Technical Appendix 10.1: Environmental Noise Assessment

Appendix 10.1: Novar 1 Wind Farm Repowering
Environmental noise assessment.

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AUTHOR: RYLAN NORCROSS

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Executive Summary

Hoare Lea (HL) have been commissioned by Ramboll to undertake a noise assessment for the construction and operation of the proposed Novar 1 Wind Farm Repowering (the repowered wind farm). Noise will be emitted by the turbines during operation and equipment and vehicles used during decommissioning of the Novar 1 Wind Farm, the construction of the repowered wind farm and the decommissioning of the repowered wind farm. The level of noise emitted by the sources and the distance from those sources to the receiver locations are the main factors determining levels of noise at receptor locations.

Construction Noise

Construction noise, including the decommissioning of the Novar 1 Wind Farm, has been assessed by a desk-based study of a potential programme and by assuming the repowered wind farm is constructed using standard and common methods. Noise levels have been calculated for receiver locations closest to the areas of work and compared with guideline and baseline values. Construction noise, by its very nature, tends to be temporary and highly variable and therefore much less likely to cause adverse effects. Factors including in particular the restrictions of hours of working have been taken into consideration. It is concluded that noise generated through construction activities would have a minor impact. Activities associated with the decommissioning of the Novar 1 Wind Farm included in the construction phase of the repowered wind farm would have a negligible impact.

Decommissioning of the repowered wind farm is likely to result in less noise than during construction of the repowered wind farm. The construction phase has been considered to have minor noise impacts, therefore decommissioning will, in the worst case, also have minor noise impacts.

Operational Noise

Operational turbines emit noise from the rotating blades as they pass through the air. This noise can sometimes be described as having a regular 'swish'. The amount of noise emitted tends to vary depending on the wind speed. When there is little wind the turbine rotors will turn slowly and produce lower noise levels than during high winds when the turbine reaches its maximum output and maximum rotational speed. Background noise levels at nearby properties will also change with wind speed, increasing in level as wind speeds rise due to wind in trees and around buildings, etc.

Noise levels from operation of the turbines have been predicted for those locations around the Site most likely to be affected by noise. Historical surveys have been performed at some properties as part of the Clach Liath Wind Farm application (superseded by the Abhainn Dubh Wind Farm application) to establish existing baseline noise levels at a number of these properties. Noise limits have been derived either from historical baseline data about the existing noise environment or derived following a simplified assessment method at the assessment properties, following the methods stipulated in national planning guidance. Noise limits for the separate Ceislein Wind Farm cumulative noise assessment were derived using the baseline data from the Ceislein Wind Farm application noise assessment at some assessment properties. Predicted noise levels take full account of the potential combination of the noise from the repowered wind farm along with the Novar 2 Wind Farm, Abhainn Dubh Wind Farm and separately account for the Ceislein Wind Farm. Other, more distant wind farms were not considered as they do not make an acoustically relevant contribution to cumulative noise levels.

Predicted operational wind turbine noise levels have been compared to the limit values to demonstrate that turbines of the type and size which would be installed can operate within the limits so derived. It is concluded therefore that operational noise levels from the wind farm will be within levels recommended in national guidance for wind energy schemes.

A separate assessment was undertaken for an uninhabited location on Loch Glass, whose status is unclear, using background noise measurements at a representative location. Predicted levels at this location are either low or effectively unchanged from the existing situation.

The impact of the proposed substation infrastructure was assessed in line with the relevant standard and could be associated with a negligible impact. The addition of this source to that of the wind turbines would not result in additional impacts.

1. Introduction

1.1 This report presents an assessment of the potential construction and operational noise impacts of the Novar 1 Wind Farm Repowering (the repowered wind farm) on the residents of nearby dwellings. If consented the repowered wind farm will replace the operational Novar 1 Wind Farm. The assessment considers both the construction (including de-commissioning of the Novar 1 Wind Farm) and operation of the repowered wind farm and also the likely impacts of its de-commissioning. Assessment of operational noise accounts for the cumulative total of the repowered wind farm as well as other wind farms nearby. Other wind farms considered were those closest and consisted of: Novar 2 Wind Farm (adjacent to the south of the repowered wind farm) and the Abhainn Dubh Wind Farm (approximately 3.8 kilometres south). The recently submitted Ceislein Wind Farm (approximately 1 kilometres to the east of the repowered wind farm) was considered in a separate cumulative assessment. Other, more distant wind farms were not considered because as their potential noise contribution was considered negligible.

1.2 Noise and vibration which arises from the construction of a wind farm is a factor which should be taken into account when considering the repowered wind farm. However, in assessing the impacts of construction noise, it is accepted that the associated works are of a temporary nature. The main work locations for construction of the turbines are distant from nearest noise sensitive residences and are unlikely to cause strong impacts. The construction and use of access tracks may, however, occur at lesser separation distances. Assessment of the temporary impacts of construction noise is primarily aimed at understanding the need for dedicated management measures and, if so, the types of measures that are required. Further details of relevant working practices, traffic routes, and proposed working hours are described in the construction and traffic chapters of the Environmental Impact Assessment Report.

1.3 Once constructed and operating, wind turbines may emit two types of noise. Firstly, aerodynamic noise is a 'broad band' noise, sometimes described as having a characteristic modulation, or 'swish', which is produced by the movement of the rotating blades through the air. Secondly, mechanical noise may emanate from components within the nacelle of a wind turbine. This is a less natural sounding noise which is generally characterised by its tonal content. Traditional sources of mechanical noise comprise gearboxes or generators. Due to the acknowledged lower acceptability of tonal noise in otherwise 'natural' noise settings such as rural areas, modern turbine designs have evolved to minimise mechanical noise radiation from wind turbines. Aerodynamic noise tends to be perceived when the wind speeds are low, although at very low wind speeds the blades do not rotate or rotate very slowly and so, at these wind speeds, negligible aerodynamic noise is generated. In higher winds, aerodynamic noise is generally masked by the normal sound of wind blowing through trees and around buildings. The level of this natural 'masking' noise relative to the level of wind turbine noise determines the subjective audibility of the wind farm. The relationship between wind turbine noise and the naturally occurring masking noise at residential dwellings lying around the repowered wind farm will therefore generally form the basis of the assessment of the levels of noise against accepted standards.

1.4 The main noise sources associated with the substation are likely to be the power transformers and their cooling fans. The transformer noise is generally fairly constant, once energised, whereas the cooling fans operate as needed, depending on load and ambient temperature. The noise from the transformers is usually tonal in nature with most energy contained within discrete frequency components at 100 Hz and harmonics thereof. The cooling fans are likely to be broadband in nature but switch on and off.

1.5 An overview of environmental noise assessment and a glossary of noise terms are provided in Annex A.

2. Policy and Guidance Documents

2.1 Planning Policy and Advice Relating to Noise

2.1.1 The Scottish National Planning Framework 4 (NPF)[1] provides advice on how the planning system should manage the process of encouraging, approving and implementing renewable energy proposals including onshore wind farms. NPF4 suggests that renewable energy developments must demonstrate how impacts including noise are to be addressed through design and mitigation, going on to advise that "In considering these impacts, significant weight will be placed on the contribution of the proposal to renewable energy generation targets and on greenhouse gas emissions reduction targets."; however, NPF4 provides no specific advice on noise. Planning Advice Note PAN1/2011[2] provides general advice on the role of the planning system in preventing and limiting the adverse effects of noise without prejudicing investment in enterprise, development and transport. PAN1/2011 provides general advice on a range of noise related planning matters, including references to noise associated with both construction activities and operational wind farms. In relation to operational noise from wind farms, Paragraph 29 states that:

> 'There are two sources of noise from wind turbines - the mechanical noise from the turbines and the aerodynamic noise from the blades. Mechanical noise is related to engineering design. Aerodynamic noise varies with rotor design and wind speed, and is generally greatest at low speeds. Good acoustical design and siting of turbines is essential to minimise the potential to generate noise. Web based planning advice on renewable technologies for Onshore wind turbines provides advice on 'The Assessment and Rating of Noise from Wind Farms' (ETSU-R-97) published by the former Department of Trade and Industry [DTI] and the findings of the Salford University report into Aerodynamic Modulation of Wind Turbine Noise.'

2.1.2 The Scottish Government's Onshore Wind Policy Statement 2022[3] confirms that the recommendations of 'The Assessment and Rating of Noise from Wind Farms' (ETSU-R-97)[4] should be followed by all applicants to assess and rate noise from wind energy developments. The aim of ETSU-R-97 is:

> 'This document describes a framework for the measurement of wind farm noise and gives indicative noise levels thought to offer a reasonable degree of protection to wind farm neighbours, without placing unreasonable restrictions on wind farm development or adding unduly to the costs and administrative burdens on wind farm developers or local authorities. The suggested noise limits and their reasonableness have been evaluated with regard to regulating the development of wind energy in the public interest. They have been presented in a manner that makes them a suitable basis for noise-related planning conditions or covenants within an agreement between a developer of a wind farm and the local authority.'

2.1.3 The recommendations contained in ETSU-R-97 provide a robust basis for assessing the noise implications of a wind farm. ETSU-R-97 has become the accepted standard for such developments within the UK. Guidance on good practice on the application of ETSU-R-97 has been provided by the Institute of Acoustics (IOA Good Practice Guide or GPG)[5]. This was subsequently endorsed by the Scottish Government[6] and is referenced in the Onshore Wind Policy Statement 2022[3]. The

1 Scottish National Planning Framework 4, Scottish Government. Adopted 13 February 2023.
2 Planning Advice Note 1/2011: Planning & Noise, Scottish Government, March 2011.
3 Scottish Government (2022) - Onshore wind - policy statement 2022, December 2022..
4 ETSU-R-97, the Assessment and Rating of Noise from Wind Farms, Final ETSU-R-97 Report for the Department of Trade & Industry. The Working Group on Noise from Wind Turbines, 1997.
5 A Good Practice Guide to the Application of ETSU-R-97 for the Assessment and Rating of Wind Turbine Noise, M. Cand, R. Davis, C. Jordan, M. Hayes, R. Perkins, Institute of Acoustics, May 2013.
6 Letter from John Swinney MSP, Scottish Government, 29/05/2013

methodology of ETSU-R-97 and the IOA GPG has therefore been adopted for the present assessment and is described in greater detail below.

2.1.4 The Scottish Government Onshore Wind Policy Statement 2022[3] mentions the potential for the advice in ETSU-R-97 to be modified in future based on a review from the UK Government, but continues to support its use in the meantime, confirming the advice from the Online Renewables Planning Advice set out above. A report on this topic commissioned by the UK Government has been published (WSP BEIS Report)[7], with some recommendations for updates to some aspects of the ETSU-R-97 methodology which will need to be considered by the national governments. The WSP BEIS report does not provide a replacement or update to ETSU-R-97 and until it is replaced or updated, the Scottish Government has confirmed in the Onshore Wind Policy Statement 2022 that the ETSU-R-97 methodology continues to be applicable. In relation to infrasound and low frequency noise, the WSP BEIS report is clear that the approach in ETSU-R-97 is robust in this respect and that infrasound levels from wind turbines are clearly below relevant thresholds (see Annex A). The UK Government then published[8] in July 2025 a draft for consultation of a revision of the ETSU-R-97 guidelines but noted that this draft guidance should not be used until a response to this consultation is published. Although updated guidance was recently published by the UK Government, inclusion of this updated guidance was outside the scope of the present report.

2.1.5 For assessing noise from non-wind turbines sources associated with the repowered wind farm, such as fixed plant associated with the substation, PAN1/2011 advises the use of the BS 4142 standard. Although PAN1/2011 references the 1997 version of the standard, the more recent 2019 version[9] is now applicable.

2.1.6 PAN1/2011 and the Technical Advice Note[10] accompanying PAN1/2011 note that construction noise control can be achieved through planning conditions that limit noise from temporary construction-sites, or by means of the Control of Pollution Act (CoPA) 1974[11]. The CoPA provides two means of controlling construction noise and vibration. Section 60 provides the Local Authority with the power to impose at any time operating conditions on the development site. Section 61 allows the developer to negotiate a prior consent for a set of operating procedures with the Local Authority before commencement of site works.

2.1.7 For detailed guidance on construction noise and its control, the Technical Advice Note refers to British Standard BS 5228[12] 'Noise control on construction and open sites', Parts 1 to 4 but confirms that the updated version of this standard, published in January 2009 is relevant when used within the planning process. The 2009 version consolidates all previous parts of the standard into BS 5228-1: 2009 (amended 2014)[13] (BS 5228-1) for airborne noise and BS 5228-2: 2009 (amended 2014)[14] (BS 5228-2) for ground-borne vibration. These updated versions have therefore been adopted as the relevant versions upon which to base this assessment.

2.1.8 BS 5228-1 provides guidance on a range of considerations relating to construction noise including the legislative framework, general control measures, example methods for estimating construction noise levels and example criteria which may be considered when assessing impact magnitude. Similarly,

7 WSP, A Review of Noise Guidance for Onshore Wind Turbines, report for the UK Department for Business, Energy & Industrial Strategy, October 2022 (published 10 February 2023).
8 https://www.gov.uk/government/consultations/assessment-and-rating-of-wind-turbine-noise-guidance-proposed-updates [accessed December 2025]
9 British Standard 4142: 2014+A1 2019 Method for rating and assessing industrial and commercial sound. British Standards Institution. 2019.
10 PAN1/2011 Technical Advice Note – Assessment of Noise, Scottish Government, March 2011.
11 Control of Pollution Act, Part III, HMSO, 1974.
12 BS 5228 Noise and Vibration Control on Construction and Open Sites, Parts 1 to 4.
13 BS 5228-1:2009-A:2014 'Code of practice for noise and vibration control on construction and open sites – Part 1: Noise'.
14 BS 5228-2:2009-A:2014 'Code of practice for noise and vibration control on construction and open sites – Part 2: Vibration'.

BS 5228-2 provides general guidance on legislation, prediction, control and assessment criteria for construction vibration.

2.1.9 Planning Advice Note PAN50[15] "Controlling the Environmental Effects of Surface Mineral Workings" gives guidance on the environmental effects of mineral working. The main document summarises the key issues with regard to various environmental effects relating to surface mineral extraction and processing such as road traffic, blasting, noise, dust, visual intrusion etc. In addition, several annexes to the main document have been published which consider specific aspects in more detail: Annex A, "The Control of Noise at Surface Mineral Workings" and Annex D "The Control of Blasting at Surface Mineral Workings". BS 5228-1 and BS 5228-2 also provide guidance relating to surface mineral extraction including the assessment of noise and vibration impacts associated with quarry blasting. BS 6472-2 2008[16] gives similar guidance on assessing vibration from blasting associated with mineral extraction.

3. Scope and Methodology

3.1 Methodology for Assessing Construction Noise

3.1.1 Construction works include both moving sources and static sources. The moving sources normally comprise mobile construction plant and Heavy Goods Vehicles (HGVs). The static sources include construction plant temporarily placed at fixed locations and in some instances, noise arising from blasting activities where rock is to be worked through.

3.1.2 The analysis of construction noise has been undertaken in accordance with BS 5228-1 which provides methods for predicting construction noise levels on the basis of reference data for the emissions of typical construction plant and activities. These methods include for the calculation of construction traffic along access tracks and haul routes and also for construction activities at fixed locations such as the bases of turbines, site compounds or sub stations.

3.1.3 The BS 5228 calculated levels are then compared with absolute noise limits for temporary construction activities which are commonly regarded as providing an acceptable level of protection from the short-term noise levels associated with construction activities.

3.1.4 Separate consideration is also given to the possible noise impacts of construction related traffic passing to and from the site along local surrounding roads. In considering potential noise levels associated with construction traffic movement on public roads, reference is made to the accepted UK prediction methodology provided by 'Calculation of Road Traffic Noise'[17] (CRTN).

3.1.5 The nature of works and distances involved in the construction of a wind farm are such that the risk of non-negligible impacts relating to ground borne vibration are very low (excluding blasting). Occasional momentary vibration can arise when heavy vehicles pass dwellings at very short separation distances, but again this is not sufficient to constitute a risk of moderate or major impacts. Accordingly, vibration impacts do not warrant detailed assessment and are therefore not discussed further in this assessment.

3.1.6 It is assumed as a worst-case that use of blasting for rock extraction from borrow pits would be used in some instances. The analysis of the related potential impacts has been made in accordance with PAN50, BS 6472-2 2008 and BS 5228.

15 Planning Advice Note 50: Controlling The Environmental Effects of Surface Mineral Workings, 1996.
16 BS 6472-2:2008:Guide to evaluation of human exposure to vibration in buildings - Part 2: Blast-induced vibration.
17 Calculation of Road Traffic Noise, HMSO Department of Transport, 1988.

3.2 Methodology for Assessing Wind Turbine Operational Noise

3.2.1 The ETSU-R-97 assessment procedure specifies that noise limits should be set relative to existing background noise levels at the nearest properties and that these limits should reflect the variation in both turbine source noise and background noise with wind speed. The wind speed range which should be considered is between the cut-in speed (the speed at which the turbines begin to operate) for the turbines and 12 m/s (43.2 km/h), where all wind speeds are referenced to a ten-metre measurement height (refer to Annex G for a discussion of how wind speeds are referenced to ten metre height).

3.2.2 Separate noise limits apply for the day-time and night-time. Day-time limits are chosen to protect a property's external amenity whilst outside their dwellings in garden areas and night-time limits are chosen to prevent sleep disturbance indoors. Absolute lower limits, different for day-time and night-time, are applied where the line of best-fit representation of the measured background noise levels equates to very low levels (< 30 dB(A) to 35 dB(A) for day-time, and < 38 dB(A) during the night).

3.2.3 The day-time noise limit is derived from background noise data measured during the 'quiet periods of the day' defined in ETSU-R-97: these comprise weekday evenings (18:00 to 23:00), Saturday afternoons and evenings (13:00 to 23:00) and all day and evening on Sundays (07:00 to 23:00). Multiple samples of ten-minute background noise levels using the $L_{A90,10min}$ measurement index are measured contiguously over a wide range of wind speed conditions (a definition of the $L_{A90,10min}$ index is given in Annex A). The measured noise levels are then plotted against the simultaneously measured wind speed data and a 'best-fit' curve is fitted to the data to establish the background noise level as a function of wind speed. The ETSU-R-97 day-time noise limit is then set to the greater of either: a level 5 dB(A) above the best-fit curve to the background noise data over a 0-12 m/s wind speed range or a fixed level in the range 35 dB(A) to 40 dB(A). The precise choice of the fixed lower limit within the range 35 dB(A) to 40 dB(A) depends on a number of factors: the number of noise affected properties, the likely duration and level of exposure and the consequences of the choice on the potential power generating capability of the wind farm.

