Chapter 12: Noise

Creag Riabhach Wind Farm Extension

This page is intentionally left blank

Contents

12 Noise

12.1 Introduction

This Chapter addresses the potential noise issues associated with the construction and operation of the proposed development. This Chapter has been produced by the Hayes McKenzie Partnership Ltd, who have worked on over 1000 proposed, consented or existing wind farm sites, particularly in the UK and the Irish Republic; but also in the rest of Europe, Australia, New Zealand, Canada and the USA, and have provided evidence for around 100 UK public inquiries together with other hearings and in court. All consultants are associate or corporate members of the UK Institute of Acoustics (IOA). The company is a member of the UK Association of Noise Consultants (ANC) and a Sponsor Member of the UK Institute of Acoustics. All work is carried out in line with recognised industry standards, and best practice recommendations of the IOA and ANC.
The noise sensitive receptors in this case are people at residential properties, and therefore, noise effects are evaluated at residential properties in the vicinity. Only one residential property (The Crask Inn) is close enough to the proposed development to warrant an assessment.

Construction noise impacts have been scoped out of detailed assessment as the noise limits referred to in relevant guidance (*BS 5228-1:2009+A1:2014. Code of Practice for Noise and Vibration Control on Construction and Open Sites* [1]) will be met at all noise sensitive receptors. Temporary impacts associated with construction traffic assessing the site have also been scoped out.

Operational noise impacts have been assessed in line with *ETSU-R-97, The Assessment and Rating of Noise from Wind Farms* [2], and the associated guidance provided by the IOA document*, A Good Practice Guide to the Application of ETSU-R-97 for the Assessment and Rating of Wind Turbine Noise* [3] (*IOA GPG*). Predicted operational noise levels have been compared with relevant noise limits for the proposed development acting in combination with the adjacent operational Creag Riabhach Wind Farm (CRWF). No other wind farms are considered close enough to the proposed development to be included in this assessment.

The operational noise associated with the battery energy storage system (BESS) has been reviewed and assessed according to *BS 4142: 2014+A1:2019 Methods for rating and assessing industrial and commercial sound* [4].

12.2 Legislation & Policy Context

This Chapter has been prepared taking cognisance of the *Electricity Works (Environmental Impact Assessment) Regulations 2017 (EIA Regulations)* and relevant policies set out in **Chapter 4: Statutory and Policy Framework** of this EIA Report.

The guidelines below have also been used to inform this assessment.

12.2.1 NPF4

National Planning Framework 4 [5] (February 2023) sets out the Scottish Government's overarching ambitions with regards to national planning. Policy 11 states that development proposals for all forms of renewable, low-carbon and zero emissions technologies will be supported, but that noise effects on communities should be assessed. Policy 23 states that development proposals that are likely to raise unacceptable noise issues will not be supported.

12.2.2 Planning Advice Note PAN1/2011: Planning and Noise

PAN1/2011 [6] 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 Scottish Government's 'web-based planning advice' on renewables technologies for onshore wind turbines, as discussed below.

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

The web-based planning advice on onshore wind turbines [7] 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 wind farm noise, which should be followed by applicants and consultees, and used by planning authorities to assess and rate noise from wind energy developments, until such time as an update is available".* 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".*

The document goes on to reference the *IOA GPG* discussed below in terms of assessing noise associated with wind turbine developments.

12.2.4 The Scottish Government's Technical Advice Note, Assessment of Noise

This *Technical Advice Note* [8] states that, for planning purposes, construction noise should be assessed according to *BS 5228* which is described below.

12.2.5 Onshore Wind Policy Statement 2022

The *Onshore Wind Policy Statement 2022* [9] references *ETSU-R-97* and the *IOA GPG* as the framework by which noise from wind energy developments is measured and assessed. These are discussed at **Section 12.3**.

12.2.6 The Highland Council

The Highland Council (THC) has produced its own *Onshore Wind Energy Supplementary Guidance* [10], which confirms that the assessment of wind farm noise should be carried out in line with *ETSU-R-97* and the *IOA GPG*. It states that THC will seek to achieve noise limits at the lower range specified within national guidance, but does not specify limits in this document.

The guidance confirms that cumulative noise impacts must be taken into account in line with best practice, and that they require the assessment to consider both predicted operational noise levels, as well as the consented noise limits. That means that where existing consented wind farm sites are predicted to operate below the planning condition noise limits, but where they could operate up to the limit, then this should be considered.

One additional aspect of the noise assessment that has been raised by THC where there are multiple wind farms in an area is the notion of noise exposure. The noise limits within *ETSU-R-97* apply to cumulative noise from all wind turbines in the vicinity, but they generally envisage that the residential receptor locations would be downwind of wind turbines in predominantly one direction and therefore, when the wind blows from other directions, the receptor would get respite from turbine noise.

With regards to amplitude modulation, THC state that '*Research into amplitude modulation is ongoing and currently there is no accepted best practice for measuring, monitoring or setting limits. Should any such guidance become available, Highland Council will expect developers to follow its recommendations*.'

