableuk.com/page/IndustryStatementOAM/page/CommunitiesEnergy
- Turnbull et al. (April 2012) Measurement and Level of Infrasound from Wind Farms and Other Sources. 40(1). Acoustics Australia.
- Verein Deutscher Ingenieure (1997). VDI 2720, Noise control by barriers outdoors. VDI
- VN TEAS, Prime Minister's Office, Finland (June 2020). Infrasound Does Not Explain Symptoms Related to Wind Turbines. VN TEAS
- World Health Organization (1999). Guidelines for Community Noise. WHO
- World Health Organization (2009). Night Noise Guidelines for Europe. WHO
- World Health Organization (2018). Environmental Noise Guidelines for the European Region. WHO
- Wyle Research (1988). Wyle Research Report WR 99-19, Measurement and Evaluation of Environmental Noise from Wind Energy Conversion Systems in Alameda and Riverside Counties. WR.