3.2.4 ETSU-R-97 clearly indicates that the day-time limit is intended to lie within the range from 35 dB(A) to 40 dB(A). Therefore, one can conclude that there must be projects where 35 dB(A) is appropriate and conversely, projects where 40 dB(A) is appropriate. Within ETSU-R-97 there is a specific example: "A single wind turbine causing noise levels of 40 dB(A) at several nearby residences would have less planning merit (...) than 30 wind turbines also causing the same amount of noise at several nearby residences". Therefore, where a project offers relatively low power generating potential, the day-time limit should naturally tend towards the lower end of the range, unless the number of noise affected properties and the extent to which those properties would be affected by the higher noise levels is sufficiently low to justify noise limits tending towards the upper end of the range. Conversely, sites with relatively large power generating capacity should naturally justify limits towards the upper end of the range. The appropriate choice of value is considered subsequently in Section 5.7 in this Report.

3.2.5 The night-time noise limit is derived from background noise data measured during the night-time periods (23:00 to 07:00) with no differentiation being made between weekdays and weekends. The ten minute $L_{A90,10min}$ noise levels measured over these night-time periods are again plotted against the concurrent wind speed data and a 'best-fit' correlation is established. As with the day-time limit, the night-time noise limit is also set as the greater of: a level 5 dB(A) above the best-fit background curve or a fixed level of 43 dB(A). This fixed lower night-time limit of 43 dB(A) was set in ETSU-R-97 on the basis of World Health Organization (WHO) guidance[18] for the noise inside a bedroom and an assumed difference between outdoor and indoor noise levels with windows open. In the time since ETSU-R-97 was released, the WHO guidelines were revised to suggest a lower internal noise level, but conversely, a higher assumed difference between outdoor and indoor noise levels. Notwithstanding the WHO

18 Environmental Health Criteria 12 – Noise. World Health Organisation, 1980.

guideline revisions, the ETSU-R-97 limit remains consistent with current national planning policy guidance with respect to night-time noise levels. In addition, following revision of the night-time WHO criteria, ETSU-R-97 has been incorporated into planning guidance for Wales, England and Scotland and at no point during this process was it felt necessary to revise the guidance within ETSU-R-97 to reflect the change in the WHO guideline internal levels. The advice contained within ETSU-R-97 remains a valid reference on which to continue to base the fixed limit at night.

3.2.6 As discussed below in Section 3.7, The Highland Council expressed a preference for more stringent fixed lower limits and this has been taken into account in the assessment.

3.2.7 The exception to the setting of both the day-time and night-time lower fixed limits occurs in instances where a property occupier has a financial involvement in the wind farm development. Where this is the case then the lower fixed portion of the noise limit at that property may be increased to 45 dB(A) during both the day-time and the night-time periods alike.

3.2.8 ETSU-R-97 also offers an alternative simplified assessment methodology:

'For single turbines or wind farms with very large separation distances between the turbines and the nearest properties a simplified noise condition may be suitable. We are of the opinion that, if the noise is limited to an $L_{A90,10min}$ of 35dB(A) up to wind speeds of 10m/s at 10m height, then this condition alone would offer sufficient protection of amenity, and background noise surveys would be unnecessary.

3.2.9 The noise limits defined in ETSU-R-97 relate to the total noise occurring at a dwelling due to the combined noise of all operational wind turbines. The assessment will therefore need to consider the combined operational noise of the repowered wind farm with other wind farms in the area to be satisfied that the combined cumulative noise levels are within the relevant ETSU-R-97 criteria. ETSU-R-97 also requires that the baseline levels on which the noise limits are based do not include a contribution from any existing turbine noise, to prevent unreasonable cumulative increases.

3.2.10 To undertake the assessment of operational noise in accordance with the foregoing methodology the following steps are required:

- specify the number and locations of the wind turbines on all wind farms;
- identify the locations of the nearest, or most noise sensitive, neighbours;
- measure the background noise levels as a function of site wind speed at the nearest neighbours, or at least at a representative sample of the nearest neighbours;
- determine the day-time and night-time noise limits from the measured background noise levels at the nearest neighbours;
- specify the type and noise emission characteristics of the wind turbines;
- calculate the noise immission levels due to the operation of the wind turbines as a function of site wind speed at the nearest neighbours; and
- compare the calculated wind farm noise immission levels with the derived noise limits and assess in the light of planning requirements.

3.2.11 The foregoing steps, as applied to the repowered wind farm, are set out subsequently in this assessment.

3.2.12 Note that in the above, and subsequently in this assessment, the term 'noise emission' relates to the sound power level actually radiated from each wind turbine, whereas the term 'noise immission' relates to the sound pressure level (the perceived noise) at any receptor location due to the combined operation of all wind turbines on the repowered wind farm.

3.3 Methodology for Assessing Operational Noise – non-turbine sources

3.3.1 Noise from non-wind turbines sources associated with the repowered wind farm, such as fixed plant associated with the substation, will be assessed using the BS 4142 standard. This standard provides a method for rating the potential impact of noise from fixed plant installations based on the background noise levels that prevail on a site. This is compared to a "rated level" of noise which is based on the L_{Aeq} level with the potential addition of penalties to account for some characteristics of the sound, considering the context of the situation: this requires consideration of factors such as the nature of the area and, particularly at night-time, the absolute level of the specific noise considered. The impact magnitude is then determined on the basis of the difference between rated level and background, with consideration of these contextual factors:

- A difference of around +10 dB is likely to be an indication of a significant adverse impact, depending on context;
- A difference of around +5 dB is likely to be an indication of an adverse impact, depending on context; and
- A difference of +0 dB or less is an indication of the specific sound source having a low impact, depending on the context.

3.4 Criteria – Construction Noise

3.4.1 BS 5228-1 indicates a number of factors are likely to affect the acceptability of construction noise including site location, existing ambient noise levels, duration of Site operations, hours of work, attitude of the site operator and noise characteristics of the work being undertaken.

3.4.2 BS 5228-1 informative Annex E provides example criteria that may be used to consider the magnitude of any construction noise impacts. The criteria do not represent mandatory limits but rather a set of example approaches intended to reflect the type of methods commonly applied to construction noise. The example methods are presented as a range of possible approaches (both facade and free field noise levels, hourly and day-time averaged noise levels) according to the ambient noise characteristics of the area in question, the type of development under consideration, and the expected hours of construction activity. In broad terms, the example criteria are based on a set of fixed limit values which, if exceeded, may result in a large impact unless ambient noise levels (i.e. regularly occurring levels without construction) are sufficiently high to provide a degree of masking of construction noise.

3.4.3 Based on the range of guidance values set out in BS 5228 Annex E, and other reference criteria provided by the World Health Organization (WHO) and PAN50 Annex A: The Control of Noise at Surface Mineral Workings (1996), the following impact assessment scale has been derived. The values have been chosen in recognition of the relatively low ambient noise typically observed in rural environments. The presented criteria have been normalised to free-field day-time noise levels occurring over a time period, T, equal to the duration of a working day on-site. BS 5228-1 Annex E provides varied definitions for the range of day-time working hours which can be grouped for equal consideration. The values presented in Table 1 have been chosen to relate to day-time hours from 07:00 to 19:00 on weekdays, and 07:00 to 13:00 on Saturdays.

Table 1 - Construction Noise Impact Assessment

Impact	Noise Level dB $L_{Aeq,T}$		Description
	4 weeks or more	up to 4 weeks	
Major	> 75	> 85	Trigger level for noise insulation works, or costs thereof, as set out in E.4 of BS 5228-1.
Moderate	> 65 ≤ 75	> 75 ≤ 85	Most stringent threshold values for potential significant effects given in Annex E of BS 5228-1 for example methods relevant to repowered wind farm is exceeded.
Minor	> 55 ≤ 65	> 65 ≤ 75	Noise is likely to be audible, but unlikely to change behaviour. of BS 5228-1 thresholds not exceeded.
Negligible	≤ 55	≤ 65	At least 10 dB below the most stringent criteria provided in of BS 5228-1.
The values presented above relate to noise impacts that occur during working hours from 07:00 to 19:00 on weekdays, and 07:00 to 13:00 on Saturdays. Alternate criteria would apply to noise impacts outside of these hours. For noise impacts 13:00 to 19:00 on Saturdays and 07:00 to 19:00 on Sundays the above thresholds would reduce by 10 dB(A) in each category. For noise impacts 19:00 to 07:00 on any day the above thresholds would reduce by 20 dB(A) in each category.			

3.4.4 When considering the impact of short-term changes in traffic, associated with the construction activities, on existing roads in the vicinity of the Project, reference can be made to the criteria set out in the Design Manual for Roads and Bridges (DMRB[19]). A classification of magnitudes of changes in the predicted traffic noise level calculated using the CRTN methodology is set out: for short-term changes such as those associated with construction activities, changes of less than 1 dB(A) are considered negligible, 1 to 3 dB(A) is minor, 3 to 5 dB(A) moderate and changes of more than 5 dB(A) constitute a major impact. This classification can be considered in addition to the criteria of Table 1.

3.4.5 Blasting operations can generate airborne pressure waves or "air overpressure". This covers both those pressure waves generated which are in the frequency range of human audibility (approximately 20 Hz to 20 kHz) as well as infrasonic pressure waves (those with a frequency of below 20 Hz), which, although outside the range of human hearing, can sometimes be felt at very high amplitude.

3.4.6 Noise from blasting (i.e. pressure waves in the human audible range) is not considered in the same way as noise from other construction activities due to the fact that a large proportion of the energy contained within pressure waves generated by a blast is at frequencies that are below the lower frequency threshold of human hearing, and that the portion of energy contained within the audible range is generally of low frequency and of smaller magnitude than the infrasonic pressure variations.

3.4.7 The relevant guidance documents advise controlling air overpressure (and hence noise from blasting) through the use of good practices during the setting and detonation of charges as opposed to absolute limits on the levels produced, therefore no absolute limits for air overpressure or noise from blasting will be presented in this assessment.

3.4.8 In accordance with the guidance in BS 6472-2: 2008, ground vibration caused by blasting operations will be considered acceptable if peak particle velocity (PPV) levels, at the nearest sensitive locations, do not exceed 6 mm/s for 95% of all blasts measured over any 6-month period, and no individual blast exceeds a PPV of 12 mm/s. Because of the difficulties in predicting vibration from blasting operation, this is best controlled in practice where relevant using a testing process, with progressively increased charges, in consultation with the relevant local authority.

19 The Highways Agency, Transport Scotland, Transport Wales and The Department for Regional Development (Northern Ireland) (2020). 'Design Manual for Roads and Bridges, LA 111 Noise and vibration', revision 2.

3.5 Criteria - Operational Wind Turbine Noise

3.5.1 The acceptable limits for wind turbine operational noise are clearly defined in the ETSU-R-97 document and these limits should not be breached. Consequently, the test applied to operational noise is whether or not the calculated wind farm noise immission levels at nearby noise sensitive properties lie below the noise limits derived in accordance with ETSU-R-97. Depending on the levels of background noise the satisfaction of the ETSU-R-97 derived limits can lead to a situation whereby, at some locations under some wind conditions and for a certain proportion of the time, the wind farm noise may be audible. However, noise levels at the properties in the vicinity of the repowered wind farm will still be within levels considered acceptable under the ETSU-R-97 assessment method.

3.6 Criteria - Operational Non-wind-Turbine Noise

3.6.1 The noise impact of non-turbine sources (the substation) will be considered in line with the method of BS 4142 which considers the difference between the source considered and background noise levels, taking into account contextual factors. In particular, a noise level not exceeding 35 dB would be considered low in absolute terms[20]. Table 1 outlines the resulting impact magnitude criteria.

Table 2 – Operational Noise Impact Criteria – non-wind turbine sources (excluding further contextual considerations)

Impact	Description
Major	Rating level exceeds background by 10 dB or more, and is greater than 35 dB(A)
Moderate	Rating level exceeds background by 5 dB to 10 dB, and is greater than 35 dB(A)
Minor	Rating level exceeds background, by a maximum of 5 dB, or is less than 35 dB(A)
Negligible	Rating level equal to, or less than, background or less than 25 dB(A)

3.7 Consultation

3.7.1 A scoping response was received from The Highland Council (THC) in May 2025 for the repowered wind farm. The response outlined in particular a preference for lower fixed limits as 35 dB(A) for daytime and 38 dB(A) for night or 5 dB above prevailing background level instead of those prescribed in ETSU-R-97. The scoping response also required a careful consideration of cumulative noise with reference to good practice guidance, consideration of increased noise exposure due to noise from different sites being experienced in different wind directions, and recommendations to consult with THC in relation to background noise level measurements.

3.7.2 Prior to undertaking the background surveys, a summary of the likely proposed proxy measurement location at Wyvis Lodge and the proposed use of existing baseline survey data from the Clach Liath Wind Farm application, was forwarded to the Environmental Health Department of The Highland Council (THC) for comment on the 8th August 2024. This consultation was based on a preliminary project layout which was of a similar form to the layout currently proposed.

3.7.3 The proposed approach was accepted on the 15th August 2024 with regards to the use of historical data and new survey data from a conservative proxy location, to inform the most representative baseline noise levels in the area.

20 Consideration of the levels set out in Table A1 in Annex A highlights that an external level of 35 dB(A) would be considered low in the context of World Health Organisation guidelines for community noise, as internal levels within habitable spaces would be at least 10 dB lower even with an opened window.

3.7.4 The response from THC also noted in the case of differing historical baseline results at similar locations in the area, the more conservative baseline levels should inform the assessment unless there is good reason not to.

3.7.5 The agreed baseline noise measurement location is shown on the plan in Annex B. Further information about the monitoring location, the equipment used and pictures of the survey position are presented in Annex C.

3.7.6 The scoping response also noted that stringent criteria would be sought for noise from the proposed substation:

- L_{eq} (unweighted) levels in the 100 Hz 1/3 octave band not exceeding 30 dB; and
- Rated noise levels (with reference to BS 4142) not exceeding background noise levels.

3.7.7 The response also noted that "noise from sub-stations and battery sites would not normally be considered cumulatively with wind farms."

4. Baseline

4.1 General Description

4.1.1 The repowered wind farm is located in an area of relatively low population density, to the north of Loch Glass. The noise environment in the surrounding area is generally characterised by 'natural' sources, such as wind disturbed vegetation, birds and water noise in some cases from Loch Glass and the River Glass. Other sources of noise observed at Loch Glass House included existing wind turbine noise from the operational Novar 1 and Novar 2 Wind Farms.

4.2 Details of the Baseline Background Noise Survey

4.2.1 Although Loch Glass House was observed to be uninhabited, and its status is unclear, it is considered this assessment (section 5.8). One noise measurement location was agreed with The Highland Council (THC) Local Authority as being a representative proxy for the background noise environment at this property. The Wyvis Lodge baseline proxy noise measurement location is shown on the plan in Annex B and listed in Table 3. The use of the data in this way is justified by the relative proximity of both properties to Loch Glass, similarities in the local terrain at each location and the dominant influence of 'natural' sources on background noise levels throughout the area, shared by both properties following site observations. However, unlike at the Loch Glass House location, no existing wind turbine noise was observed at the Wyvis Lodge property. By excluding existing turbine noise from noise measurements using a representative proxy measurement location, this approach is consistent with the guidance provided by ETSU-R-97 and current good practice as set out in the IOA GPG[21].

4.2.2 A review of the assessment for the superseded Clach Liath Wind Farm and Abhainn Dubh Wind Farm has confirmed that suitable historical baseline background noise levels for some noise sensitive receptors to the south of the repowered wind farm have already been sufficiently defined (through a previous survey of four locations in July/August 2011 for the Clach Liath Wind Farm assessment) for the purposes of an assessment in accordance with ETSU-R-97. Accordingly, additional baseline surveys were not undertaken for the repowered wind farm at these properties, as agreed with THC. This survey was not considered to be influenced by operational wind turbine noise: in particular, the Novar 2 Wind Farm was not operational at the time of this survey, and the Novar 1 turbines located at a larger distance to the surveyed properties. The resulting data remains representative of the noise environment, as no

[21] IOA GPG, May 2013, Section 5.2, Paragraph 5.2.2 states: "Where a new wind farm is proposed and a receptor is also within the area acoustically affected by an already operational wind farm, then noise from the existing wind farm must not be allowed to influence the background noise measurements for the proposed development."

substantial change in the noise environment or terrain is understood to have occurred since. The use of this data and the approach to combining this data to form representative baseline noise levels was agreed in consultation with THC and a full discussion of these background noise levels is presented in Annex D.

Table 3 - Baseline Noise Measurement Locations (approximate Easting / Northing)

No.	Property	Easting	Northing
1	Wyvis Lodge	248460	873683
2	Eileanach Lodge (Historical)	254494	868916
3	Eileanach Farm (Historical)	254806	868589

4.2.3 The assessment has considered operational noise from the repowered wind farm at the monitoring locations noted above, as well as other residential properties: these assessment locations are listed in Table 4. The list of receptor locations is not intended to be exhaustive but sufficient to be representative of noise levels typical of those receptors closest to the repowered wind farm. The status of Loch Glass House is uncertain, therefore the assessment at this location is considered separately in Section 5.8. For properties to the north of the repowered wind farm such as Douchan, the simplified assessment method of ETSU-R-97 can be applied (see 3.2.8). Those locations which are further from the repowered wind farm than those in Table 4 would be less exposed to noise from the repowered wind farm, with consequently reduced impacts, and are not considered further.

4.2.4 Some relatively distant receptors have however been included in the assessment where these are considered relevant initially, to demonstrate that cumulative noise levels remain within the ETSU-R-97 noise limits where the contribution from the repowered wind farm is lower but adjacent wind farms may be higher. This approach is consistent with the guidance provided by ETSU-R-97 and current good practice as set out in the IOA GPG.

Table 4 - Assessment properties in the vicinity of the repowered wind farm.

Property	Easting	Northing	Approximate Distance to Closest Turbine (m)	Closest Proposed Turbine (ID)	Survey Location
Douchan	257258	873472	2161	RP_9	Simplified assessment
Glaick	256796	873737	2240	RP_9	Simplified assessment
Loch Glass House*	252709	870738	2292	RP_4	Wyvis Lodge
Easter Ballone	257995	873460	2584	RP_9	Simplified assessment
Eileanach Lodge	254507	868941	2325	RP_7	Eileanach Lodge (Historical)
West End	256298	868908	2430	RP_7	Eileanach Farm (Historical)
Tighnacraig	255729	869091	2078	RP_7	Eileanach Farm (Historical)
Eileanach Farm Cottage	254804	868599	2575	RP_7	Eileanach Farm (Historical)
Caravan	254973	868874	2275	RP_7	Eileanach Lodge (Historical)
Eileanach Farm House	254719	868667	2526	RP_7	Eileanach Farm (Historical)
* See specific discussion on Loch Glass House in Section 5.8					

4.2.5 The background noise monitoring exercise at Wyvis Lodge was conducted over a period of just over 4 weeks between October and November of 2024. The equipment used for the survey comprised one Rion NL-52 logging sound level meter. The meter was enclosed in an environmental case with battery power to enable 14 days continuous logging at the required ten-minute averaging periods. Outdoor enhanced windshield systems were used to reduce wind induced noise on the microphones and provide protection from rain. These windshield systems were supplied by the sound level meter manufacturer

and maintain the required performance of the whole measurement system when fitted. The environmental enclosures provided an installed microphone height of approximately 1.4 metres above ground level, consistent with the requirements of ETSU-R-97.