12.3 Guidance and Potential Impacts

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

ETSU-R-97 presents the recommendations of the Working Group on Noise from Wind Turbines, set up in 1993 by the Department of Trade and Industry (DTI), as a result of difficulties experienced in applying the noise guidelines existing at the time to wind farm noise assessments. The group comprised independent experts on wind turbine noise, wind farm developers, DTI personnel and local authority Environmental Health Officers. In September 1996, the Working Group published its findings by way of report *ETSU-R-97*. This document describes a framework for the measurement of wind farm noise and contains suggested noise limits, which were derived with reference to existing standards and guidance relating to noise emission[1] from various sources.

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

For daytime periods, the noise limit specified by *ETSU-R-97* is 35-40dB L_{A90} or 5dB(A) above the 'quiet daytime hours' prevailing background noise, whichever is the greater. The actual value within the 35-40dB L_{A90} range (the lower limiting value) 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.

[1] 'Noise emission' is the noise emitted from a source

For night-time periods, the noise limit specified by *ETSU-R-97* is 43dB L_{A90} or 5dB(A) above the prevailing night-time hours background noise, whichever is the greater. The 43dB(A) lower limit is based on a sleep disturbance criterion of 35dB(A) with an allowance of 10dB(A) for attenuation through an open window and 2dB(A) subtracted to account for the use of L_{A90} rather the L_{Aeq}.

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

Quiet daytime 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 appropriate time period with background noise measured in terms of $L_{A90,t}$. The $L_{A90,t}$ is the noise level which is exceeded for 90% of the measurement period 't'. It is recommended that at least one weeks' worth of measurements is required.

Where predicted noise levels are low at the nearest residential dwellings, a simplified noise limit can be applied, such that daytime and night-time noise is restricted to the minimum *ETSU-R-97* level of 35dB L_{A90} for wind speeds up to 10m/s at 10m height. This removes the need for extensive background noise measurements for smaller or more remote schemes.

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 2.5dB 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 for wind farm noise allows reliable measurements to be made without corruption from relatively loud, transitory noise events from other sources.

Tonal Noise

ETSU-R-97 specifies that, in line with other noise guidance, a penalty should be added to measured or predicted wind turbine noise levels if there is tonal noise above a certain level which is audible at residential properties. In this assessment it has been assumed that there would be no tonal noise associated with the operation of the wind farm which would give rise to such a tonal penalty as most modern turbines operate without significant tonal noise. A tonal analysis method and threshold is usually included with the planning conditions for wind farms requiring a tonal penalty to be added to measured noise levels, where required, before comparing them with the noise limits. A standard tonal penalty clause is included in the planning conditions for CRWF.

Cumulative Impact

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 dwellings in question. Existing wind farms should therefore, be included in cumulative predictions of noise level for proposed wind turbines and not considered as part of the prevailing background noise.

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

In May 2013, the IOA published the GPG. This was subsequently endorsed by the Secretary of State for Energy and Climate Change and by the Scottish Ministers. The publication of the GPG followed a review of current practice carried out for the Department of Energy and Climate Change (DECC) and an IOA discussion document, which preceded the *IOA GPG*.

The *IOA 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 50kW, 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".*

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. These are referred to in the relevant sections below.

12.3.3 Wind Shear

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.

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 (e.g., 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 *IOA GPG.* The hub height wind speeds are then converted to 'standardised 10m wind speeds', assuming standardised conditions as used by turbine manufacturers when specifying turbine sound power levels.

12.3.4 Vibration

An ETSU study [11] found that vibration from wind turbines, as measured at 100m from the nearest machine, was well below the *BS 6472-1:2008, Guide to evaluation of human exposure to vibration in buildings - Vibration sources other than blasting* [12] criteria recommended for human exposure in critical working areas such as precision laboratories. At greater distances from turbines, vibration levels are even lower. This has been confirmed through a study by Keele University study [13], which showed vibration levels of around $10^{-8}m/s^2$ at a distance of 2.4km from the Dun Law Wind Farm site under high wind conditions, orders of magnitude lower than the criteria referred to above which specify levels in the region of $0.005m/s^2$.

12.3.5 Audibility

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.

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 dependent absolute noise level, reducing and becoming less intrusive as noise level decreases. Where predicted noise levels are below 35dB L_{A90} a comparison against background noise level is not required by *ETSU-R-97*, and potential audibility falls off below this level.

12.3.6 Sleep Disturbance

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 – 15dB 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 30dB L_{Aeq}. 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 10-15dB from the predicted turbine noise level and comparing with this criterion, after also adding 2dB to convert the predicted turbine noise level to an L_{Aeq} value.

It should be noted that the latest guidance from the WHO on night noise levels is in the form of the *Night Noise Guidelines for Europe* [14], published in 2009, which recommends that the population is not exposed to average external night-time noise levels, over a whole year, of more than 40dB 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.

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 (see above) than by average noise level.

12.3.7 Low Frequency and Infrasound

Low frequency sound is typically defined as sound in the audible hearing frequency range of 20Hz up to about 200Hz. Infra-sound is noise occurring at frequencies below that at which sound is normally audible, i.e., at less than about 20Hz, due to the significantly reduced sensitivity of the ear at such frequencies. In this frequency range, for sound to be perceptible, it must be at very high amplitude, which is not the case for wind turbine noise.