4.2.6 The sound level meter was positioned in a large garden on the side of the property exposed to the loch, to represent similar terrain conditions as the Loch Glass House location, however set back to minimise potential wave noise as a conservative measure. Additionally, the logger was distanced more than 3.5 metres from the façade of any nearby buildings at Wyvis Lodge and as far away as was practical from obvious localised sources of noise, such as running water from a distant stream and tall trees to the north of the position. Atypical, localised noise from the pool pump room to the side of the property was also avoided at the install position. Details and photographs of the measurement location is presented in Annex C.

4.2.7 All measurement systems were calibrated on their deployment on the 1st October, during the interim service visit on the 14th October and upon collection of the equipment on the 1st November 2024. No acoustically important (>0.5 dB(A)) drifts in calibration were found to have occurred on any of the systems. This equates to a total ETSU-R-97 analysis period of at least 30 days at this location, which is in excess of the minimum of one week suggested by ETSU-R-97 and is compliant with the IOA GPG requirements.

4.2.8 All measurement systems were set to log the $L_{A90,10min}$ and $L_{Aeq,10min}$ noise levels continuously over the deployment period. The internal clocks on the sound level meters were all synchronized with Greenwich Mean Time (GMT/UTC) by the use of a smartphone. The clock on the LIDAR unit from which wind data was subsequently collected for the analysis of the measured background noise as function of wind speed was also set to GMT/UTC time.

4.3 Measured Background Noise Levels

4.3.1 The ETSU-R-97 assessment method requires noise data to be related to wind speed data at a standardised height of ten metres, with wind speeds either directly measured at a height of ten metres or by calculation from measurement at other heights, the appropriate choice being determined by practitioner judgement and the available data sources. Since the publication of ETSU-R-97, the change in wind speed with increasing height above ground level has been identified as a potential source of variability when carrying out wind farm noise assessments. The effect of site-specific wind shear can be appropriately addressed by implementing the ETSU-R-97 option of deriving ten metre height reference data from measurements made at taller heights. It is this method that has been used in the noise assessment for the repowered wind farm to account for the potential effect of site-specific wind shear. This method is consistent with the preferred method described in the IOA GPG. Wind speeds and directions were measured using a LIDAR located within the boundary of the repowered wind farm site (approximate easting and northing 253998 / 872714). Values of wind speed at a standardised height of ten metres were calculated from those measured on the LIDAR ("standardised wind speed"). Full details of the calculation method are given in Annex G.

4.3.2 Charts E1 and E2 reproduced at Annex E show the range of wind conditions experienced during the noise survey period. During the quiet day-time and night-time periods wind speeds of up to a maximum of 15 m/s were measured. The strongest winds were observed to be directed from the southwest for the majority of the survey period, consistent with the typical prevailing wind direction for the UK. Easterly to north easterly winds were also present.

4.3.3 Charts F1 to F2 of Annex F show the results of the background noise measurements at the survey location. The background noise data are presented in terms of $L_{A90,10min}$ background noise levels plotted as a function of standardised ten metre height wind speed. Two plots are shown for each location, one for quiet day-time periods and the other for night-time periods, both derived in accordance with ETSU-R-97.

4.3.4 Data from all survey locations were inspected to identify periods which may have been influenced by extraneous noise sources, giving rise to atypical and elevated levels. ETSU-R-97 requires that any data

affected by rainfall be excluded from the analysis. A rain gauge was installed at the Wyvis Lodge location during the noise survey period; data from this gauge were therefore used to exclude those periods where rain was indicated.

4.3.5 In addition to the impact noise on surrounding vegetation and the sound level meter itself, in some environments rainfall can result in appreciable changes in background sound levels, for example dissipating flow noise in water courses and drainage systems. Whilst occasionally observed in the distance during site visits, distant watercourse noise had a negligible influence on the measured baseline data, and thus the possible effect of increased noise from watercourses in the vicinity is not considered relevant to this site. This was due to positioning the logger as far as practically possible from any residential drainage or watercourse systems, to minimise any associated noise influence. Inspection of the data in Charts F1 and F2 generally tends to support this, given the absence of any identifiable clear data trends that are normally characteristic of a site affected by rain related background sound levels (such as flat clusters of data on the noise versus wind plot, or sharp increases in noise followed by a progressive decrease with time).

4.3.6 The measured background noise data may also have been increased by other extraneous sources or atypical events. Time-histories of the noise levels at each survey location were therefore inspected to look for any atypical relationships when compared to the wind speeds present during that time. Any elevated levels found in this way were excluded. The trend of the data when plotted against wind speed was also inspected to look for atypical relationships or outliers within the data-set (particularly at low wind speeds) which were excluded. Any data removed from the analysis in this way is indicated on the charts as red circles. The analysis and filtering of the data was therefore undertaken in accordance with current good practice as set out in the IOA GPG.

4.3.7 The existing Novar 1 and Novar 2 Wind Farms to the east were operating at the time of the baseline survey. However, the choice of undertaking baseline measurements at Wyvis Lodge as a representative proxy location on the other end of Loch Glass, instead of Loch Glass House (located opposite Loch Glass from these sites), resulted in baseline measurements that were not influenced by any contribution from existing wind turbine noise, as required by ETSU-R-97 and the IOA GPG.

4.3.8 As discussed in Annex D, the analysis of the historical data measured at Eileanach Lodge and Eileanach Farm was analysed and corrected to account for potential wind shear effects, in line with IOA GPG guidance.

4.3.9 The resulting background noise levels (see Table 5 and Table 6), where relevant, were used to derive the noise limits required by ETSU-R-97 that apply during the day-time and night-time periods up to 12 m/s. The corresponding ETSU-R-97 noise limits are summarised in Table 7 and Table 8. The noise limits have been set either at the prevailing measured background level plus 5 dB, or at the relevant fixed lower limit, whichever is the greater. Stringent fixed lower limit values set to 35 dB(A) and 38 dB(A) for day-time and night-time periods respectively, were applied on the basis of the preferences expressed by THC as part of the consultation for the project (see section 3.7).

Table 5 - Day time L_{A90} (dB) background noise levels from the baseline noise survey and historical wind shear corrected baseline survey data according to ETSU-R-97.

Property	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Wyvis Lodge	30.0	27.6	26.3	25.8	26.1	27.0	28.4	30.1	32.0	33.9	35.8	37.6
Eileanach Lodge (Historical)*	-	-	42.8	43.2	43.5	43.9	44.2	44.6	44.9	45.3	45.6	45.9
Eileanach Farm (Historical)*	-	-	30.7	31.4	32.1	32.7	33.4	34.0	34.7	35.3	36.0	36.7

* See Annex D for the wind shear correction details of the historical day baseline data.

Table 6 - Night time L_{A90} (dB) background noise levels from the baseline noise survey and historical wind shear corrected baseline survey data according to ETSU-R-97.

Property	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Wyvis Lodge	20.5	21.8	23.3	24.8	26.4	28.1	29.9	31.7	33.6	35.6	37.6	39.7
Eileanach Lodge (Historical)*	-	-	43.2	43.5	43.9	44.2	44.5	44.8	45.1	45.4	45.7	46.0
Eileanach Farm (Historical)*	-	-	31.4	32.0	32.6	33.2	33.8	34.4	35.0	35.6	36.2	36.8
* See Annex D for the wind shear correction details of the historical night baseline data.												

Table 7 - Day time L_{A90} (dB) noise limits derived according to ETSU-R-97 either from the day baseline data or using the simplified method.

Property	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Douchan	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	-	-
Glaick	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	-	-
Loch Glass House	See Section 5.8											
Easter Ballone	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	-	-
Eileanach Lodge	47.8	47.8	47.8	48.2	48.5	48.9	49.2	49.6	49.9	50.3	50.6	50.9
West End	35.7	35.7	35.7	36.4	37.1	37.7	38.4	39.0	39.7	40.3	41.0	41.7
Tighnacraig	35.7	35.7	35.7	36.4	37.1	37.7	38.4	39.0	39.7	40.3	41.0	41.7
Eileanach Farm Cottage	35.7	35.7	35.7	36.4	37.1	37.7	38.4	39.0	39.7	40.3	41.0	41.7
Caravan	47.8	47.8	47.8	48.2	48.5	48.9	49.2	49.6	49.9	50.3	50.6	50.9
Eileanach Farm House	35.7	35.7	35.7	36.4	37.1	37.7	38.4	39.0	39.7	40.3	41.0	41.7

Table 8 - Night time L_{A90} (dB) noise limits derived according to ETSU-R-97 either from the night baseline data or using the simplified method.

Property	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Douchan	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	-	-
Glaick	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	-	-
Loch Glass House	See Section 5.8											
Easter Ballone	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	-	-
Eileanach Lodge	48.2	48.2	48.2	48.5	48.9	49.2	49.5	49.8	50.1	50.4	50.7	51.0
West End	38.0	38.0	38.0	38.0	38.0	38.2	38.8	39.4	40.0	40.6	41.2	41.8
Tighnacraig	38.0	38.0	38.0	38.0	38.0	38.2	38.8	39.4	40.0	40.6	41.2	41.8

Property	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Eileanach Farm Cottage	38.0	38.0	38.0	38.0	38.0	38.2	38.8	39.4	40.0	40.6	41.2	41.8
Caravan	48.2	48.2	48.2	48.5	48.9	49.2	49.5	49.8	50.1	50.4	50.7	51.0
Eileanach Farm House	38.0	38.0	38.0	38.0	38.0	38.2	38.8	39.4	40.0	40.6	41.2	41.8

5. Noise Impact Assessment

5.1 Predicted Construction Noise Levels

5.1.1 The level of construction noise that occurs at the surrounding properties will be highly dependent on a number of factors such as the final Site programme, equipment types used for each process, and the operating conditions that prevail during construction. It is not practically feasible to specify each and every element of the factors that may affect noise levels, therefore it is necessary to make reasonable allowance for the level of noise emissions that may be associated with key phases of the construction.

5.1.2 In order to determine representative emission levels for this study, reference has been made to the scheduled sound power data provided by BS 5228. Based on experience of the types and number of equipment usually associated with the key phases of constructing a wind farm, the scheduled sound power data has been used to deduce the upper sound emission level over the course of a working day. In determining the rating applicable to the working day, it has generally been assumed that the plant will operate for between 75% and 100% of the working day. In many instances, the plant would actually be expected to operate for a reduced percentage, thus resulting in noise levels lower than predicted in this assessment. The decommissioning of the Novar 1 Wind Farm turbines was also assessed as part of the construction phase.

5.1.3 To relate the sound power emissions to predicted noise levels at surrounding properties, the prediction methodology outlined in BS 5228 has been adopted. The prediction method accounts for factors including screening and soft ground attenuation. The size of the Site and resulting separation distances to surrounding properties allows the calculations to be reliably based on positioning all the equipment at a single point within a particular working area (for example, in the case of turbine erection, it is reasonable to assume all associated construction plant is positioned at the base of the turbine under consideration). In applying the BS 5228 methodology, it has been conservatively assumed that there are no screening effects, and that the ground cover is characterised as 50% hard/ 50% soft.

5.1.4 Table 9 lists the key construction activities, the associated types of plant normally involved, the expected worst-case sound power level over a working day for each activity, the property which would be closest to the activity for a portion of construction, and the predicted noise level. It must be emphasised that these predictions only relate the noise level occurring during the time when the activity is closest to the referenced property. In many cases such as access track construction and turbine erection, the separating distances will be considerably greater for the majority of the construction period and the predictions are therefore the worst-case periods of the construction phase.

Table 9 - Predicted construction noise levels

Task Name	Plant/Equipment	Upper Collective Sound Emission Over Working Day $L_{WA,T}$ dB(A)	Nearest Receiver	Minimum Distance to Nearest Receiver (m)	Predicted Upper Day-Time L_{Aeq}
Dismantle existing Novar 1 turbines	Cranes / turbine delivery vehicles / articulated lorry /	120	Tighnacraig	1620	44

Task Name	Plant/ Equipment	Upper Collective Sound Emission Over Working Day $L_{WA,T}$ dB(A)	Nearest Receiver	Minimum Distance to Nearest Receiver (m)	Predicted Upper Day-Time L_{Aeq}
	generators / torque guns				
Cutting existing Novar 1 turbine foundations	Concrete breakers / crushers / excavators / dump trucks	120	Tighnacraig	1620	44
Reinstate Novar 1 turbine bases and hard-standings	Excavator / dump truck	115	Tighnacraig	1620	39
Reinstate disused Novar 1 access tracks	Excavator / dump truck	115	Tighnacraig	1621	39
Upgrade Access Track	excavator / dump trucks / tippers / dozers / vibrating rollers	120	14 Fyrish Crescent (261376 / 866720)	90	72
Construct temporary site compounds	excavator / dump truck / tippers / rollers/ delivery trucks	120	14 Fyrish Crescent (261376 / 866720)	540	54
Construct site tracks	excavators / dump trucks / tippers / dozers / vibrating rollers	120	Tighnacraig	2070	41
Construct Sub-Station	excavator / concrete truck / delivery truck	110	Easter Ballone	690	42
Construct crane hard-standings	excavators / dump trucks	115	Tighnacraig	2070	36
Construct turbine foundations	Piling Rigs / excavators / tippers / concrete trucks / mobile cranes / water pumps / pneumatic hammers / compressors / vibratory pokers	120	Tighnacraig	2070	41
Excavate and lay site cables	excavators / dump trucks / tractors & cable drum trailers / wacker plates	115	Easter Ballone	750	46
Erect turbines	cranes / turbine delivery vehicles / artics for crane movement / generators / torque guns	115	Tighnacraig	2070	36
Reinstate crane bases	excavator / dump truck	115	Tighnacraig	2070	36
Reinstate road verges	excavator / dump truck	115	14 Fyrish Crescent (261376 / 866720)	90	67

Task Name	Plant/ Equipment	Upper Collective Sound Emission Over Working Day $L_{WA,T}$ dB(A)	Nearest Receiver	Minimum Distance to Nearest Receiver (m)	Predicted Upper Day-Time L_{Aeq}
Winning Stone	Boudler Breakers / excavators / Dump trucks / lorry	125	Glaick	2800	44
Forest Felling	Harvesters and forwarders, characterised by saw noise diesel engine noise emissions commonly associated with tractors and excavation noise	115	14 Fyrish Crescent (261376 / 866720)	440	51
Borrow Pit Quarrying	Lorries / breakers / crushers stockpilers / conveyors / hoppers	125	Glaick	2800	44
Aggregate rock processing	Concrete breakers / crushers / excavators / dump trucks / graders	120	Douchan	1930	42

5.1.5 Comparing the above predicted noise levels in Table 9 to the range of background noise levels measured around the repowered wind farm suggests that the noisier construction activities would be audible at various times throughout the construction phase. However, comparing the levels to the significance criteria presented previously indicates that the majority of construction activities will have impacts of negligible to minor magnitude. Decommissioning work activities associated with the Novar 1 Wind Farm in preparation for the construction of the repowered wind farm, are also assessed in Table 9. Comparing the levels to the significance criteria presented previously, indicates that the majority of construction activities are predicted to have impacts of negligible magnitude.

5.1.6 Decommissioning work activities associated with the Novar 1 Wind Farm, in preparation for the construction of the repowered wind farm, are also assessed in Table 9. Comparing the levels to the significance criteria presented previously indicates that these construction activities are predicted to have impacts of negligible magnitude.

5.1.7 For the upgrade access tracks and reinstate road verges activities which are closest to 14 Fyrish Crescent, predicted noise levels are likely to represent those for a very short-term period when activity is closest to the receptor. Noise levels will quickly diminish as the track roadwork activity progresses, moving these construction activities further from the property. The short-term nature of this activity consequently categorises the impact to be of minor magnitude.

5.1.8 In addition to on-site activities, construction traffic passing to and from the site will also represent a potential source of noise to surrounding properties. The traffic statement for the proposal is presented in Chapter 11: Traffic and Access. Specifically, the highest volume of traffic generated by construction is expected to occur in the seventh and eighth months of construction on concrete pour days, in which an average of 338 total vehicle daily trips (two-way, large heavy good vehicles (HGV) and cars/ light good vehicles (LGV)) are predicted, resulting in a worst case 26 two-way HGV trips per hour, across a typical 12 hour day. This is assuming 100% of aggregate materials are imported to the Site as a worst case. Table 11.10, Table 11.14 and Table 11.17 of Chapter 11: Traffic and Access have been used to ascertain the projected traffic flows for scenarios without and with the repowered wind farm and with the cumulative traffic flows, in 2029.

Table 10 - Projected traffic flows

Road	Without Development Future Baseline		With Development	
	Annual Average Daily Traffic Flow	% Heavy Goods Vehicles	Annual Average Daily Traffic Flow	% Heavy Goods Vehicles
B817, east of the proposed Site access junction	1818	12.2%	2156	24.7%
B9176, north of its junction with the A9	1569	32.8%	1907	43.3%
A9, east of the A9 / B9176 Junction	10330	18.7%	10334	18.7%
A9, north of Tain at Morangie	7421	16.4%	7425	16.4%
A9, between Poles and The Mound	4565	18.5%	4569	18.5%
A9, east of Ardullie Roundabout	13175	18.1%	13513	20.0%
Road	Without Development Future Baseline		With Development and Cumulative traffic	
	Annual Average Daily Traffic Flow	% Heavy Goods Vehicles	Annual Average Daily Traffic Flow	% Heavy Goods Vehicles
B817, east of the proposed Site access junction	1818	12.2%	2156	24.7%
B9176, north of its junction with the A9	1569	32.8%	2004	42.8%
A9, east of the A9 / B9176 Junction	10330	18.7%	10336	18.7%
A9, north of Tain at Morangie	7421	16.4%	7798	20.0%
A9, between Poles and The Mound	4565	18.5%	4772	21.3%
A9, east of Ardullie Roundabout	13175	18.1%	13966	21.9%

Table 11 - CRTN predicted increase in day time average traffic noise levels ($L_{A10,18hour}$) - repowered wind farm alone and cumulative

Road	Maximum Change in Traffic Noise Level, dB(A)	Magnitude of Impact
B817, east of the proposed Site access junction	2.7	Minor (see paragraph 5.1.9 below)
B9176, north of its junction with the A9	2.2	Minor (see paragraph 5.1.9 below)
A9, east of the A9 / B9176 Junction	0.0	No Change
A9, north of Tain at Morangie	0.0	No Change
A9, between Poles and The Mound	0.0	No Change
A9, east of Ardullie Roundabout	0.3	Negligible
Road	Maximum Change in Cumulative Traffic Noise Level, dB(A)	Magnitude of Impact for cumulative traffic noise
B817, east of the proposed Site access junction	2.7	Minor (see paragraph 5.1.9 below)
B9176, north of its junction with the A9	2.5	Minor (see paragraph 5.1.9 below)
A9, east of the A9 / B9176 Junction	0.0	No Change
A9, north of Tain at Morangie	0.6	Negligible
A9, between Poles and The Mound	0.5	Negligible

Road	Maximum Change in Traffic Noise Level, dB(A)	Magnitude of Impact
A9, east of Ardullie Roundabout	0.7	Negligible

5.1.9 In conclusion for all routes assessed in line with the DMRB criteria outlined in 3.4.4 above, the maximum changes in traffic noise level for both the repowered wind farm alone and with cumulative sites, are below 3 dB(A) and therefore correspond to a minor impact at most. The predicted traffic flow values on two of the identified road links (B817 and B9176) surrounding the repowered wind farm are of less than 4000 vehicles per day, which is considered low within the CRTN prediction methodology, which is potentially associated with increased uncertainties. Assessment of construction traffic noise along these two routes are therefore supplemented with an assessment of absolute noise levels, based on the prediction methodology in BS 5288.