Noise from wind turbines is not inherently low-frequency and it is typically broad-band in nature, and close to a wind turbine the dominant frequencies are usually in the 250 to 2000Hz range. As the 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 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 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, however, the overall noise level is so low, such that any bias in the frequency spectrum is insignificant.

Work carried out in 2006 by Hayes McKenzie for the UK Department of Trade and Industry to investigate the extent of low frequency and infrasonic noise from three UK wind farms [15] concluded that *"the common cause of complaints associated with noise at all three wind farms is not associated with low frequency noise, but is the audible modulation of the aerodynamic noise, especially at night*". It is, therefore, considered that low frequency noise during operation can be scoped out of the assessment.

In November 2016, a study into low frequency and infrasound was published by the State Office for the Environment, Measurement and Nature Conservation of the Federal State of Baden-Wuerttemberg [12] that contained a comprehensive review of low frequency and infrasound from wind turbines and evaluated such noise in relation to other sources. The results state that *"the infrasound level in the vicinity of wind turbines is – at distances between 120m and 300m – well below the threshold of what humans perceive"* and that *"at a distance of 700m from the wind turbines, it was observed by means of measurements that when the turbine is switched on, the measured infrasound level did not increase or only increased to a limited extent. The infrasound was generated mainly by the wind and not by the turbines".*

The report concludes that *"Infrasound is caused by a large number of different natural and technical sources. It is an everyday part of our environment that can be found everywhere. Wind turbines make no considerable* *contribution to it. The infrasound level generated by them lie clearly below the limits of human perception. There is no scientifically proven evidence of adverse effects in this level range".*

12.3.8 Blade Swish (Amplitude Modulation of Aerodynamic Noise)

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 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 3dB(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 6dB(A) (peak to trough)".* There have been instances where levels of amplitude modulation ratings are higher than this, which results in the noise being perceived as more intrusive (in the same way as tonal content makes the noise more intrusive).

It has been noted that complaints about wind farm noise have, in many cases, 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.

RenewableUK (RUK), the main renewable energy trade association in the UK, completed research into the causes and subjective effects of amplitude modulation following various reports of increased levels of amplitude modulation being experienced at dwellings neighbouring some wind turbine sites [13]. 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.

This resulted in the inclusion of a mechanism to assess and regulate amplitude modulation effects, proposed as an update to the standard form of condition frequently applied to wind farm developments, as included in the *IOA GPG.* The IOA reviewed this mechanism and released a discussion document which reviewed several different methods for rating amplitude modulation in wind turbine noise and subsequently released a recommended method by which to characterise the peak to trough level in any given 10-minute period [14]. 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 amplitude modulation 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 [15].

The Department of Energy & Climate Change commissioned a *Wind Turbine AM Review report* [16] that was published in two phases: Phase 1 in September 2015 and Phase 2 in October 2016 (although the Phase 2 report is dated August 2016). Phase 1 of the report sets out the approach and methodology to the review and research, and the Phase 2 report includes a literature review, research into human response to amplitude modulation, and recommends how excessive amplitude modulation might be controlled through the use of a planning condition. The report includes recommendations on how amplitude modulation should be addressed when quantified according to the recommendations of a separate IOA working group document, *A Method for Rating Amplitude Modulation in Wind Turbine Noise* [17].

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

It should be noted that most wind farms operate without significant amplitude modulation, and that it is not possible to predict the likely occurrence of amplitude modulation. At the time of writing, there has been no official response to those recommendations from the IOA Noise Working group or endorsement from any Scottish Government Minister or Department. The *IOA GPG*, states that *"the evidence in relation to "Excess" or "other" Amplitude Modulation (AM) is still developing. At the time of writing, current practice is not to assign a planning condition to deal with AM",* although it is possible to control such noise with an appropriately worded planning condition if necessary.

The combination of these two 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. It should be noted that this is in addition to any penalty for tonal noise.

12.3.9 BS 5228-1: 2009+A1: 2014 Code of practice for noise and vibration control on construction and open sites

This document 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.

The first is based on the use of criteria defined in Department of the Environment Advisory Leaflet (AL) 72, *Noise Control On Building Sites* [22] which sets a fixed limit of 70dB(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 3dB lower giving an equivalent noise criterion of 67dB L_{Aeq}.

The second is based on noise change, but applies minimum criteria of 45, 55 and 65dB 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, applicable when existing noise levels are low, which they would be at this location, and subject to 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}.

Guidance on air over-pressure as a consequence of any blasting associated with borrow pit activities is provided within Annex I to the Standard (*BS 5228-1*). Guidance with respect to vibration induced from blasting is also provided within *BS 5228-2* [23] and additional advice for air over-pressure (Annex G).

12.3.10 BS 4142:2014+A1:2019 Methods for rating and assessing industrial and commercial sound

The relevant standard for the assessment of operational noise arising from the BESS is *BS 4142*. It provides an assessment methodology for determining the likely impact of noise experienced by people at neighbouring residential properties from industrial and commercial sources. The standard describes a method for determining the significance of the noise impact based on the difference between the level of existing background noise (in the absence of the industrial or commercial source) and the noise immission[2] level of the source at a particular receiver location (known as the specific noise level). In instances where the specific noise level exhibits an identifiable or perceived character (such as tonality, impulsiveness, or other identifiable character), then a penalty is added to the same noise level to give the 'rating level'. The maximum penalty for tonal content is +6dB. The difference between the background noise level and the rating level is then used to determine the potential impact, as shown at **Table 12.1**.

Table 12.1: Extract from BS 4142

Difference	Assessment
Around 10dB or more	Significant adverse impact, depending on context
Around 5dB	Adverse impact depending on context

Whilst *BS 4142* gives an indicative assessment of the impact on residential amenity, there are no specific guidelines on what is acceptable and, in this respect, the standard is left open to interpretation. Generally, noise limits contained in planning conditions are derived taking into account the context of the locality and the requirements of relevant development plans. For noise sources operating less frequently or only during normal working hours, a higher margin above the background noise could be considered to be acceptable.
It is stated, however, that, *"Where background sound levels and rating levels are low, absolute levels might be as, or more, relevant than the margin by which the rating level exceeds the background. This is especially true at night."*

This latest revision of the standard does not provide values for what may be considered low background noise and rating levels. The previous edition *BS 4142:1997* does, however, state that for the purpose of the standard, background noise levels below about 30dB L_{A90} and rating levels below about 35dB L_{Aeq} can be considered as very low.

[2] 'Noise immission' is the noise perceived at a receptor location

12.4 Stakeholder Consultation

The EIA Scoping Report set out the proposed assessment methodology including a description of the aspects that would be scoped out of the assessment. This section describes the stakeholder responses to the EIA Scoping Report and further consultation.

Stakeholder responses to Scoping

THC's scoping response (July 2022) indicated that the target noise levels were either a simplified limit of 35dB L_{A90} at wind speeds up to 10m/s or a composite standard of 35dB L_{A90} (daytime) and 38dB L_{A90} (night-time) or up to 5dB above background noise levels at up to 12m/s. The night-time lower limit of 43dB L_{A90} as suggested in *ETSU-R-97* was not considered acceptable in many areas of the highlands due to very low background levels. These limits would apply to cumulative noise levels from more than one development.

THC state that consideration to noise exposure should be given. Respite loss could occur in situations where a property becomes exposed to wind turbine noise from more than one direction.

THC state that background noise measurements should be undertaken in accordance with *ETSU-R-97* and the *IOA GPG*.

THC state that, should complains arise relating to amplitude modulation, these would be investigated in terms of the *Statutory Nuisance provisions of the Environmental Protections Act 1990* [24].

THC state that where noisy construction works occur outside of 8am to 7pm Monday to Friday and 8am to 1pm on Saturdays, a detailed construction noise assessment for the written approval of the planning authority is required. This would need to be carried out in accordance with *BS 5882-1*.

The Scottish Ministers response (July 2022) stated that the final list of receptors in respect of noise assessment should be agreed following discussion between the Company and THC, and that the noise assessment report should be formatted as per Table 6.1 of the *IOA GPG*.

Further Correspondence

Hayes McKenzie wrote to THC to seek to agree that the property Vagastie Cottage would not be included in the noise assessment, that the only noise sensitive receptor property that required assessing was The Crask Inn, and that there were no other wind farms in the vicinity that would need to be included in the cumulative operational noise impact assessment.

12.5 Difficulties & Limitations

There are no specific difficulties or limitations relating to noise deriving appropriate significance criteria as the *ETSU-R-97* simplified noise limit has been used which does not depend on background noise measurements or relate to wind speed, which are usually where difficulties can occur.

Noise predictions have been based on a candidate turbine. Conservative assumptions including additional uncertainty corrections have been made in the prediction methodology.

12.6 Baseline Conditions

Background noise measurements at the nearest noise sensitive receptors have not been undertaken due to the cumulative operational predicted noise level being below the *ETSU-R-97* simplified noise limit of 35dB L_{A90}. Background noise in rural areas is generally made up of bird song, wind in nearby vegetation and, in some cases, noise from water courses. The simplified *ETSU-R-97* limit is designed to be applied in situations such as this where operational noise from developments is low, and carrying out background noise measurements would not be necessary.

12.7 Assessment Methodology & Significance Criteria

12.7.1 Effects Scoped Out

A location that was assessed in the EIA for the operational CRWF, Vagistie Cottage, has now been demolished and therefore, is not considered sensitive as a result and this receptor has therefore been excluded from the noise assessment.

Noise from Construction Activities

The construction noise limits prescribed within *BS 5228* are designed to offer residents a reasonable level of protection with the regard to the typical short-term duration and typical noise levels associated with construction noise. In this case, 65dB $L_{Aeq,12hr}$ daytime significance criterion has been adopted for the purposes of the assessment. However, noise associated with construction may be controlled through planning condition or through discussions with the relevant authorities.