5.1.10 The nearest residential property locations in respect of vehicle movements along the B817 (east of the proposed Site access junction) and the B9176 (north of its junction with the A9) lie within 5 to 10 metres and 30 to 35 metres to the midsection of these routes respectively. Large heavy goods vehicles can generate noise levels in the order of 108 dB (sound power level) when in motion. However, these types of plant usually pass a receiver location quite quickly. When stationary the same vehicles will be operating in idle which considerably lowers the noise output to the environment. Based on the prediction methodology in BS 5288 and accounting for a worst case 26 two-way HGV trips per hour on both routes and moving at an estimated 50 km/h, the predicted noise levels at those properties are 65 dB and 57 dB $L_{Aeq,T}$ respectively. Based on the assessment criteria of BS 5288, these noise levels correspond to a minor impact and a negligible impact for each route respectively, during the peak construction months. The same conclusions are reached for both the repowered wind farm alone and cumulatively based on the assumptions in Chapter 11: Traffic and Access.

5.1.11 For the remainder of the site access route, the nearest properties along are situated 80 to 200 metres from the site access route. These properties currently likely experience low levels of road traffic. Assuming a worst-case worst case 26 two-way HGV trips per hour along the site access route moving at an estimated 50 km/h, a level of $L_{Aeq,T}$ 53 dB(A) at most is predicted at these properties using the same BS 5228 methodology. This level is predicted during the two peak construction months and assumes 100% imported aggregate materials. Based on the assessment criteria of BS 5288, this noise level corresponds to a negligible impact at the properties along the site access route.

5.1.12 In conclusion, noise from construction activities and associated construction traffic has been assessed and is predicted to result in a temporary minor impact at most.

5.1.13 This conclusion is based on construction activities being limited to the following standard working hours: from 07:00 to 19:00 on weekdays, and 08:00 to 13:00 on Saturdays. No construction activities would be undertaken on Saturday afternoons after 13:00, or on Sundays. However, activities that are unlikely to give rise to noise audible at the Site boundary will continue outside of the stated hours. Furthermore, turbine deliveries may take place outside these times with the prior consent of the relevant authorities. In addition, good practice measures recommended in BS 5228-1 should be used to minimise construction noise levels.

5.2 Construction Noise & Vibration Levels – Blasting

5.2.1 It is assumed (as a worst-case) that blasting may be used at the proposed borrow pit. Because of the difficulties in predicting noise and air overpressure resulting from blasting operations at on-site borrow pits, these activities are best controlled following the use of good practice during the setting and detonation of charges, as set out earlier in this report. Given the separation distances between the location of the borrow pit and the nearest noise sensitive receptor (approximately 2.8 kilometres as a

minimum from the nearest receptor, Glaick) it is very unlikely that these activities would cause non-negligible adverse impacts, and therefore no further mitigation is required.

5.3 Decommissioning Noise

5.3.1 Decommissioning of the repowered wind farm is likely to result in less noise than during construction of the repowered wind farm. The construction phase has been considered to have minor noise impacts as a worst case, therefore decommissioning will, in the worst case, also have minor noise impacts.

5.4 Operational Wind Turbine Emissions Data

5.4.1 The exact model of turbine to be used will be the result of a future tendering process and therefore a representative turbine model has been assumed for this noise assessment. This operational noise assessment is based upon the noise specification of the Nordex N163 wind turbine. 9 turbines have been modelled using the layout as indicated on the map at Annex B. The candidate turbine is a variable speed, pitch regulated machine with a rotor diameter of 163 metres and modelled hub height of 98.5 metres (see Annex B). Due to its variable speed operation, the sound power output of the Nordex N163 turbine varies considerably with wind speed, being quieter at the lower wind speeds when the blades are rotating more slowly. The candidate turbine also incorporates the use of Serrated Trailing Edges (or STE), which reduce noise emissions, as standard. Data for the "6.X" variant of the turbine, with generation capacity of up to 7 MW, was considered as the basis for the analysis. The data assumed for the repowered wind farm is considered likely to represent the upper range of noise emissions for turbines typical for the repowered wind farm.

5.4.2 Nordex have supplied specified noise emission data for the N163 turbine which has been derived from various manufacturers sound power tests. In the absence of specific information about uncertainty allowances in the data, a further correction factor of +2 dB was added to the specification data in line with advice in the IOA GPG. The sound power data has been made available for standardised reference wind speeds of 3 m/s to 12 m/s inclusive. In addition to the overall sound power data, reference has been made to specified sound spectrum data for the N163 Nordex turbine, based on an energetic average of the available third octave band information to calculate each octave band. The overall sound power and spectral data are presented in Table B3 and B4 in Annex B.

5.4.3 Assessment of the cumulative noise from operating the repowered wind farm with other wind farms requires source information for the turbine types similar to that discussed above for the repowered wind farm for each wind farm to be considered. Assessment of the cumulative noise included operating the repowered wind farm along with the Novar 2 and the Abhainn Dubh Wind Farms. Further information and details on the turbines modelled, their source data and the assumptions made are outlined further in Annex B. In addition, representative sound spectra for the turbine types have been derived from the reported one third octave band spectrum and converted to octave bands, also detailed in Annex B.

5.4.4 For the Abhainn Dubh Wind Farm, three turbines were modelled to operate in reduced noise modes as detailed in Annex B, to meet its proposed noise limits and maintain consistency with the Abhainn Dubh noise assessment. It is unlikely that noise emissions from this site could be higher without resulting in potential excess of its individual noise limits. For the Novar 2 Wind Farm, in the absence of specific restrictions associated with its consent noise limits at specific neighbouring properties, a further reasonable increase of +2 dB was added to the noise emission data for the installed turbines, to provide a robust assessment. This is therefore considered consistent with the guidance of the IOA GPG.

5.5 Choice of Wind Farm Operational Noise Propagation Model

5.5.1 The ISO 9613-2 model[22] has been used to calculate the noise immission levels at the selected nearest residential neighbours as advised in the IOA GPG. The model accounts for the attenuation due to geometric spreading, atmospheric absorption, and barrier and ground effects. All attenuation calculations have been made on an octave band basis and therefore account for the sound frequency characteristics of the turbines.

5.5.2 For the purposes of the present assessment, all noise level predictions have been undertaken using a receiver height of four metres above local ground level, mixed ground (G=0.5) and an air absorption based on a temperature of 10°C and 70% relative humidity, and a receiver height of four metres. The attenuation due to terrain screening accounted for in the calculations has been limited to a maximum of 2 dB(A). In situations of propagation above concave ground, a correction of +3dB was added. These propagation factors are shown in Annex B.

5.5.3 This method is consistent with the recommendations of the above-referenced Institute of Acoustics Good Practice Guide which provides recommendations on the appropriate approach when predicting wind turbine noise levels. The IOA GPG also allows for directional effects to be taken into account within the noise modelling: under upwind propagation conditions between a given receiver and the wind farm the noise immission level at that receiver can be as much as 10 dB(A) to 15 dB(A) lower than the level predicted using the ISO 9613-2 model. However, predictions have been made assuming downwind propagation from every turbine to every receptor at the same time as a worst-case.

5.6 Predicted Wind Turbine Operational Noise Immission Levels

5.6.1 Table 12 shows predicted noise immission levels for the repowered wind farm alone at each of the selected assessment locations for each wind speed over the range of wind speeds where source noise emission level data are available. All wind farm noise immission levels in this report are presented in terms of the L_{A90} noise indicator in accordance with the recommendations of the ETSU-R-97 report, obtained by subtracting 2 dB(A) from the calculated L_{Aeq} noise levels based on the turbine sound power levels presented in Annex B. The Loch Glass House location is considered separately in Section 5.8.

Table 12 - Predicted L_{A90} (dB) wind farm noise immission levels at each of the noise assessment locations as a function of standardised wind speed for the repowered wind farm alone.

Property	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Douchan	-	-	19.3	20.6	25.2	29.6	30.9	30.9	30.9	30.9	30.9	30.9
Glaick	-	-	18.4	19.7	24.3	28.7	30.0	30.0	30.0	30.0	30.0	30.0
Easter Ballone	-	-	17.7	19.0	23.6	28.0	29.3	29.3	29.3	29.3	29.3	29.3
Eileanach Lodge	-	-	16.5	17.8	22.4	26.8	28.1	28.1	28.1	28.1	28.1	28.1
West End	-	-	19.1	20.4	25.0	29.4	30.7	30.7	30.7	30.7	30.7	30.7
Tighnacraig	-	-	18.4	19.7	24.3	28.7	30.0	30.0	30.0	30.0	30.0	30.0
Eileanach Farm Cottage	-	-	15.0	16.3	20.9	25.3	26.6	26.6	26.6	26.6	26.6	26.6

22 ISO 9613-2:1996 'Acoustics – Attenuation of sound during propagation outdoors – Part 2: General method of calculation', International Standards Organisation, 1996.

Property	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Caravan	-	-	15.8	17.1	21.7	26.1	27.4	27.4	27.4	27.4	27.4	27.4
Eileanach Farm House	-	-	15.4	16.7	21.3	25.7	27.0	27.0	27.0	27.0	27.0	27.0

5.6.2 Table 13 shows the predicted cumulative noise immission levels at each of the selected assessment locations for each wind speed, with the repowered wind farm, Novar 2 and Abhainn Dubh Wind Farms operating in combination. The cumulative impact of the Ceislein Wind Farm, which was proposed more recently, is considered separately in section 6 below. The lowest available standardised wind speed available in the source sound power data for all three sites assessed is 4 m/s (see Annex B for full details). These predictions are cumulative assuming all other wind farms are operating as set out in Section 5.4 and that all receptors are downwind of all wind turbines at the same time as a conservative assumption. These cumulative noise levels are therefore unlikely to occur in practice.

Table 13 - Predicted cumulative L_{A90} (dB) wind farm noise immission levels at each of the noise assessment locations as a function of standardised wind speed.

Property	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Douchan	-	-	-	21.8	26.0	30.5	32.4	33.6	34.5	34.5	34.5	34.5
Glaick	-	-	-	21.3	25.4	29.8	32.0	33.3	34.3	34.3	34.3	34.3
Easter Ballone	-	-	-	20.5	24.7	29.1	31.1	32.4	33.4	33.4	33.4	33.4
Eileanach Lodge	-	-	-	25.3	29.7	33.4	35.2	36.6	37.6	37.6	37.6	37.6
West End	-	-	-	24.7	29.2	33.0	34.5	35.3	36.0	36.0	36.0	36.0
Tighnacraig	-	-	-	25.3	29.7	33.4	35.0	36.1	37.0	37.0	37.0	37.0
Eileanach Farm Cottage	-	-	-	25.8	30.3	33.9	35.3	36.3	37.1	37.1	37.1	37.1
Caravan	-	-	-	24.6	29.1	32.8	34.4	35.6	36.6	36.6	36.6	36.6
Eileanach Farm House	-	-	-	25.8	30.3	33.9	35.4	36.4	37.3	37.3	37.3	37.3

5.7 ETSU-R-97 assessment

5.7.1 The ETSU-R-97 noise limits assume that the wind turbine noise contains no audible tones. Where tones are present a correction is added to the measured or predicted noise level before comparison with the recommended limits. The audibility of any tones can be assessed by comparing the narrow band level of such tones with the masking level contained in a band of frequencies around the tone called the critical band. The ETSU-R-97 recommendations suggest a tone correction which depends on the amount by which the tone exceeds the audibility threshold and should be included as part of the consent conditions. The turbines to be used for this site will be chosen to ensure that the noise emitted will comply with the requirements of ETSU-R-97 including any relevant tonality corrections.

5.7.2 The predicted noise immission levels from the repowered wind farm in Table 13 indicates that for three of the assessment locations (highlighted in Table 13), cumulative noise immission levels from the repowered wind farm operating with the Novar 2 Wind Farm and Abhainn Dubh Wind Farm are clearly below 35 dB(A), which is the lowest noise limit available in the ETSU-R-97 lower fixed portion range and therefore these properties are not considered further in the assessment.

5.7.3 The calculated cumulative wind farm noise immission levels at the remaining six noise assessment locations, as set out in Table 13, are compared to the relevant ETSU-R-97 noise limits. These were derived from historical measured background noise data as detailed in Annex D. The noise limits were set either at the prevailing measured background level plus 5 dB or at the relevant fixed lower limit whichever is the greater.

5.7.4 The assessment (shown in tabular form in Table 14 and Table 15) shows that the predicted cumulative wind farm noise immission levels at the relevant properties are below the derived noise limits (Table 7 & Table 8) under all wind speeds considered and at all locations, based on a lower day-time limit of 35 dB(A) and a lower night-time limit of 38 dB(A), as suggested by THC.

Table 14 - Difference between the ETSU-R-97 derived day time noise limits and the cumulative predicted L_{A90} (dB) wind farm Noise immission levels at each noise assessment location. Values are based on 35 lower day time limit and negative values indicate the noise immission level is below the limit.

Property	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Eileanach Lodge	-	-	-	-22.9	-18.9	-15.5	-14.0	-13.0	-12.3	-12.7	-13.0	-13.3
West End	-	-	-	-11.7	-7.9	-4.7	-3.9	-3.7	-3.7	-4.3	-5.0	-5.7
Tighnacraig	-	-	-	-11.2	-7.4	-4.3	-3.4	-2.9	-2.7	-3.3	-4.0	-4.7
Eileanach Farm Cottage	-	-	-	-10.6	-6.8	-3.8	-3.1	-2.7	-2.6	-3.2	-3.9	-4.6
Caravan	-	-	-	-23.6	-19.4	-16.1	-14.8	-14.0	-13.4	-13.8	-14.1	-14.4
Eileanach Farm House	-	-	-	-10.6	-6.8	-3.8	-3.1	-2.6	-2.4	-3.0	-3.7	-4.4

Table 15 - Difference between the ETSU-R-97 derived night time noise limits and the cumulative predicted L_{A90} (dB) wind farm Noise immission levels at each noise assessment location. Values are based on 38 lower night time limit and negative values indicate the immission level is below the limit

Property	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Eileanach Lodge	-	-	-	-23.2	-19.3	-15.8	-14.3	-13.2	-12.5	-12.8	-13.1	-13.4
West End	-	-	-	-13.3	-8.8	-5.2	-4.3	-4.1	-4.0	-4.6	-5.2	-5.8
Tighnacraig	-	-	-	-12.8	-8.3	-4.8	-3.8	-3.3	-3.0	-3.6	-4.2	-4.8
Eileanach Farm Cottage	-	-	-	-12.2	-7.7	-4.3	-3.5	-3.1	-2.9	-3.5	-4.1	-4.7
Caravan	-	-	-	-23.9	-19.8	-16.4	-15.1	-14.2	-13.6	-13.9	-14.2	-14.5
Eileanach Farm House	-	-	-	-12.2	-7.7	-4.3	-3.5	-3.0	-2.7	-3.3	-3.9	-4.5

5.7.5 The ETSU-R-97 fixed part of the limit during the day-time should lie within the range from 35 dB(A) to 40 dB(A). The factors to be used to determine where in this range have been discussed above. These are:-

- Number of dwellings in the neighbourhood of the wind farm;
- The effect of noise limits on the number of kWh generated; and
- Duration and level of exposure.

5.7.6 The above factors are to be considered together in the context of the repowered wind farm, other nearby wind energy schemes, as well as the local environment at receptor locations which may be affected by noise from the repowered wind farm. By defining this range within ETSU-R-97, it is clear that there must be circumstances where accounting for the above factors would lead to a value of 40 dB(A) and conversely where such factors would lead to a value of 35 dB(A), or somewhere within this range. It is also clear that ETSU-R-97 does not propose there to be a default choice within this range. These are considered in turn below:

- ETSU-R-97 provides a specific example when discussing the effect on energy generated: "A single wind turbine causing noise levels of 40 dB(A) at several nearby residences would have less planning merit (...) than 30 wind turbines also causing the same amount of noise at several nearby residences". This points towards the upper end of this range where there is significant energy generation. The generating capacity of the repowered wind farm is therefore a relevant consideration. Nine wind turbines with a potential generation capacity of 7 MW each (based on the candidate turbine selected), represents a substantial energy generation capacity of more than 50 MW. At the time the ETSU-R-97 guidelines were produced, a wind farm might have turbines with a capacity of around 0.6 MW, whereas the repowered wind farm's candidate turbines each have a capacity with an approximate seven-fold increase. Therefore, at the time of production of the guidelines, achieving a similar energy capacity to the repowered wind farm could have been expected to require installation of around 105 wind turbines, highlighting the substantial scale of the energy generation from the repowered wind farm. This would tend to justify a choice of lower limit within the middle or upper end of the ETSU-R-97 range.
- The area of the repowered wind farm can generally be characterised as having a low population density. For those receptor locations that are nearby, there are relatively few exposed to the highest levels of wind turbine noise when considered in the context of the scale of the repowered wind farm and the number of receptors. This would tend to justify a choice for the fixed part of the limit within the middle or upper end of the ETSU-R-97 range.
- In terms of the level and duration of exposure, properties located to the northeast, which would tend to be downwind from the turbines under south westerly winds typically experienced in the UK, are located such that predicted levels are low (below 35 dB L_{A90}). The receptor locations to the south of the scheme would be upwind from the turbines under prevailing conditions, reducing the duration of exposure, and several of these properties experience elevated background noise levels due to water noise (see Annex D), which reduces the effective level of exposure to wind turbine noise. These factors would tend to justify a higher noise limit within the ETSU-R-97 range.

5.7.7 Considering all the above factors in the round would tend to justify a limit which would not be at the lowest value within the 35 dB(A) to 40 dB(A) range. However, the repowered wind farm has been designed such that cumulative noise levels meet the lowest day-time limit within the ETSU-R-97 range, given the expressed preference of THC.