Due to the temporary nature of construction works, including the excavation and filling works associated with turbine bases, and the typically large distances between turbines and neighbouring receptors, noise levels associated with the erection of wind turbines are relatively low and are rarely a cause for concern.

Noise from blasting is not considered in the same way as other construction noise since a large portion of the energy from the blast is infrasonic i.e., below the range of human hearing. As such, absolute noise limits from blasting or air overpressure are not used. *PAN50* [25] *Annex D* suggests that ground vibrations caused by blasting operations are considered acceptable if their peak particle velocity (PPV) at the nearest sensitive locations are below 6mm/s for 95% of all blasts measured over any 6-month period, and no individual blast exceeds a PPV of 12mm/s.

Noise during construction works would be controlled by generally restricting works to standard working hours and exclude Sundays, unless specifically agreed otherwise as detailed in **Chapter 3: Description of Development**.

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

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

- relevant EU Directives and UK Statutory Instruments that limit noise emissions from a variety of construction plant;
- the guidance set out in *PAN1/2011* and *BS 5228*; and
- Section 61 of the *Control of Pollution Act 1974* and Section 80 of the *Environmental Protection Act*.

The way in which noise effects would be minimised would be set out in a Construction Environmental Management Plan (CEMP) that would be prepared prior to commencement of construction activities. An outline CEMP has been included in **Technical Appendix 3.1**.

In light of the above, noise from construction activities has therefore been **scoped out** of the assessment as construction noise arising from the proposed development would be controlled in the same way as was required for the operational CRWF and the relevant noise limits set out in **Section 12.3.3** would be met. Therefore, no significant construction noise effects are envisaged.

Road Traffic Noise

Noise associated with heavy goods vehicle (HGV) and site traffic movements along local roads during the construction of the proposed development would cause a temporary increase in noise levels, particularly for dwellings located along the proposed routes to the proposed development and given the rural nature of the area. However, even during the most intensive periods of deliveries to the construction site, it is unlikely that noise limits (i.e., those specified within *BS 5228*) would be breached, particularly for typical daytime periods, due to the sporadic and intermittent nature of the noise from vehicles passing the neighbouring dwellings and the slow speeds at which HGVs would pass the dwellings. Any planned deliveries during night-time and/or other sensitive hours have the potential to wake or disturb the residents of neighbouring dwellings. As a result, any such events, if unavoidable, would be agreed with the Environmental Health Officer (EHO) dealing with the proposed development and residents would be kept informed of these activities prior to any night-time deliveries taking place.

An assessment of changes in traffic noise on the wider road network has been undertaken by comparing existing road usage with planned vehicle use during the busiest two months of the construction period. Construction vehicle routes within the site itself do not come any closer to the nearby dwellings than the planned vehicle routes that use the existing road network, so no further consideration of on-site vehicle movements is necessary.

In respect of road traffic noise, a doubling of road traffic (i.e., and increase of 100%) would see a 3dB increase in the noise level at receptor locations, and it is considered that if the increase in road traffic noise during the construction phase is below 3dB, then no significant effects would occur.

Table 10.11 of **Chapter 10: Transport and Access** states that the increase in both HGV traffic and total traffic is less than 100%. Therefore, noise impacts from road traffic noise during the operation of the proposed development are **Not Significant** and **scoped out**.

Operational Noise from Substation and BESS

Operational noise from the BESS is assessed according to *BS 4142,* which assesses the significance of the noise impact by comparing rating noise levels arising from the operation of the development with existing background noise levels. In this case, both background noise levels at low wind speeds and noise arising from the operation of the substations and battery storage are low, and in which case, *BS 4142* states the *"Where background sound levels and rating levels are low, absolute levels might be as, or more, relevant than the margin by which the rating level exceeds the background. This is especially true at night".*

In this case, based on a review of operational noise levels arising from similar installations, and given the separation distance between the BESS and the Crask Inn is at least 2.5km, operational rating noise levels at the Crask Inn would be considered very low by BS 4142. Therefore, the assessment of operational noise from the BESS has been **scoped out**.

Operational Noise from Wind Turbines

Vibration

For the reasons described at **Section 12.3.4**, vibration during operation is **scoped out**.

Tonal Noise

It is recommended that the same clause as in the planning conditions of CRWF is included for the proposed development. A warranty should be sought from the supplier of turbines for the proposed development to ensure that no tonal penalty site would be required in practice. As such, tonal noise is **scoped out**.

Blade Swish (Amplitude Modulation of Aerodynamic Noise)

It should be noted that most wind farms operate without significant amplitude modulation, and that it is not possible to predict the likely occurrence of amplitude modulation, and therefore its specific assessment for planning purposes is **scoped out**. Methods have been identified should assessment of the proposed development in operation be required.

Low Frequency & Infrasound

For the reasons described at **Section 12.3.7**, infrasound during operation is **scoped out**.

12.7.2 Effects Scoped In

Operational Noise

Operational noise impacts have been scoped in, and an increase in the consented noise limit for the operational CRWF may be necessary as cumulative operational noise levels from the proposed development together with the operational CRWF could be in the range of 33 to 35dB L_{A90}.