5.7.8 Satisfactory control of cumulative noise immission levels could be achieved through enforcement of individual consent limits for each of the individual wind energy developments. Site-specific noise limits which could be applied to the repowered wind farm in isolation are set out in Table 16, applicable to day-time and night-time periods at all wind speeds up to 10 m/s (to provide a simplified approach). These site-specific limits were derived by using the remaining 'noise budget' approach[23], which involves

23 The IOA GPG provides a specific example of an apportioned noise limit (IOA GPG Figure 7) which shows the full ETSU-R-97 noise limit divided between two wind farms in proportion to their relative contributions. The remaining noise budget approach yields assessment criteria which vary with wind speed due to changes in both the ETSU-R-97 noise limits as well as the contribution from the subtracted wind farm, and usually yields noise budgets which are greater at lower wind speeds than mid-range wind speeds. An alternate approach has been applied where the remaining noise budget is calculated in the same way but the lowest value obtained was applied as a limit applicable over the entire range of up to 10m/s.

taking the ETSU-R-97 noise limits which apply at an assessment location and subtracting[24] the contribution from the relevant adjacent wind farms. This remaining noise budget is calculated assuming all receptors are downwind from all wind farms simultaneously and discounts directional effects, representing a robust approach and accounts for the THC noise limit preferences.

Table 16 - Site-specific noise limits applicable to the repowered wind farm in isolation

Property	Noise limit (≤ 10 m/s)*
Douchan	32.1
Glaick	31.8
Easter Ballone	32.7
Eileanach Lodge	35.7
West End	35.7
Tighnacraig	35.7
Eileanach Farm Cottage	35.7
Caravan	35.7
Eileanach Farm House	35.7
* Specific limit applies at all wind speeds of no more than 10 m/s	

5.7.9 The resulting Site-specific noise limits would therefore apply to the repowered wind farm alone, whilst enabling total cumulative noise immission levels to meet the ETSU-R-97 noise limits applying at each noise assessment location. This approach would maintain the conclusion of the cumulative assessment and result in cumulative levels which do not exceed the derived ETSU-R-97 noise limits. The predicted levels in Table 12 are below the site-specific limits in Table 16, which demonstrates the repowered wind farm can operate within these Site-specific noise limits.

5.7.10 It is finally concluded that predicted cumulative noise immission levels from the repowered wind farm when operating with the Novar 2 Wind Farm and the Abhainn Dubh Wind Farm are compliant with the stringent noise limits derived at the specified locations and wind speeds. This outcome has been achieved using the Nordex 6.X VPC 7MW wind turbine operating unconstrained and by assuming worst-case downwind predictions. The selection of the final turbine to be installed at the Site should be made on the basis of enabling the relevant Site-specific noise limits of Table 16 to be achieved at surrounding properties.

5.8 Loch Glass House assessment

5.8.1 Loch Glass House is one of the closest buildings to the repowered wind farm, however it is uninhabited (and reportedly has not been occupied since its construction more than 30 years ago). However, it does not appear obviously uninhabitable, therefore it is considered further in this section.

5.8.2 The EIA for the Novar 2 Wind Farm had a noise section that mentions other properties but not Loch Glass House. It is also not specifically mentioned in the consent (which only outlines a general noise limit in the schedule associated with condition 28).

24 This is logarithmic decibel subtraction using the equation given in IOA GPG Page 39 GN4 Clause F.

5.8.3 Monitoring background noise levels at Loch Glass House itself could not be undertaken directly, as the ETSU-R-97 guidance requires that noise limits are derived from background noise which is not influenced by noise from existing operational wind turbines. Therefore, in consultation with the Highland Council, measurement at Wyvis Lodge, located more than 4 km from the repowered wind farm, were undertaken to represent background noise levels at Loch Glass House, as described earlier in this report. Historical monitoring was undertaken in 1994 at Culzie Lodge, a now demolished property located west of Loch Glass House on the shore of the Loch. However, details are unclear and these measurements are unlikely to be referenced to a wind speed representative of the increased height of the repowered wind farm turbines (given the age of that data), in line with current practice. It is nevertheless considered for contextual purposes.

5.8.4 Table 14 below shows the relative contributions at the Loch Glass House location, of the predicted Abhainn Dubh Wind Farm compared to the contribution of the repowered wind farm and Novar 2 Wind Farm.

Table 17 – Predicted contributions of the Abhainn Dubh Wind Farm compared to the combined repowered wind farm and Novar 1 Wind Farm at the Loch Glass House assessment location.

Loch Glass House: Abhainn Dubh assessment	Standardised 10 m Wind Speed (m/s)								
	4	5	6	7	8	9	10	11	12
Abhainn Dubh	14.4	19.2	22.5	23.1	23.2	23.2	23.2	23.2	23.2
repowered wind farm + Novar 2 (proposed cumulative)	26.7	29.9	34.5	38.0	40.5	42.1	42.1	42.1	42.1
Abhainn Dubh - repowered wind farm and Novar 2	-12.2	-10.7	-12.0	-14.8	-17.4	-19.0	-19.0	-19.0	-19.0

5.8.5 As shown in Table 17, the contribution of Abhainn Dubh Wind Farm is more than 10 dB below that of the repowered wind farm and Novar 2 Wind Farm. Therefore, at the Loch Glass House location, Abhainn Dubh Wind Farm is not acoustically important[25].

5.8.6 Table 18 and Chart 1 below show the prediction and assessment results at Loch Glass House, including only those wind farms which add an acoustically important contribution. Predicted noise immission levels shown assume the wind farms considered are operating as set out in Section 5.4 and in Annex B.

Table 18 – Loch Glass House assessment results

Loch Glass House: repowered wind farm assessment	Standardised 10 m Wind Speed (m/s)								
	4	5	6	7	8	9	10	11	12
Predictions at Loch Glass House									

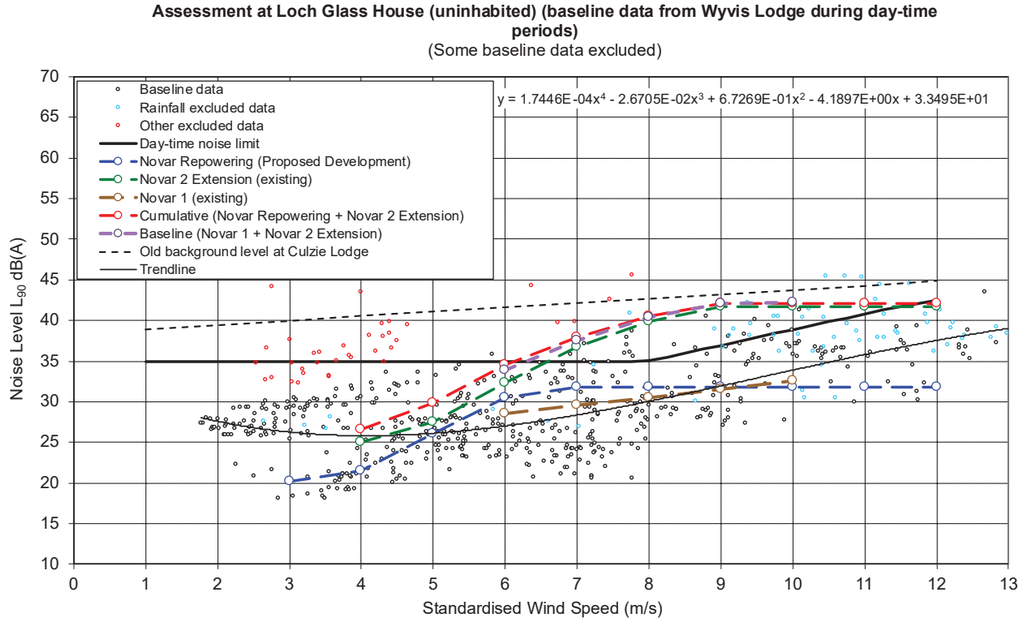
[25] The IOA GPG suggests that cumulative noise effects need not be considered where differences between existing and proposed wind farm noise levels are 10 dB(A) or more. This would also mean that cumulative effects also need not be considered at receptor locations where noise levels from the proposed wind farm are 10 dB(A) or more below those of existing wind farm noise levels.

Loch Glass House: repowered wind farm assessment	Standardised 10 m Wind Speed (m/s)								
	4	5	6	7	8	9	10	11	12
Repowered wind farm (Novar Repowering)	21.5	26.1	30.5	31.8	31.8	31.8	31.8	31.8	31.8
Novar 2 Wind Farm (existing)	25.1	27.6	32.4	36.8	39.9	41.7	41.7	41.7	41.7
Novar 1 (existing)*	-	-	28.6	29.6	30.6	31.6	32.6	-	-
Novar 1 + Novar 2 Wind Farm (Existing baseline)	-	-	33.9	37.5	40.4	42.1	42.2	-	-
Repowered wind farm + Novar 2 Wind Farm (Proposed cumulative)	26.7	29.9	34.5	37.9	40.5	42.1	42.1	42.1	42.1
Assessments at Loch Glass House									
Difference between the Proposed cumulative and Existing baseline prediction	-	-	0.6	0.4	0.1	0.0	-0.1	-	-

* Source sound power data for the Novar 1 turbine modelled was only available over a limited range of standardised wind speeds, from 6 m/s to 10 m/s, detailed in Annex B.

5.8.7 The prediction modelling and survey baseline data results are shown in Chart 1 below (and in Chart F1/F2 in Annex F), in addition to a notional ETSU-R-97 day noise limit which would apply for Loch Glass House, if it was considered residential, determined in accordance with the preferences of the Highland Council. Predictions of the existing baseline noise situation (Novar 1 and Novar 2) and the historical Culzie Lodge background noise levels are also shown for comparison.

Chart 1 – Chart of background noise levels against wind speeds, the best fit curve to the data, the indicative noise limit curve for Loch Glass House during quiet day time periods. Predicted immission noise levels are also shown for the repowered wind farm, the existing Novar wind farms considered and the cumulative total of Novar 2 and the repowered wind farm.



5.8.8 As shown in Table 18 and Chart 1, the existing Novar 2 Wind Farm clearly dominates immission levels at the Loch Glass House location, from medium to high wind speeds. As outlined in Annex B, an additional +2 dB uplift was applied to the sound power levels of the Novar 2 turbines meaning that the resultant levels are conservative. Additionally, Chart 1 shows the repowered wind farm alone is clearly below 35 dB(A).

5.8.9 Table 18 shows that and below 7 m/s, the existing and proposed cumulative scenario levels are below 35 dB(A) (highlighted green), which is less than the lowest applicable day time noise limit in ETSU-R-97. Table 18 also shows that, above 7 m/s, the increase between the cumulative predictions for the proposed scenario relative to the existing baseline situation are negligible (less than 0.5 dB), which would not be perceptible. This represents the difference between the existing cumulative baseline (Novar 1 + Novar 2) and the proposed cumulative (repowered wind farm + Novar 2) scenarios.

5.8.10 For comparison, all predicted noise levels are also well below the historical background noise levels which were measured at Culzie Lodge (now demolished). Therefore, if previous historical measurement data at Culzie Lodge (as referenced in the Novar 1 life extension) was used to derive ETSU-R-97 noise limits, there would be no exceedances of those noise limits.

5.8.11 In conclusion, given that the property is currently uninhabited, if this changed then levels experienced would be likely above the stringent ETSU-R-97 noise limits derived, but this would mainly be due to the influence of the Novar 2 Wind Farm. Furthermore, the repowering would not change the baseline noise situation substantially, with only a marginal (and negligible) increase on the current baseline scenario predicted. Furthermore, for the property to become inhabited it may require a new planning application which could be refused on the basis of the existing baseline noise levels from the Novar 2 Wind Farm. Therefore, although the status of the uninhabited Loch Glass House is unclear, the r

5.8.12 epowered wind farm does not introduce a substantial change in relation to noise.

5.9 Low Frequency Noise, Vibration and Amplitude Modulation from Wind Turbines

5.9.1 Low frequency noise and vibration resulting from the operation of wind farms are issues that have been attracting a certain amount of attention over recent years. Consequently, Annex A includes a detailed discussion of these topics. This shows that ground-borne vibration and very low frequency noise (infrasound) from wind turbines are below the threshold of human perception. In summary of the information provided therein, the current recommendation is that ETSU-R-97 should continue to be used for the assessment and rating of operational noise from wind farms.

5.9.2 Annex A also discusses the published research on the subject of wind turbine blade swish Amplitude Modulation (or AM). As a consequence of the combined results of this research, and in particular the development by the IOA of an objective technique for identifying and quantifying AM noise, as well as a review of the subjective response to AM noise by a Government-commissioned research group, a penalty-type approach to account for instances of increased AM outside what is expected from 'normal' blade swish has been proposed. Some uncertainty remains at this stage over the application of such a penalty and this will be subject to a period of testing and review over the next few years. However, the ETSU-R-97 method continues to be applicable in the absence of further guidance.

5.10 Operational noise from non-turbine sources

5.10.1 The main noise sources associated with the substation are likely to be the power transformers and their cooling fans. The transformer noise is generally fairly constant, once energised, whereas the cooling fans operate as needed, depending on load and ambient temperature. The noise from the transformers is usually tonal in nature with most energy contained within discrete frequency components at 100 Hz and harmonics thereof. The cooling fans are likely to be broad band in nature but switch on and off.

Battery storage facilities also have a combination of electrical plant as well as temperature control equipment but are less likely overall to have a noise which includes tones at low frequencies[26].

5.10.2 The proposed main onsite substation is located approximately 690 m to the southwest from the nearest residential property, Easter Ballone. The specifications of the transformer(s) likely to be used for the substation are not defined at this stage; however, it is considered likely based on experience of similar installations (with a total equipment source sound power of 88 dB L_{wA}) that the noise levels from the substation at the property would not exceed 17 dB L_{Aeq}. This calculation is based on the ISO 9613-2 method, assuming soft ground propagation conditions (except near the source) but neglecting any screening effects from the terrain which may reduce actual levels in practice.

5.10.3 The noise from the substation would be expected to be potentially tonal in nature. Therefore, with the addition of a penalty of 2 dB(A) for a potential tonal or other character in the noise, corrected or "rated" levels of no more than 19 dB L_{Ar} would be expected, which is less than 25 dB(A), and likely to be very low and less than typically occurring background noise levels in the area. According to the BS 4142 criteria in Table 2, this represents a negligible impact.

5.10.4 In addition, predicted levels at 100 Hz are likely to be well below 30 dB (unweighted) which would also satisfy the additional criteria proposed by THC.

5.10.5 With some properties potentially exposed to noise from the plant considered in this section and from wind turbine noise, it is relevant to consider whether there could be additional in-combination noise impacts. However, both types of noise are assessed under different guidance documents. The predicted levels from the proposed wind turbines would likely arise when receptors are downwind from the turbines and would only tend to be produced during windy conditions. In contrast, the operational noise levels from the other electrical plant elements considered are assessed in line with BS 4142, which is based on background noise levels obtained during quieter conditions with no wind. Furthermore, the maximum cumulative levels predicted from the wind turbines at Easter Ballone (33 dB L_{A90}, the nearest property to the proposed substation area) is 14 dB above the absolute rated noise level predicted for the substation (19 dB L_{Ar}), which would represent a difference of more than 10 dB, which is acoustically negligible and unlikely to be perceptible. There is therefore on balance, based on professional judgement and considering the above factors in terms of levels of noise exposure, unlikely to be any significant additional impacts expected when considering these operational noise sources in combination.

5.10.6 The above conclusions can be secured if necessary through a planning condition requiring noise levels from the substation facility that do not exceed 25 dB L_{Ar} (rated in accordance with BS 4142) at the nearest residential properties.

6. Cumulative noise assessment with the Ceislein Wind Farm

6.1 Introduction

6.1.1 An application for the proposed Ceislein Wind Farm, sited approximately 1 km to the east of the repowered wind farm, was submitted by RWE Renewables UK Onshore Wind Ltd on the 13th March 2026 under ECU reference ECU00005174. The cumulative assessment in the present section addresses the operational noise impact with the repowered wind farm, the Ceislein Wind Farm and the other cumulative schemes considered in the above operational noise assessment.

6.1.2 With the introduction of the Ceislein Wind Farm scheme, Table 19 below outlines the updated list of noise assessment receptors considered. The list of receptor locations is not intended to be exhaustive

26 Although inverters may produce high-frequency tonal noise above 2 kHz, this is more likely to be absorbed by the atmosphere.

but sufficient to be representative of noise levels typical of those receptors closest to the Repowered wind farm and the Ceislein Wind Farm.

Table 19 – Updated list of assessment properties in the vicinity of the repowered wind farm and Ceislein Wind Farm.

Property	Easting	Northing	Approximate Distance to Closest Turbine (m)	Closest Proposed Turbine (ID)	Survey Location (source)
Douchan	257258	873472	2161	RP_9	Glaick (Ceislein survey)
Glaick	256796	873737	2240	RP_9	Glaick (Ceislein survey)
Eileanach Lodge	254507	868941	2325	RP_7	Eileanach Lodge (Historical)
West End*	256298	868908	2430	RP_7	Assynt House (Ceislein survey)
Tighnacraig	255729	869091	2078	RP_7	Assynt House (Ceislein survey)
Easter Ballone*	257995	873460	2584	RP_9	Easter Ballone (Ceislein survey)
Eileanach Farm Cottage	254804	868599	2575	RP_7	Eileanach Farm (Historical)
Caravan	254973	868874	2275	RP_7	Eileanach Lodge (Historical)
Eileanach Farm House	254719	868667	2526	RP_7	Eileanach Farm (Historical)
Lynchork	256705	867272	4099	RP_7	Redburn (Ceislein survey)
* Financially involved with the proposed Ceislein Wind Farm scheme					

6.2 Baseline and Noise Limits

6.2.1 Baseline noise measurements were undertaken by TNEI for the Ceislein Wind Farm application's noise assessment, from 20th November 2024 to 15th January at seven noise measurement locations, with a minimum of four weeks data collected. This is in excess of the minimum of one week suggested by ETSU-R-97 and is compliant with the IOA GPG requirements. Further information on the background measurements is detailed in the Ceislein Wind Farm application's Noise Technical Appendix 12.2[27].

6.2.2 Baseline noise levels from four of the Ceislein Wind Farm measurement locations are referenced in this assessment (Table 19), in addition to the historical background levels referenced at the remaining assessment locations from the superseded Clach Liath Wind Farm by the Abhainn Dubh Wind Farm. Use of historical background measurement data is discussed in Section 4.2 above and corrected for wind shear effects as outlined in Annex D.

6.2.3 The background noise survey for Ceislein Wind Farm was referenced to wind speeds derived from a measured 170 m reference height on the Ceislein Wind Farm site, using LIDAR wind monitoring equipment. This was a conservative approach, as the proposed turbines on the Ceislein Wind Farm include hub heights of 118 m and 164 m for the candidate N167 6.X VPC "7MW" modelled turbine model, as detailed in Annex B. This is higher than the hub height considered for the repowered wind farm. Therefore, no further adjustments for wind shear were applied to the derived Ceislein Wind Farm background noise levels.

6.2.4 Table 20 and Table 21 below summarise the noise levels derived from the referenced baseline noise measurement sources referenced in the updated ETSU-R-97 noise assessment for the properties in Table 19.

[27] Section 5.2, Ceislein Wind Farm Noise Technical Appendix 12.2 – Operational Noise Report – Part 1 of 3. January 2026, TNEI.

Table 20 - Day time L_{A90} (dB) baseline noise levels from the Ceislein Wind Farm baseline noise survey and Clach Liath/Abhainn Dubh Wind Farm historical wind shear corrected background survey data according to ETSU-R-97.

Property	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Redburn	35.4	35.7	35.7	35.7	35.6	35.5	35.5	35.6	36.0	36.6	37.6	39.1
Assynt House	27.5	28.9	29.7	30.3	30.6	30.8	31.1	31.6	32.4	33.7	35.6	38.1
Easter Ballone	33.6	33.6	33.6	33.7	33.9	34.5	35.2	36.3	37.7	39.3	41.3	43.7
Glaick	29.5	29.5	29.5	29.6	30.1	30.9	32.1	33.7	35.6	37.8	40.5	43.5
Eileanach Lodge (Historical)*	42.8	42.8	42.8	43.2	43.5	43.9	44.2	44.6	44.9	45.3	45.6	45.9
Eileanach Farm (Historical)*	30.7	30.7	30.7	31.4	32.1	32.7	33.4	34.0	34.7	35.3	36.0	36.7
* See Annex D for the wind shear correction details of the historical day baseline data.												

Table 21 - Night time L_{A90} (dB) baseline noise levels from the Ceislein Wind Farm baseline noise survey and Clach Laith/Abhainn Dubh Wind Farm historical wind shear corrected background survey data according to ETSU-R-97.

Property	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Redburn	35.4	36.0	36.5	36.9	37.3	37.6	37.8	38.0	38.2	38.3	38.4	38.5
Assynt House	26.8	27.4	28.1	28.9	29.7	30.7	31.7	32.8	34.0	35.2	36.6	38.0
Easter Ballone	34.2	34.4	34.8	35.1	35.6	36.1	36.6	37.2	37.9	38.7	39.5	40.4
Glaick	29.7	29.7	29.8	30.3	31.1	32.1	33.3	34.4	35.5	36.4	37.0	37.1
Eileanach Lodge (Historical)*	43.2	43.2	43.2	43.5	43.9	44.2	44.5	44.8	45.1	45.4	45.7	46.0
Eileanach Farm (Historical)*	31.4	31.4	31.4	32.0	32.6	33.2	33.8	34.4	35.0	35.6	36.2	36.8
* See Annex D for the wind shear correction details of the historical night baseline data.												

6.2.5 The resulting background noise levels (see Table 20 and Table 21), where relevant, were used to derive the noise limits required by ETSU-R-97 that apply during the day-time and night-time periods up to 12 m/s. The corresponding ETSU-R-97 noise limits are summarised in Table 22 and Table 23 below. The noise limits have been set either at the prevailing measured background level plus 5 dB, or at the relevant fixed lower limit, whichever is the greater. Initially, lower day-time limits of 40 dB(A) and a lower night-time limit of 43 dB(A) are assumed, for consistency with those assumed in the Ceislein Wind Farm noise assessment. The West End and Easter Ballone properties are described as financially involved with the Ceislein Wind Farm, therefore the fixed lower limit is set to 45 dB(A).

Table 22 - Day time L_{A90} (dB) noise limits derived according to ETSU-R-97 from the day baseline data (lower fixed limit of 40 dB(A)).

Property	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Douchan	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.6	42.8	45.5	48.5
Glaick	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.6	42.8	45.5	48.5
Eileanach Lodge	47.8	47.8	47.8	48.2	48.5	48.9	49.2	49.6	49.9	50.3	50.6	50.9
West End*	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0
Tighnacraig	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.6	43.1
Easter Ballone*	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	46.3	48.7
Eileanach Farm Cottage	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.3	41.0	41.7
Caravan	47.8	47.8	47.8	48.2	48.5	48.9	49.2	49.6	49.9	50.3	50.6	50.9
Eileanach Farm House	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.3	41.0	41.7
Lynchork	40.4	40.7	40.7	40.7	40.6	40.5	40.5	40.6	41.0	41.6	42.6	44.1
* Financially involved with the proposed Ceislein Wind Farm scheme												

Table 23 - Night time L_{A90} (dB) noise limits derived according to ETSU-R-97 from the night baseline data (lower fixed limit of 43 dB(A)).

Property	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Douchan	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0
Glaick	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0
Eileanach Lodge	48.2	48.2	48.2	48.5	48.9	49.2	49.5	49.8	50.1	50.4	50.7	51.0
West End*	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0
Tighnacraig	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0
Easter Ballone*	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.4
Eileanach Farm Cottage	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0
Caravan	48.2	48.2	48.2	48.5	48.9	49.2	49.5	49.8	50.1	50.4	50.7	51.0
Eileanach Farm House	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0
Lynchork	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.2	43.3	43.4	43.5
* Financially involved with the proposed Ceislein Wind Farm scheme												

6.3 Predicted Wind Turbine Cumulative Operational Noise Immission Levels

6.3.1 The lowest available standardised wind speed available in the source sound power data for all four sites assessed is 4 m/s (see Annex B for full details). These predictions are cumulative assuming all other wind farms are operating as set out in Section 5.4 and that all receptors are downwind of all wind turbines at the same time as a conservative assumption. Nordex have supplied specified noise emission data for the N163 6.X VPC turbine which has been derived from various manufacturers sound power

tests. Data for the "6.X" variant of the turbine, with generation capacity of up to 7 MW, was considered as the basis for the analysis. In the absence of specific information about uncertainty allowances in the data, a further correction factor of +2 dB was added to the specification data in line with advice in the IOA GPG. Further information and details on the Ceislein Wind Farm turbines modelled, the turbine's source data and the assumptions made are outlined further in Annex B. In addition, representative sound spectra for the turbine types have been derived from the reported one third octave band spectrum and converted to octave bands, also detailed in Annex B. The 11 Ceislein wind turbines are assumed to operate unconstrained in operational mode 'Mode 0.b'.

6.3.2 Table 24 below shows the predicted cumulative noise immission levels at each of the selected assessment locations for each wind speed, with the repowered wind farm, the Novar 2 Wind Farm, the Ceislein Wind Farm and the Abhainn Dubh Wind Farm operating in combination. These cumulative noise levels are therefore unlikely to occur in practice in many cases.

Table 24 – Predicted cumulative L_{A90} (dB) wind farm noise immission levels at each of the noise assessment locations as a function of standardised wind speed.

Property	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Douchan	-	-	-	25.8	30.4	34.8	36.1	36.6	37.1	37.1	37.1	37.1
Glaick	-	-	-	24.1	28.6	33.0	34.5	35.3	36.0	36.0	36.0	36.0
Eileanach Lodge	-	-	-	26.0	30.4	34.3	35.9	37.1	38.1	38.1	38.1	38.1
West End	-	-	-	28.7	33.4	37.5	38.6	38.9	39.3	39.3	39.3	39.3
Tighnacraig	-	-	-	27.4	32.0	36.1	37.3	38.0	38.6	38.6	38.6	38.6
Easter Ballone	-	-	-	26.4	31.0	35.4	36.6	37.0	37.3	37.3	37.3	37.3
Eileanach Farm Cottage	-	-	-	26.7	31.3	35.0	36.3	37.1	37.8	37.8	37.8	37.8
Caravan	-	-	-	25.7	30.2	34.1	35.5	36.5	37.3	37.3	37.3	37.3
Eileanach Farm House	-	-	-	26.6	31.1	34.9	36.2	37.1	37.9	37.9	37.9	37.9
Lynchork	-	-	-	24.1	28.7	32.8	33.8	34.2	34.5	34.5	34.5	34.5

6.4 Operational ETSU-R-97 assessment

6.4.1 The calculated cumulative wind farm noise immission levels at the 10 noise assessment locations of Table 19 are compared to the updated ETSU-R-97 noise limits in Table 22 and Table 23. This assumes lower day-time limit of 40 dB(A) and a lower night-time limit of 43 dB(A), for consistency with the Ceislein Wind Farm application's noise assessment.

6.4.2 The assessment (shown in tabular form in Table 25 and Table 26) shows that the predicted cumulative wind farm noise immission levels at the relevant properties are below the derived noise limits (Table 22 & Table 23) under all wind speeds considered and at all locations.

Table 25 - Difference between the ETSU-R-97 derived day time noise limits and the cumulative predicted L_{A90} (dB) wind farm Noise immission levels at each noise assessment location. Values are based on a 40 dB(A) lower day time limit and negative values indicate the noise immission level is below the limit.

Property	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Douchan	-	-	-	-14.2	-9.6	-5.2	-3.9	-3.4	-3.5	-5.7	-8.4	-11.4
Glaick	-	-	-	-15.9	-11.4	-7.0	-5.5	-4.7	-4.7	-6.8	-9.6	-12.6
Eileanach Lodge	-	-	-	-22.2	-18.1	-14.6	-13.3	-12.5	-11.8	-12.2	-12.5	-12.8
West End	-	-	-	-16.3	-11.6	-7.5	-6.4	-6.1	-5.8	-5.8	-5.8	-5.8
Tighnacraig	-	-	-	-12.6	-8.0	-3.9	-2.7	-2.0	-1.5	-1.5	-2.1	-4.6
Easter Ballone	-	-	-	-18.6	-14.0	-9.6	-8.4	-8.0	-7.7	-7.7	-9.0	-11.4
Eileanach Farm Cottage	-	-	-	-13.3	-8.7	-5.0	-3.7	-2.9	-2.3	-2.6	-3.3	-4.0
Caravan	-	-	-	-22.5	-18.3	-14.8	-13.7	-13.1	-12.6	-13.0	-13.3	-13.6
Eileanach Farm House	-	-	-	-13.5	-8.9	-5.1	-3.8	-2.9	-2.1	-2.4	-3.1	-3.8
Lynchork	-	-	-	-16.7	-11.9	-7.7	-6.7	-6.4	-6.5	-7.1	-8.1	-9.6

Table 26 - Difference between the ETSU-R-97 derived night time noise limits and the cumulative predicted L_{A90} (dB) wind farm Noise immission levels at each noise assessment location. Values are based on a 43 dB(A) lower night time limit and negative values indicate the immission level is below the limit

Property	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Douchan	-	-	-	-17.2	-12.6	-8.2	-6.9	-6.4	-5.9	-5.9	-5.9	-5.9
Glaick	-	-	-	-18.9	-14.4	-10.0	-8.5	-7.7	-7.1	-7.1	-7.1	-7.1
Eileanach Lodge	-	-	-	-22.5	-18.5	-14.9	-13.6	-12.7	-12.0	-12.3	-12.6	-12.9
West End	-	-	-	-16.3	-11.6	-7.5	-6.4	-6.1	-5.8	-5.8	-5.8	-5.8
Tighnacraig	-	-	-	-15.6	-11.0	-6.9	-5.7	-5.0	-4.5	-4.5	-4.5	-4.5
Easter Ballone	-	-	-	-18.6	-14.0	-9.6	-8.4	-8.0	-7.7	-7.7	-7.7	-8.1
Eileanach Farm Cottage	-	-	-	-16.3	-11.7	-8.0	-6.7	-5.9	-5.3	-5.3	-5.3	-5.3
Caravan	-	-	-	-22.8	-18.7	-15.1	-14.0	-13.3	-12.8	-13.1	-13.4	-13.7
Eileanach Farm House	-	-	-	-16.5	-11.9	-8.1	-6.8	-5.9	-5.1	-5.1	-5.1	-5.1
Lynchork	-	-	-	-19.0	-14.3	-10.2	-9.2	-8.8	-8.7	-8.8	-8.9	-9.0

6.4.3 Satisfactory control of cumulative noise immission levels with the ETSU-R-97 limits in Table 22 and Table 23 can be achieved through enforcement of individual consent limits for each of the individual wind energy developments, to comply above. The site-specific noise limits derived previously in Table 16 above remain suitable to control noise emissions from the repowered wind farm in isolation, even when considering the additional cumulative Ceislein Wind Farm. These site-specific noise limits are applicable to day-time and night-time periods at all wind speeds up to 10 m/s (to provide a simplified approach).

6.4.4 As discussed in Section 3.7, The Highland Council (THC) expressed a preference for more stringent lower fixed limits of 35 dB(A) for daytime and 38 dB(A) for night or 5 dB above prevailing background level instead of those prescribed in ETSU-R-97, and that these limits should apply cumulatively. Whilst this would be excessively stringent to consider cumulative noise levels including the Ceislein Wind Farm, more stringent noise limits than those of Table 22 and Table 23 can be considered to account for the consultation feedback from THC.

6.4.5 With regards to the level of exposure to turbine noise at nearby properties, background noise levels at standardised 6 m/s to 12 m/s wind speeds are comparable to the predicted cumulative noise levels. The prediction model assumes all receptors are downwind of all wind turbines at the same time and additionally some receptors are located at large separation distances from some cumulative schemes assessed. Therefore, exposure to predicted cumulative turbine noise levels is likely to be reduced in practice. Furthermore, considering the effect of noise limits on the kWh generation for the proposed Wind Farm sites, lower fixed limits of 38 dB(A) both during the day time and night time, or 5 dB above prevailing background noise levels, could be justified without materially reducing the energy generation potential of the proposed schemes. The energy generation potential of the repowered wind farm combined with the Ceislein Wind Farm would also therefore be substantial. A lower fixed level of 38 dB for day-time periods can therefore be robustly justified for this cumulative analysis, and the same lower fixed limit used for night-time periods in line with THC preferences.

6.4.6 Table 27 and Table 28 below show revised day time and night time noise limits set either at the prevailing measured background level plus 5 dB, or at the fixed 38 dB lower limit, whichever is the greater. The West End and Easter Ballone properties are financially involved with the Ceislein Scheme, therefore their fixed lower limit is set to 45 dB(A).

Table 27 - Day time L_{A90} (dB) noise limits derived according to the 38 dB(A) lower fixed cumulative limit from the day baseline data.

Property	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Douchan	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.7	40.6	42.8	45.5	48.5
Glaick	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.7	40.6	42.8	45.5	48.5
Eileanach Lodge	47.8	47.8	47.8	48.2	48.5	48.9	49.2	49.6	49.9	50.3	50.6	50.9
West End*	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0
Tighnacraig	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.7	40.6	43.1
Easter Ballone*	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	46.3	48.7
Eileanach Farm Cottage	38.0	38.0	38.0	38.0	38.0	38.0	38.4	39.0	39.7	40.3	41.0	41.7
Caravan	47.8	47.8	47.8	48.2	48.5	48.9	49.2	49.6	49.9	50.3	50.6	50.9
Eileanach Farm House	38.0	38.0	38.0	38.0	38.0	38.0	38.4	39.0	39.7	40.3	41.0	41.7
Lynchork	40.4	40.7	40.7	40.7	40.6	40.5	40.5	40.6	41.0	41.6	42.6	44.1
* Financially involved with the proposed Ceislein Wind Farm scheme												

Table 28 - Night time L_{A90} (dB) noise limits derived according to the 38 dB(A) lower fixed cumulative limit from the night baseline data.

Property	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Douchan	38.0	38.0	38.0	38.0	38.0	38.0	38.3	39.4	40.5	41.4	42.0	42.1
Glaick	38.0	38.0	38.0	38.0	38.0	38.0	38.3	39.4	40.5	41.4	42.0	42.1
Eileanach Lodge	48.2	48.2	48.2	48.5	48.9	49.2	49.5	49.8	50.1	50.4	50.7	51.0
West End*	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0
Tighnacraig	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	39.0	40.2	41.6	43.0
Easter Ballone*	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.4
Eileanach Farm Cottage	38.0	38.0	38.0	38.0	38.0	38.2	38.8	39.4	40.0	40.6	41.2	41.8
Caravan	48.2	48.2	48.2	48.5	48.9	49.2	49.5	49.8	50.1	50.4	50.7	51.0
Eileanach Farm House	38.0	38.0	38.0	38.0	38.0	38.2	38.8	39.4	40.0	40.6	41.2	41.8
Lynchork	40.4	41.0	41.5	41.9	42.3	42.6	42.8	43.0	43.2	43.3	43.4	43.5
* Financially involved with the proposed Ceislein Wind Farm scheme												

6.4.7 The assessment (shown in tabular form in Table 29 and Table 30 below) shows that the predicted cumulative wind farm noise immission levels at the relevant properties are below the derived noise limits (Table 27 & Table 28) under all wind speeds considered and at all locations, except at Tighnacraig where an excess of 0.5 dB at 9 m/s above the day time limit is predicted.

6.4.8 However, the noise prediction model assumes all receptors lie downwind of all sites as a conservative assumption and does not account for directional effects. In practice, Tighnacraig cannot lie downwind of all the schemes assessed. Under prevailing south-westerly winds, the repowered wind farm, Novar 2 and Ceislein Wind Farms would lie downwind of the property, whereas Abhainn Dubh Wind Farm would lie upwind. Taking directional effects into account and given that the predicted exceedance is less than 1 dB, it is considered unlikely that the 38 dB(A) day time limit would be exceeded in practice at this location.

Table 29 - Difference between the derived cumulative day time noise limits and the cumulative predicted L_{A90} (dB) wind farm Noise immission levels at each noise assessment location. Values are based on a 38 dB(A) lower day time limit and negative values indicate the noise immission level is below the limit.