As the proposed development would be owned and operated by the operators of CRWF effectively as one wind farm, it is considered that the operation of the consented and proposed developments can be assessed together and that any noise limits applied via the planning conditions for the proposed development would apply to cumulative operational noise from both the consented and proposed developments.

Operational noise from the combined effect of the proposed development with operational CRWF has been assessed against the *ETSU-R-97* simplified noise limit (which applies to both day and night-time operation) of 35dB L_{A90} to all dwellings at all wind speeds. This is the lowest target noise limit applicable to cumulative wind farm noise that was specified by THC in their Scoping Response and is the lowest noise limit set out in *ETSU-R-97*.

Cases in which this noise limit is exceeded will be described as significant, and cases in which this noise limit is not exceeded will be described as not significant.

Operational Noise Prediction Methodology

Noise predictions have been carried out using I*nternational Standard ISO 9613, Acoustics – Attenuation of Sound During Propagation Outdoors* [26], as referred to within the *IOA GPG*. The propagation model described in Part 2 of this standard provides for the prediction of sound pressure levels based on either short-term downwind (i.e., worst-case) conditions or long-term overall averages.

The 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:

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

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

L_W – Source Sound Power Level

The sound power level of a noise source is normally expressed in dB re:1pW. Noise predictions are based on sound power levels detailed at **Section 12.8.1**.

The octave band noise spectra used for the predictions have been taken from the results of a measurement on a sample turbine with the results also given at **Section 12.8.1**.

D - Directivity Factor

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 this case, 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

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

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

where d = distance from the turbine

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

A_{atm} – Atmospheric Absorption

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

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

where α = the atmospheric absorption coefficient for the relevant frequency band
Published values of 'α' from *ISO 9613 Part 1* 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 12.2** and according to the requirements of the *IOA GPG*.

Table 12.2: 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

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 *IOA GPG* recommends that the use of G = 0.5 and a receptor height of 4m 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 in this assessment are based on G = 0.5 with a receptor height of 4m, due to the conservatism in the sound power levels assumed here.

A_{bar} – Barrier Attenuation

The effect of any barrier between the noise source and the receiver position is that noise would be reduced according to the relative heights of the source, receiver and barrier and the frequency spectrum of the noise. The barrier attenuations predicted by the *ISO 9613* model have, however, been shown to be significantly greater than that measured in practice under downwind conditions. The results of a study of propagation of noise from wind farm sites carried out for ETSU concludes that an attenuation of just 2dB(A) should be allowed where the direct line of site between the source and receiver is just interrupted and that 10dB(A) should be allowed where a barrier lies within 5m of a receiver and provides a significant interruption to the line of site. The effect of barrier attenuation has been included within the prediction model for this assessment.

A_{misc} – Miscellaneous Other Effects

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

Concave Ground Profile

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 *IOA GPG*. Paragraph 4.3.9 in the *IOA GPG* states that, *"A further correction of +3dB (or +1.5dB 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:*

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

where hm 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."

It should be noted 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.

Directivity

The predictions assume downwind propagation conditions for all turbines.

12.8 Predicted Effects

12.8.1 Operational Noise

The noise predictions for the proposed development are based on the installation of three Enercon E115 4.2MW turbines with a hub height of 92.4m. The adjacent operational CRWF has been included in cumulative predictions and it has been assumed that the same turbine as installed at CRWF would be installed at the proposed development.

The assumed turbine locations for the proposed development and the neighbouring operational CRWF are given at **Table 12.3**.

Table 12.3: Turbine Locations and Details

Wind Farm	Turbine	Easting	Northing	Hub Height (m)	Model	Capacity (MW)
Proposed Development	EXT-01	252944	927105	92.4	E115	4.2
	EXT-02	253071	928221	92.4	E115	4.2
	EXT-03	253056	927846	92.4	E115	4.2
Operational Creag Riabhach Wind Farm	T1	252232	927010	67.5	E115	4.2
	T2	251931	927272	67.5	E115	4.2
	T3	252621	927224	67.5	E115	4.2
	T4	252267	927417	67.5	E115	4.2
	T5	251986	927747	67.5	E115	4.2
	T6	252672	927675	67.5	E115	4.2
	T7	252364	928078	67.5	E115	4.2
	T8	252727	928195	67.5	E115	4.2
	T9	252062	928346	67.5	E115	4.2
	T10	252421	928489	67.5	E115	4.2
	T11	252097	928757	67.5	E115	4.2
	T12	252792	928639	67.5	E115	4.2
	T13	253189	928593	67.5	E115	4.2
	T14	252490	928889	67.5	E115	4.2
	T15	252170	929110	67.5	E115	4.2
	T16	252530	929337	67.5	E115	4.2
	T17	252840	929038	67.5	E115	4.2
	T18	253243	929222	67.5	E115	4.2

Wind Farm	Turbine	Easting	Northing	Hub Height (m)	Model	Capacity (MW)
	T19	252220	929544	67.5	E115	4.2
	T20	252899	929577	67.5	E115	4.2
	T21	253288	929607	67.5	E115	4.2
	T22	252593	929867	67.5	E115	4.2

Table 12.4 shows the octave band sound power levels for the Enercon E115 4.2MW turbine at a wind speed of 10m/s (10m standardised height), with +2dB uncertainty added.