Property	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Douchan	-	-	-	-12.2	-7.6	-3.2	-1.9	-2.1	-3.5	-5.7	-8.4	-11.4
Glaick	-	-	-	-13.9	-9.4	-5.0	-3.5	-3.4	-4.7	-6.8	-9.6	-12.6
Eileanach Lodge	-	-	-	-22.2	-18.1	-14.6	-13.3	-12.5	-11.8	-12.2	-12.5	-12.8
West End	-	-	-	-16.3	-11.6	-7.5	-6.4	-6.1	-5.8	-5.8	-5.8	-5.8
Tighnacraig	-	-	-	-10.6	-6.0	-1.9	-0.7	0.0	**0.5**	-0.2	-2.1	-4.6
Easter Ballone	-	-	-	-18.6	-14.0	-9.6	-8.4	-8.0	-7.7	-7.7	-9.0	-11.4
Eileanach Farm Cottage	-	-	-	-11.3	-6.7	-3.0	-2.1	-1.9	-2.0	-2.6	-3.3	-4.0

Property	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Caravan	-	-	-	-22.5	-18.3	-14.8	-13.7	-13.1	-12.6	-13.0	-13.3	-13.6
Eileanach Farm House	-	-	-	-11.5	-6.9	-3.1	-2.2	-1.9	-1.8	-2.4	-3.1	-3.8
Lynchork	-	-	-	-16.7	-11.9	-7.7	-6.7	-6.4	-6.5	-7.1	-8.1	-9.6

Table 30 - Difference between the derived cumulative night time noise limits and the cumulative predicted L_{A90} (dB) wind farm Noise immission levels at each noise assessment location. Values are based on a 38 dB(A) lower night time limit and negative values indicate the immission level is below the limit

Property	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Douchan	-	-	-	-12.2	-7.6	-3.2	-2.2	-2.8	-3.4	-4.3	-4.9	-5.0
Glaick	-	-	-	-13.9	-9.4	-5.0	-3.8	-4.1	-4.6	-5.5	-6.1	-6.2
Eileanach Lodge	-	-	-	-22.5	-18.5	-14.9	-13.6	-12.7	-12.0	-12.3	-12.6	-12.9
West End	-	-	-	-16.3	-11.6	-7.5	-6.4	-6.1	-5.8	-5.8	-5.8	-5.8
Tighnacraig	-	-	-	-10.6	-6.0	-1.9	-0.7	0.0	-0.5	-1.7	-3.1	-4.5
Easter Ballone	-	-	-	-18.6	-14.0	-9.6	-8.4	-8.0	-7.7	-7.7	-7.7	-8.1
Eileanach Farm Cottage	-	-	-	-11.3	-6.7	-3.2	-2.5	-2.3	-2.3	-2.9	-3.5	-4.1
Caravan	-	-	-	-22.8	-18.7	-15.1	-14.0	-13.3	-12.8	-13.1	-13.4	-13.7
Eileanach Farm House	-	-	-	-11.5	-6.9	-3.3	-2.6	-2.3	-2.1	-2.7	-3.3	-3.9
Lynchork	-	-	-	-17.9	-13.6	-9.8	-9.0	-8.8	-8.7	-8.8	-8.9	-9.0

6.4.9 At the assessment properties considered, the repowered wind farm operating together with the Ceislein, Novar 2 and Abhainn Dubh wind farms would therefore also comply with more stringent cumulative noise limits based on 38 dB fixed lower limits. However, further consultation with The Highland Council and RWE Renewables would be necessary to agree suitable site-specific limits for both proposed schemes and provide satisfactory control of cumulative noise immission levels in line with these alternative noise limits.

6.5 Operational assessment from non-turbine sources

6.5.1 The Ceislein Wind Farm application includes a substation and battery energy storage solution (BESS) facility to be located approximately 650 m from the Easter Ballone property. Easter Ballone is both the nearest property to the repowered wind farm substation and the Ceislein Wind Farm BESS and substation facility. Therefore, as a worst case, operational cumulative noise impacts are also considered at Easter Ballone.

6.5.2 The rated noise level predicted for the BESS and substation noise assessment in the Ceislein Wind Farm application[28] is 30 dB L_{Ar} at Easter Ballone. A representative background noise level of 31 dB L_{A90} was derived from the survey undertaken at Easter Ballone, representative of both the day time and

[28] Table 6.1, Ceislein Wind Farm Technical Appendix 12.3 – Battery Energy Storage System Noise Report. January 2026, TNEI.

night time periods. This was derived in the Ceislein Wind Farm noise assessment from the background noise measurements referenced in the operational wind turbine noise assessment above.

6.5.3 Operational noise from the repowered wind farm substation, with a proposed noise limit of 25 dB L_{Ar} in isolation (see Section 5.10), in combination with a 30 dB L_{Ar} operational noise level from the proposed Ceislein Wind Farm BESS and substation facility, results in a cumulative rated noise level of 31 dB(A). This rated noise level is equal to the measured representative background noise level at this property. Based on the criteria in Table 2 above and the existing background noise level, this corresponds to a negligible impact. Therefore, in the case both the repowered wind farm and the Ceislein Wind Farm application are consented, cumulative operational noise impacts from non-wind turbine sources are likely to have a negligible impact and no additional mitigation is required.

7. Summary of Key Findings and Conclusions

7.1.1 This report has presented an assessment of the impacts of construction and operational noise from the repowered wind farm on the residents of nearby dwellings.

7.1.2 Several residential properties lying around the wind farm have been selected as being representative of the closest located properties to the wind farm. Noise assessments have been undertaken at these properties by comparing predicted construction and operational noise levels with relevant assessment criteria. In the case of construction noise, relevant assessment criteria are in the form of absolute limit values derived from a range of environmental noise guidance. In relation to operational noise, the limits have been derived from the existing and historical background noise levels at nine surrounding properties, as derived from historical baseline measurements at representative measurement locations.

7.1.3 The construction and construction traffic noise assessments (including the decommissioning of the Novar 1 Wind Farm) has determined that associated levels are expected to be perceived at various times throughout the construction programme but remain with acceptable limits such that their temporary impacts are considered of negligible to minor magnitude.

7.1.4 Operational noise from the wind farm has been assessed in accordance with the methodology set out in ETSU-R-97, 'The Assessment and Rating of Noise from Wind farms'. This document provides a robust basis for assessing the operational noise of a wind farm as recommended by the Scottish Government's planning guidance.

7.1.5 It has been demonstrated that both the day-time and night-time noise limits can be satisfied at all assessment properties across all wind speeds. This assessment has been based on the use of the manufacturer's sound power data for the Nordex N163 6.X VPC 7MW wind turbine which is typical of the type and size of turbine which may be considered for this site, and assuming worst case downwind propagation.

7.1.6 The Loch Glass House property is uninhabited (and has reportedly been uninhabited since its construction more than 30 years ago). It is unlikely that this would change due to the baseline situation, and the repowering would not change this baseline noise situation substantially, with only a marginal or negligible increase predicted.

7.1.7 The impact of the proposed substation has been considered on a precautionary basis and determined to correspond to negligible impacts. The addition of this source to that of the wind turbines would not affect the outcome of the above assessment and operational noise would remain a minor impact.

7.1.8 In the case the recently submitted Ceislein Wind Farm is consented, an additional cumulative noise assessment concludes that both the day-time and night-time noise limits consistent with the Ceislein Wind Farm application assumptions can be satisfied at all assessment properties across all wind speeds. More stringent noise limits were also considered, taking into account consultation feedback from THC and these can also be satisfied with negligible assumptions, but further consultation would be necessary to agree suitable site-specific noise limits. The cumulative impact of the proposed substation with the

Ceislein Wind Farm scheme BESS and substation has been assessed and is determined to correspond to a negligible impact.

7.1.9 In summary, the overall levels of construction noise are considered to represent a minor impact at most. At some locations under some wind conditions and for a certain proportion of the time, the wind farm noise may be audible; however, operational noise immission levels comply with the criteria of the guidance commended by planning policy for the assessment of wind farm noise.

Annex A - General Approach to Noise Assessment & Glossary

A.1. Some sound, such as speech or music, is desirable. However, desirable sound can turn into unwanted noise when it interferes with a desired activity or when it is perceived as inappropriate in a particular environment.

A.2. When assessing the effects of sound on humans there are two equally important components that must both be considered: the physical sound itself, and the psychological response of people to that sound. It is this psychological component which results in those exposed differentiating between desirable sound and unwanted noise. Any assessment of the effects of sound relies on a basic appreciation of both these components. This Annex provides an overview of these topics. A glossary of acoustic terminology is included at the end of this Annex.

A.3. The assessment of environmental noise can be best understood by considering physical sound levels separately from the likely effects that these physical sound levels have on people, and on the environment in general.

A.4. Physical sound is a vibration of air molecules that propagates away from the source. As acoustic energy (carried by the vibration back and forth of the air molecules) travels away from the source of the acoustic disturbance it creates fluctuating positive and negative acoustic pressures in the atmosphere above and below the standing atmospheric pressure. For most types of sound normally encountered in the environment these acoustic pressures are extremely small compared to the atmospheric pressure. When acoustic pressure acts on any solid object it causes microscopic deflections in the surface. For most types of sound normally encountered in the environment these deflections are so small they cannot physically damage the material. It is only for the very highest energy sounds, such as those experienced close to a jet engine for example, that any risk of physical damage exists. For these reasons, most sound is essentially neutral and has no cumulative damaging physical effect on the environment. The effects of environmental sound are therefore limited to its effects on people or animals.

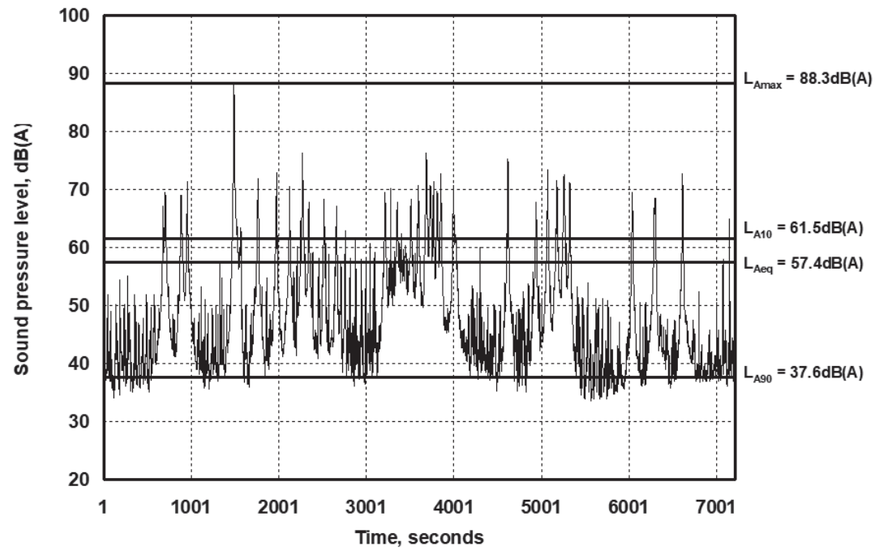
A.5. Before reviewing the potential effects of environmental sound on people, it is useful first to consider the means by which physical sound can be quantified.

Indicators of physical sound levels

A.6. Physical sound is measured using a sound level meter. A sound level meter comprises two basic elements: a microphone which responds in sympathy with the acoustic pressure fluctuations and produces an electrical signal that is directly related to the incident pressure fluctuations, and a meter which converts the electrical signal generated by the microphone into a decibel reading. Chart A1 shows an example of the time history of the decibel readout from a sound level meter located approximately 50 metres from a road. The plot covers a total time period of approximately 2 hours. The peaks in the sound pressure level trace correspond to the passage of individual vehicles past the measurement location.

A.7. Assigning a single value to the time varying sound pressure level presented in Chart A1 is clearly not straightforward, as the sound pressure level varies by over 50 dB with time. To overcome this, the measurement characteristics of sound level meters can be varied to emphasise different features of the sound that are thought to be most relevant to the effect under consideration.

Chart A1 Sample plot of the sound pressure level measured close to a road over a period of approximately two hours.



Objective measures of noise

A.8. The primary purpose of measuring environmental noise is to assess its effects on people. Consequently, any sound measuring device employed for the task should provide a simple readout that relates the objectively measured sound to human subjective response. To achieve this, the instrument must, as a minimum, be capable of measuring sound over the full range detectable by the human ear.

A.9. Perceived sound arises from the response of the ear to sound waves travelling through the air. Sound waves comprise air molecules oscillating in a regular and ordered manner about their equilibrium position. The speed of the oscillations determines the frequency, or pitch, of the sound, whilst the amplitude of oscillations governs the loudness of the sound. A healthy human ear is capable of detecting sounds at all frequencies from around 20 Hz to 20 kHz over an amplitude range of approximately 1,000,000 to 1. Even relatively modest sound level meters are capable of detecting sounds over this range of amplitudes and frequencies, although the accuracy limits of sound level meters vary depending on the quality of the unit. When undertaking measurements of wind turbine noise, as with all other noise measurements, it is important to select a measurement system that possesses the relevant accuracy tolerances and is calibrated to a matching standard.

A.10. Whilst measurement systems exist that are capable of detecting the range of sounds detected by the human ear, the complexities of human response to sound make the derivation of a likely subjective response from a simple objective measure a non-trivial problem. Not only does human response to sound vary from person to person, but it can also depend as much on the activity and state of mind of an individual at the time of the assessment, and on the 'character' of the sound, as it can on the actual level of the sound. In practice, a complete range of responses to any given sound may be observed. Thus, any objective measure of noise can, at best, be used to infer the average subjective response over a sample population.

Sound levels and decibels

A.11. Because of the broad amplitude range covered by the human ear, it is usual to quantify the magnitude of sound using the decibel scale. When the amplitude of sound pressure is expressed using decibels (dB) the resultant quantity is termed the sound pressure level. Sound pressure levels are denoted by a capital 'L', as in L dB. The conversion of sound pressure from the physical quantity of Newton per square metre, or Nm-2, to sound pressure level in dB reduces the range from 0 dB at the threshold of hearing to 120 dB at the onset of pain. Both of these values are derived with respect to the hearing of the average healthy young person.

A.12. Being represented on a logarithmic amplitude scale, the addition and subtraction of decibel quantities does not follow the normal rules of linear arithmetic. For example, two equal sources acting together produce a sound level 3 dB higher than either source acting individually, so 40 dB + 40 dB = 43 dB and 50 dB + 50 dB = 53 dB. Ten equal sound sources acting together will be 10 dB louder than each source operating in isolation. Also, if one of a pair of sources is at least 10 dB quieter than the other, then it will contribute negligibly to the combined noise level. So, for example, 40 dB + 50 dB = 50 dB.

A.13. An increase in sound pressure level of 3 dB is commonly accepted as the smallest change of any subjective significance. An increase of 10 dB is often claimed to result in a perceived doubling in loudness, although the basis for this claim is not well founded. An increase of 3 dB is equivalent to a doubling in sound energy, which is the same as doubling the number of similar sources. An increase of 10 dB is equivalent to increasing the number of similar sources tenfold, whilst an increase of 20 dB requires a hundredfold increase in the number of similar sources and an increase of 30 dB requires a thousand times increase in the number of sources.

Frequency selectivity of human hearing and A-weighting

A.14. Whilst the hearing of a healthy young individual may detect sounds over a frequency range extending from less than 20 Hz to greater than 20 kHz, the ear is not equally sensitive at all frequencies. Human hearing is most sensitive to sounds containing frequency components lying within the range of predominant speech frequencies from around 500 Hz to 4000 Hz. Therefore, when relating an objectively measured sound pressure level to subjective loudness, the frequency content of the sound must be accounted for.

A.15. When measuring sound with the aim of assessing subjective response, the frequency selectivity of human hearing is accounted for by down-weighting the contributions of lower and higher frequency sounds to reduce their influence on the overall reading. This is achieved by using an 'A'-weighting filter. Over the years, the A-weighting has become internationally standardised and is now incorporated into the majority of environmental noise standards and regulations in use around the world to best replicate the subjective response of the human ear. A-weighting filters are also implemented as standard on virtually all sound measurement systems.

A.16. Sound pressure levels measured with the A-weighting filter applied are referred to as 'A weighted' sound pressure levels. Results from such measurements are denoted with a subscripted capital A after the 'L' level designation, as in 45 dB LA, or alternatively using a bracketed 'A' after the 'dB' decibel designation, as in 45 dB(A).

Temporal variation of noise and noise indices

A.17. The simple A-weighted sound pressure level provides a snapshot of the sound environment at any given moment in time. However, as is adequately demonstrated by Chart A1, this instantaneous sound level can vary significantly over even short periods of time. A single number indicator is therefore required that best quantifies subjective response to time varying environmental noise, such as that shown in Chart A1. The question thus arises as to how temporal variations in level should be accounted for. This is most often achieved in practice by selecting a representative time period and calculating either the average noise level over that time period or, alternatively, the noise level exceeded for a stated proportion of that time period, as discussed below.

Equivalent continuous sound level, $L_{Aeq,T}$

A.18. The equivalent continuous sound level, or $L_{Aeq,T}$ averages out any fluctuations in level over time. It is formally defined as the level of a steady sound which, in a stated time period 'T' and at a given location, has the same sound energy as the time varying sound. The $L_{Aeq,T}$ is a useful 'general' noise index that has been found to correlate well with subjective response to most types of environmental noise.

A.19. The equivalent continuous sound level is expressed $L_{Aeq,T}$ in dB, where the A–weighting is denoted by the subscripted 'A', the use of the equivalent continuous index is denoted by the subscripted 'eq', and the subscripted 'T' refers to the time period over which the averaging is performed. So, for example, 45 dB $L_{Aeq,1hr}$ indicates that A-weighted equivalent continuous noise level measured over a one-hour period was 45 dB.

A.20. The disadvantage of the equivalent continuous sound level is that it provides no information as to the temporal variation of the sound. For example, an $L_{Aeq,1hr}$ of 60 dB could result from a sound pressure level of 60 dB(A) continuously present over the whole hour's measurement period, or it could arise from a single event of 96 dB(A) lasting for just 1 second superimposed on a continuous level of 30 dB(A) which exists for the remaining 59 minutes and 59 seconds of the hour-long period. Clearly, the subjective effect of these two apparently identical situations (if one were to rely solely on the L_{Aeq} index) could be quite different.

A.21. The aforementioned feature can produce problems where the general ambient noise level is relatively low. In such cases the $L_{Aeq,T}$ can be easily 'corrupted' by individual noisy events. Examples of noisy events that often corrupt $L_{Aeq,T}$ noise measurements in situations of low ambient noise levels include birdsong or a dog bark local to a noise monitoring point, or an occasional overflying aircraft or a sudden gust of wind. This potential downside to the use of $L_{Aeq,T}$ as a general measurement index is of particular relevance to the assessment of ambient noise in quiet environments, such as those typically found in rural areas where wind farms are developed.

A.22. Despite these shortcomings in low noise environments, the $L_{Aeq,T}$ index is increasingly becoming adopted as the unit of choice for both UK and European guidance and legislation, although this choice is often as much for reasons of commonality between standards as it is for overriding technical arguments. In the Government's current planning policy guidance notes the $L_{Aeq,T}$ noise level is the index of choice for the general assessment of environmental noise. This assessment is undertaken separately for day time ($L_{Aeq,16hr}$ 07:00 to 23:00) and night time ($L_{Aeq,8hr}$ 23:00 to 07:00) periods. However, it is often the case for quiet environments, or for non-steady noise environments, that more information than can be gleaned from the $L_{Aeq,T}$ index may be required to fully assess potential noise effects.

Maximum, L_{Amax}, and percentile exceeded sound level, $L_{An,T}$

A.23. Chart A1 shows, superimposed on the time varying sound pressure level trace and in addition to the $L_{Aeq,T}$ noise level, examples of three well established measurement indices that are commonly used in the assessment of environmental noise impacts. These are the maximum sound pressure level, L_{Amax}, the 90 percentile sound pressure level, $L_{A90,T}$ and the ten percentile sound pressure level, $L_{A10,T}$.

A.24. The $L_{Amax,F}$ readings is suited to indicating the physical magnitude of the single individual sound event that reaches the maximum level over the measurement period, but it gives no indication of the number of individual events of a similar level that may have occurred over the time period.