Table 12.4: Octave Band Noise Spectra for Standardised 10m Height Wind Speed

Overall dB L_{WA}	Octave Band Centre Frequency (Hz)							
	63	125	250	500	1000	2000	4000	8000
106.8	88.4	94.1	97.3	99.8	101.0	101.2	96.0	80.3

This spectrum is normalised to the sound power level data for each integer standardised 10m height wind speed shown at **Table 12.5**. The turbine noise data was taken from manufacturers technical data sheets.

Table 12.5: Turbine Source Sound Power Levels, dB L_{WA}

Overall dB L_{WA}	Standardised 10m Height Wind Speed (m/s)									
	3	4	5	6	7	8	9	10	11	12
Hub Height 92.4m	89.1	94.8	99.7	103.7	105.5	106.1	106.8	106.8	106.8	106.8
Hub Height 67.5m	88.4	93.9	98.8	102.8	105.1	105.9	106.6	106.8	106.8	106.8

The location of the nearest residential dwelling (The Crask Inn) is given at **Table 12.7**. This is the only dwelling to be considered since it is the only dwelling which lies within the 30dB L_{A90} cumulative noise contour.

An analysis of the ground profile between the turbines and the neighbouring dwellings has been carried out and where appropriate, corrections to the predicted noise levels have been made as give at **Table 12.6**.

Table 12.6: Barrier & Concave Valley Corrections for each Turbine at The Crask Inn (dB)

Turbine	Ground Profile Attenuation (dB)
EXT 01	0
EXT 02	-2
EXT 03	-2
T1	0
T2	0
T3	0
T4	0
T5	0
T6	0
T7	0
T8	0
T9	0

Turbine	Ground Profile Attenuation (dB)
T10	0
T11	0
T12	3
T13	-2
T14	3
T15	0
T16	3
T17	3
T18	-2
T19	0
T20	-2
T21	-2
T22	3

Table 12.7: Nearest Noise Sensitive Receptor Location

Dwelling	Easting	Northing	Distance and direction from nearest proposed turbine to dwelling	Distance and direction from nearest existing turbine to dwelling
The Crask Inn	252423	924746	2424m south	2280m south

Operational noise prediction results are presented for the nearest residential receptor (The Crask Inn) to the proposed development. Results are presented for the proposed development acting in isolation alongside the cumulative contribution from the operational CRWF. If the relevant limits are met at the nearest receptor, then they would be met at all other receptors which are more distant.

Only the results corresponding to when the turbines are operating at their highest sound power level, and assuming that the receptor location is downwind of all turbines, are presented. Under wind conditions other than downwind, and at lower wind speeds when the sound power levels are lower, operational noise levels would be lower. The results are shown at **Table 12.8**. The cumulative predicted impact is shown on a noise contour plot at **Figure 12.1**.

Table 12.8: Predicted Noise Levels

			Predicted Noise Level, dB L_{A90}		
Receptor	Easting	Northing	Proposed Development	Operational CRWF	Cumulative
The Crask Inn	252423	924746	22.4	30.5	31.1

The results of the operational noise predictions indicate that the relevant noise limit of 35dB L_{A90} is met at The Crask Inn, and therefore, operational noise impacts are considered to be **Not Significant**. Furthermore, the predicted noise impact from the proposed development acting in isolation are below 25dB L_{A90} which is more than 10dB below the relevant noise limit and therefore, any contribution from the proposed development in relation to the cumulative noise limit is negligible. This is because a noise which is 10dB quieter than another noise is considered to have negligible contribution.

12.9 Additional Mitigation

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

Noise from the operation of a wind farm is usually controlled through the implementation of planning conditions on noise that contain permissible limits. In this way if any operational noise issues arise then measurements can be undertaken to ascertain whether the site is operating within the appropriate noise limits.

In this case, the operational CRWF has a noise limit of 33dB L_{A90} at The Crask Inn, and it is permitted to operate at up to this level. The cumulative noise limit that would apply to the proposed development acting in conjunction with the operational CRWF must be set slightly higher to allow for this. In addition, by setting the permitted level slightly higher, this would allow for some flexibility in terms of turbine procurement. It is, therefore, suggested that a cumulative noise limit of 35dB L_{A90} is applied to the combined operational noise of the operational CRWF and the proposed development. These proposed noise limits would apply at all times of day and under all wind conditions.

12.10 Residual Effects

No significant residual effects are predicted as the relevant operational noise limits are predicted to be met, and the need for a detailed construction assessment has been scoped out.

Table 12.9: Summary of Residual Effects Following Additional Mitigation

Phase	Receptor	Sensitivity	Description of Change	Mitigation Measure	Magnitude of Change	Level of Effect	Nature of Change			
							Positive or Negative	Permanent or Temporary	Reversible or Irreversible	Residual Significance
Operation	Residential properties	High	Potential for audible noise during operation of the proposed development.	Operational noise would be controlled through planning conditions that contain the relevant operational limits.	Low	Low	Negative	Permanent	Reversible	Not Significant

12.11 Conclusions

Noise associated with the operation of the proposed development has been assessed in line with national guidelines and current good practice, and in consultation with THC and the ECU.

Construction noise impacts have been scoped out as the relevant noise limits referred to in relevant guidance for turbines (*BS 5228-1*) and BESS (*BS 4142*) would be met at the noise sensitive receptor in the vicinity of the proposed development. The overall construction noise impact is determined to be **Not Significant**, and noise would be controlled and minimised as much as possible during the construction phase of the proposed development via a CEMP, which would be prepared at the time of construction.

Operational noise impacts have been assessed in line with *ETSU-R-97*, and the associated guidance provided by the *IOA GPG*. Predicted operational noise levels have been compared with relevant noise limits for the proposed development acting in combination with other consented wind farms in the vicinity. Cumulative operational noise levels from the site operating in combination with the adjacent operational CRWF meet the relevant noise limits discussed and agreed with THC, and there are no other wind farms near enough for assessment of cumulative effects. The separation distance between the BESS compound and the nearest noise sensitive receptor, the Crask Inn, is over 2.5km, such that operational noise would not be audible at the nearest noise sensitive receptor. Therefore, operational noise effects are determined to be **Not Significant**.

12.12 References

[1] "BS 5228-1:2009+A1:2014 Code of practice for noise and vibration control on construction and open sites – Part 1: Noise," BSI Standards Limited, 2014.

[2] "ETSU-R-97 The Assessment & Rating of Noise from Wind Farms, Final Report," DTI, September 1996.

[3] "A Good Practice Guide to the Application of ETSU-R-97 for the Assessment and Rating of Wind Turbine Noise," Institute of Acoustics, May 2013.

[4] "BS 4142:2014+A1:2019 Methods for rating and assessing industrial and commercial sound," BSI Standards Limited, 2014.

[5] "National Planning Framework 4," Scottish Government, February 2023.

[6] "Planning Advice Note 1/2011: Planning and Noise," Scottish Government, March 2011.

[7] Scottish Government, "Onshore wind turbines: planning advice," 2014. [Online]. Available: https://www.gov.scot/publications/onshore-wind-turbines-planning-advice/. [Accessed 22 May 2023].

[8] "Assessment of noise: technical advice note," Scottish Government, 2011.

[9] "Onshore Wind Policy Statment 2022," Scottish Government, 2022.

[10] The Highland Council, “Web based planning guidance,” The Highland Council (2016), 2016. [Online]. Available: https://www.highland.gov.uk/downloads/file/18793/onshore_wind_energy_supplementary_guidance_november_2016. [Accessed 1 April 2023].

[11] “ETSU W/13/00392/REP, Low Frequency Noise and Vibrations Measurement at a Modern Wind Farm,” DTI, 1997.

[12] BSI Standards Limited, “BS 6472-1:2008, Guide to evaluation of human exposure to vibration in buildings - Vibration soruces other than blasting,” 2008.

[13] S. e. al, “Microseismic and Infrasound Monitoring of Low Frequency Noise and Vibrations from Wind Farms,” 2005.

[14] “Night noise guidelines for Europe,” World Health Organization, Regional Office for Europe, 2009.

[15] “ETSU W/45/00656/00/00, The Measurement of Low Frequency Noise at 3 UK Windfarms,” Department of Trade and Industry, 2006.

[16] “Low-frequency noise incl. infrasound from wind turbines and other sources. LUBW,” Landesanstalt für Umwelt, Messungen und Naturschutz Baden-Württemberg , 2016.

[17] “Wind Turbine Amplitude Modulation: Research to Improve Understanding as to its Cause and Effect,” RenewableUK, December 2013.

[18] “A Method for Rating Amplitude Modulation in Wind Turbine Noise,” Institute of Acoustics Noise Working Group, 2016.

[19] “Wind Turbine AM Review,” WSP Parsons Brinkerhoff for DECC, Phase 1 October 2015 & Phase 2 August 2016.

[20] “Wind Turbine AM Review: Phase 1 & Phase 2 Reports,” Department of Energy and Climate Change, 2016.

[21] “A Method for Rating Amplitude Modulation in Wind Turbine Noise - Version 1,” Institute of Acoustics, 2016.

[22] “Advisory Leaflet 72, Noise control on building sites,” Department of the Environment, 1976.

[23] “BS 5228-2:2009+A1:2014, Code of practice for noise and vibration control on construction and open sites – Part 2: Vibration,” BSI Standards Limited, 2014.

[24] “Environmental Protection Act 1990 - Chapter 43,” 1990.

[25] “Planning Advice Note, PAN50, Controlling the environmental effects of surface mineral workings,” The Scottish Office, Development Department, October 1996.

[26] “ISO9613: Acoustics - Attenutation of sound during propagation outdoors,” International Organization for Standards, 1996.