A.25. Unlike the $L_{Aeq,T}$ index and the $L_{Amax,F}$ indices, percentile exceeded sound levels, percentage exceeded sound levels provide some insight into the temporal distribution of sound level throughout the averaging period. Percentage exceeded sound levels are defined as the sound level exceeded by a fluctuating sound level for n% of the time over a specified time period, T. They are denoted by $L_{An,T}$ in dB, where 'n' can take any value between 0% and 100%.

A.26. The $L_{A10,T}$ and $L_{A90,T}$ indices are the most commonly encountered percentile noise indices used in the UK.

A.27. The 10%'ile index, or $L_{A10,T}$ provides a measure of the sound pressure level that is exceeded for 10% of the total measurement period. It therefore represents the typical upper level of sound associated with specific events, such as the passage of vehicles past the measurement point. It is the traditional index adopted for road traffic noise. This index is useful because traffic noise is not usually constant, but rather it fluctuates with time as vehicles drive past the receptor location. The $L_{A10,T}$ therefore characterises the typical level of peaks in the noise as vehicles drive past, rather than the lulls in noise between the vehicles.

A.28. The $L_{A90,T}$ noise index is the noise level exceeded for 90% of the time period, T. It provides an estimate of the level of continuous background noise, in effect performing the inverse task of the $L_{A10,T}$ index by detecting the lulls between peaks in the noise. It is for this reason that the $L_{A90,T}$ noise index is the favoured unit of measurement for wind farm noise where, for the reasons discussed above, the generally low $L_{Aeq,T}$ noise levels are easily corrupted by intermittent sounds such as those produced by livestock, agricultural vehicles or the occasional passing vehicle on local roads. The $L_{A90,T}$ noise level represents the typical lower level of sound that may be reasonably expected to be present for the majority (90%) of the time in any given environment. This is usually referred to as the 'background' noise level.

Temporal variations outside the noise index averaging periods, T'

A.29. Averaging noise levels over the time period 'T' of the $L_{Aeq,T}$ and $L_{An,T}$ noise indices can successfully account for variations in noise over the time period, T. Some variations, however, exhibit trends over longer periods. At larger distances from noise sources meteorological factors can significantly affect received noise levels. At a few hundred metres from a constant level source of noise the potential variation in noise levels may be greater than 15 dB(A). To account for this variability consideration must be taken of meteorological conditions, particularly wind direction, when measurements and predictions are undertaken. As a general rule, when compared with the received noise level under neutral wind conditions, wind blowing from the source to the receiver can slightly enhance the noise level at the receiver (typically by no more than 3 dB(A)), but wind blowing from the receiver to the source can very significantly reduce the noise level at the receiver (typically by 15 dB(A) or more).

A.30. A similar effect occurs under conditions of temperature inversion, such as may exist after sunset when radiative cooling from the ground lowers the temperature of the air lying at low level more quickly than the air at higher levels, by loss of temperature through convective effects. This results in the air temperature increasing with increasing height above the ground. Depending on the source to receiver distance relative to the heights of the source and receiver, this situation can lead to sound waves becoming 'trapped' in the layer of air lying closest to the ground. The consequence is that noise levels at receptor locations can increase relative to those experienced under conditions of a neutral temperature gradient or a temperature lapse. The maximum increases compared to neutral conditions are similar to those experienced under downwind conditions of no more than around 3 dB(A). It is also worth noting that temperature lapse conditions, which is the more usual situation where temperature decreases with increasing height, can result in reductions in noise level at receptor locations by 15 dB(A) or more compared with the neutral conditions. The similarity between the magnitude of potential variations in noise levels for wind induced and temperature induced effects is not surprising, as the physical mechanisms behind the variations in level are the same for both situations: both variations result from changes in the speed of sound as a function of height above local ground level.

A.31. Temperature inversions on very still days can also affect noise propagation over much larger distances of several kilometres. These effects can produce higher than expected noise levels even at these very large distances from the source. A classic example that many people have experienced is the distant, usually inaudible, railway train that suddenly sounds like it is passing within a few hundred metres of a dwelling. However, these situations must generally be considered as rare exceptions to the usually encountered range of noise propagation conditions, especially in the case of wind farm noise as they rely on calm wind conditions under which wind turbines do not operate.

Effects of sound on people

A.32. Except at very high peak acoustic pressures, the energy levels in most environmental sounds are too low to cause any physical disruption in any part of the body, just as they are too low to cause any direct physical damage to the environment. The main effects of environmental sound on people are therefore limited to possible interference with specific activities or to some kind of annoyance response. Some researchers have claimed statistical associations between environmental noise and various long term health effects such as clinical hypertension or mental health problems, although there is no consensus on possible causative mechanisms. Evidence in support of health effects other than annoyance and some indicators of sleep disturbance is weak. However, the theory that psychological stress caused by annoyance might contribute to adverse health effects in otherwise susceptible individuals seems plausible. Health effects in the 'more usual' definition of physiological health therefore remain as a theoretical possibility which has neither been proved nor disproved. However, the World Health Organisation (WHO) defines health in the wider context of:

> 'a state of complete physical, mental and social well-being and not merely the absence of infirmity'.

And within this wider context potential health effects of environmental noise are summarised by the World Health Organisation as:

- interference with speech communications;
- sleep disturbance;
- disturbance of concentration;
- annoyance; and
- social and economic effects.

Speech interference

A.33. The instantaneous masking effects of unwanted noise on speech communication can be predicted with some accuracy by using specialist methods of calculation, but the overall effect of a small amount of speech interference on everyday life is harder to judge. The significance of speech masking depends on the context in which it occurs. For example, isolated noise events could interfere with telephone conversations by masking out particular words or parts of words but, because of the high redundancy in normal speech, the masking of individual words can often have no significant effect on the intelligibility of the overall message. Notwithstanding the above, noise levels from wind farms at even the closest located dwellings in otherwise quiet environments are usually no more than around 30 dB(A) indoors, even with windows open. This internal noise level is 5 dB(A) below the 35 dB(A) suggested by the World Health Organisation as the lowest potential cut-on level for issues relating to speech intelligibility.

Sleep disturbance

A.34. Although sleep seems to be a fundamental requirement for humans, the most significant effect of sleep loss seems to be increased sleepiness the next day. Sleep normally follows a regular cyclic pattern from awake through light sleep to deep sleep and back, this cycle repeating several times during the night at around 90-minute intervals. Most people wake for short periods several times every night as part of the normal sleep cycle without necessarily being aware of this the next day. REM, or rapid eye movement, sleep is associated with dreaming and occurs several times each night during the lighter sleep stages.

A.35. Electroencephalography (EEG) and similar techniques can be used to detect transient physiological responses to noise at night. Transient responses can be detected by short bursts of activity in the recorded waveforms which often settle back down to the same pattern as immediately before the event. Sometimes a transient response will be the precursor of a definite lightening of sleep, or even of an awakening, but often no discernible physical event happens at all.

A.36. These results suggest that at least parts of the auditory system remain fully operational even while the listener is asleep. The main purpose of this seems to be to arouse the listener in case of danger or in case some particular action is required which cannot easily be accomplished whilst remaining asleep. On the other hand, the system appears to be designed to filter out familiar sounds which experience suggests do not require any action. A very loud sound is likely to overcome the filtering mechanism and wake the listener, while intermediate and quieter sounds might only wake a listener who has a particular focus on those specific sounds. There is no evidence that the transient physiological responses to noise whilst asleep are anything other than normal. There is also considerable anecdotal evidence that people habituate to familiar noise at night, although some of the research evidence on this point is contradictory.

A.37. There is no consensus on how much sleep disturbance is significant. Some authorities take a precautionary approach, under which any kind of physiological response to noise is considered important, irrespective of whether there are any next day effects or not. Other studies suggest that transient physiological responses to unfamiliar stimuli at night are merely an indication of normal function and do not need to be considered as adverse effects unless they contribute to significant next-day effects. Recent World Health Organisation guidelines based mainly on laboratory studies suggest indoor limit values of 30 dB L_{Aeq} and 45 dB L_{Afmax} to avoid sleep disturbance, while other studies carried out in-situ, where habituation to the noise in question may have occurred, have found that much higher levels can be tolerated without any noticeable ill-effects.

Noise annoyance

A.38. Noise annoyance describes the degree of 'unwantedness' of a particular sound in a particular situation. People's subjective response to noise can vary from not being bothered at all, through a state of becoming aware of the noise, right through to the point of becoming annoyed by the noise when it reaches a sufficiently high level. There is no statutory definition of noise annoyance.

A.39. Numerous noise annoyance surveys carried out over the last three decades have attempted to establish engineering relationships between the amount of noise measured objectively using sound level meters and the amount of community annoyance determined from questionnaires. The chief outcome of 'reported annoyance' has been measured using a very large range of different ideas. Both the wording of any questionnaire used and the context in which the question is put, and the manner in which it is therefore interpreted by respondents, can be very important. Some researchers are developing standardised questionnaire formats to encourage greater comparability between different studies, but this does not address the possibility of different contextual effects.

A.40. Notwithstanding these problems, there is a general consensus that average reported annoyance increases with aggregate noise level in long term static situations. However, there has been comparatively little research and consequently no real agreement on the effects of change. Some studies have found that even small changes in noise level can have unexpectedly large consequences on reported annoyance, while others have found the opposite. The most likely explanation for these apparent discrepancies is that underlying or true annoyance depends on many non-acoustic factors in addition to noise level alone, and that the extent to which reported annoyance actually represents underlying annoyance can be highly dependent on context. As a consequence, attempts to find a common relationship across all noise sources and listening situations have generally floundered. This task has been complicated by the great range of individual sensitivities to noise observed in the surveys, often affected as much by attitude as by noise level.

A.41. Whether or not an exposed individual has a personal interest in a given sound often has a significant bearing on their acceptance of it. For example, if recipients gain benefit from an association with the sound producer, or if they accept that the sound is necessary and largely unavoidable, then they are likely to be more tolerant of it. This is often the case even if they don't necessarily consider it desirable. A good example of this is road traffic noise which is the dominant noise heard by over 90% of the population but results in relatively few complaints.

A.42. Notwithstanding the fact that attitudes may be as important as overall levels in determining the acceptance of a particular noise, there still remains a need to objectively quantify any changes in noise level. Whilst it may not be possible to attribute a particular degree of annoyance to a given noise level, an objective measure of noise that bears some relationship to annoyance is still useful. This objective measure enables an assessment of the effect of changes to be assessed on the basis that any reduction in overall noise level must be beneficial. Possible noise mitigation measures form a central consideration of any noise assessment, so an appropriate methodology must be adopted for assessing the effectiveness of any noise mitigation measures adopted.

A.43. When assessing the potential effects of any new source of noise, it is common practice to compare the A-weighted 'specific' noise level produced by the new source (usually measured using the $L_{Aeq,T}$ index) against the existing A-weighted 'background' noise level measured using the $L_{A90,T}$ index, as this is the typical level of noise that can be reasonably expected to be present the majority of the time to potentially 'mask' the new 'specific' noise. The assessment is therefore undertaken within the context of the existing noise environment. In some circumstances, it may prove equally instructive to compare the absolute level of a new specific noise against accepted absolute levels defined in standards or other relevant documents. The assessment is therefore undertaken against benchmark values, rather than against the context of the existing noise environment. Whatever approach is actually adopted for final assessment purposes, and often a combination of the two approaches is appropriate, it is important that the relevance of both contextual and benchmark assessments is at least considered in all cases.

A.44. Table 4.1 of the 2000 WHO Guidelines for Community Noise presents guideline benchmark values for environmental noise levels in specific environments. The noise levels relevant to residential dwellings are listed here in Table A1.

Table A1 Relevant extracts from 'Table 4.1 - Guideline Values for Community Noise in Specific Environments'

Specific Environment	Critical Health Effects	$L_{Aeq,T}$	Time base (hrs)	L_{Amax} (dB)
Outdoor living area	Serious annoyance, day time and evening	55	16	-
	Moderate annoyance, day time and evening	50	16	-
Dwelling, indoors	Speech intelligibility and moderate annoyance, day time and evening	35	16	-
	Sleep disturbance, night time	30	8	45
Outside bedrooms	Sleep disturbance, window open (outdoors)	45	8	60
School class rooms (included for potential effects on concentration)	Speech intelligibility, disturbance of information extraction, message communication	35	-	-

A.45. The text accompanying the Table in the WHO Guidelines explains that the levels given in the Table are set at the lowest levels at which the onset of any adverse health due to exposure to noise has been identified. The text continues:

> 'These are essentially values for the onset of health effects from noise exposure. It would have been preferred to establish guidelines for exposure-response relationships. Such relationships would indicate the effects to be expected if standards were set above the WHO guideline values and would facilitate the setting of standards for sound pressure levels (noise immission standards)'.

A.46. More recently, Environmental Noise Guidelines for the European Region (2018) were published and include general recommendations for wind turbine noise. However, they are designed to inform policy on noise, at the population and strategic level. They are based on the Lden noise indicator, which requires knowledge of the noise levels experienced over the course of a full year. This type of noise index is more suitable for general strategic studies and not appropriate for assessing the acceptability of noise produced by any specific development. Furthermore, these guidelines do not provide

recommendations for indoor noise levels and the 2000 WHO Guidelines for Community Noise remain applicable in this regard. For these reasons, the 2018 guidelines will not be referenced any further.

A.47. In addition to consideration of the absolute A-weighted level of a new specific source of noise, other properties of the noise can heighten its potential effects when introduced into an existing background noise environment. Such properties of noise are commonly referred to as 'acoustic features' or the 'acoustic character'. These acoustic features can set apart the new source of noise from naturally occurring sounds. Commonly encountered acoustic features associated with transport and machinery sources, for example, can include whistles, whines, thumps, impulses, regular or irregular modulations, high levels of low frequency sound, rumbling, etc.

A.48. Due to the potential of acoustic features to increase the effects of a noise over and above the effects that would result from an otherwise 'bland' broad band noise of the same A-weighted noise level, it is common practice to add a 'character correction' to the specific noise level before assessing its potential effects. The resulting character corrected specific noise level is often referred to as the 'rated' noise level. Such character corrections usually take the form of adding a number of decibels to the physically measured or calculated noise level of the specific source. Typical character corrections are around +5 dB(A), although the actual correction depends on the subjective significance of the particular feature being accounted for.

A.49. The objective identification and rating of acoustic features can introduce a requirement to analyse sound in greater detail than has thus far been discussed. To this point all discussion has focussed on the use of the overall A-weighted noise level. This single figure value is derived by summing together all the acoustic energy present in the signal across the entire audible spectrum from around 20 Hz to 20,000 Hz, albeit with the lower and higher frequency contributions down-weighted in accordance with the A-weighting filter characteristics to account for the reduced sensitivity of the human ear at these frequencies.

A.50. However, in order to identify the presence of tones (which are concentrations of acoustic energy over relatively small bands of frequency), or in order to identify excessive levels of low frequency noise, it may be necessary to determine the acoustic energy present in the noise signal across much smaller frequency bands. This is where the concept of octave band analysis, fractional (e.g. 1/3, 1/12, 1/24) octave band analysis, or even narrow band Fast Fourier Transform (FFT) analysis is introduced. The latter enables signals to be resolved in frequency bandwidths of down to 1 Hz or even less, thereby enabling tonal content to be more easily identified and measured. As standard, noise emission data for wind turbines is supplied as octave band data, with narrow band tests also being undertaken to establish the presence of any tones in the radiated noise spectrum.

Low frequency noise and vibration – wind farms

A.51. One issue that has increasingly been raised concerning potential noise effects of operational wind farms relates not to the overall noise levels, but to the specific issue of low frequency sound. However, confusion sometimes arises from the use of the generalised term 'low frequency sound' to describe specific effects that may, or sometimes may not, actually relate the low frequency character of the sound itself.

A.52. In this respect, there are three distinct characteristics of sound that should be clearly differentiated between:

- Low frequency sound in the range from around 20 Hz to 200 Hz, which therefore lies within the commonly referenced range of human hearing of around 20 Hz to 20,000 Hz;
- Very low frequency sound, or infrasound, below 20 Hz, which therefore lies below the commonly referenced lower frequency limit of human hearing;
- Amplitude modulated sound that characterises the 'swish, swish' sound sometimes heard from rotating wind turbine blades.

A.53. Looking at the first two of the three types of sound referred to in the preceding bullet points, a distinction is usually made between low frequency sound and very low frequency sound, otherwise

termed infrasound. This distinction is based on the fact that the frequency range of audible noise is generally taken to be from 20 Hz to 20,000 Hz. Therefore, the range of frequencies from about 20 Hz to 200 Hz is usually taken to cover audible low frequency sound, whereas frequencies below 20 Hz are usually described as infrasound. The implication here is that low frequency sound is audible and infrasound is inaudible. However, this relatively arbitrary distinction between low frequency sound and infrasound can introduce some confusion in that frequencies below 20 Hz can still be heard provided they produce a sound pressure level at the ear of the listener that lies above the threshold of audibility of that listener to sound at that particular frequency.

A.54. The fact that low frequency sound and infrasound from wind farms has been highlighted as a potential problem by some groups does not mean that that the wind energy industry had not previously considered the issue. In fact, the issue of low frequency sound was one of the predominant technical hurdles associated with the some of the earliest larger scale wind turbines installed in the USA. These turbines were of the 'downwind' type, 'downwind' referring here to the fact that the rotor blades were located downwind of the turbine tower rather than upwind of it, as is the case for current machines. It was found that the interruption of wind flow past the tower resulted in a region of lower than average wind speed immediately in the wake of the tower. The passage of the blades into this region of lower wind speed in the wake of the tower, then back into the higher wind speed as they emerged from the wake of the tower back into the main wind stream, resulted in the generation of low frequency sound, often in the subjective form of a distinctive impulse, often referred to as a 'thump' or 'tower thump'.

A.55. It was for this reason that modern day turbine configurations now have the blades upwind of the tower, as research and measurements demonstrated that low frequency sound radiation is reduced to sub-audible levels once the interaction of downwind tower wake effects with the rotating blades are removed from the design. Nevertheless, possibly due to confusion introduced by the above-described historical issues, there has been over past years considerable attention paid to the possibility that infrasound or vibration from operational wind farms may cause health problems.

A.56. One of the problems inherent in the assessment of both low frequency sound and infrasound is the variability of hearing sensitivity across human subjects with otherwise healthy hearing. This threshold for sound below 200 Hz varies significantly more between different subjects than does the hearing threshold at higher frequencies. However, what is always true is that the perception threshold to lower frequency noise is much higher than the perception threshold for speech frequencies between around 250 Hz to 4,000 Hz. For example, the average person with healthy hearing is some 70 dB less sensitive to sounds at 20 Hz than to sounds that fall within the range of speech frequencies. An additional factor relevant to the perception of infrasound is that, although audibility remains below 20 Hz, tonality is lost below 16 Hz to 18 Hz, thus losing a key element of perception.

A.57. Both low frequency sound and infrasound are generally present all around us in modern life. They may be generated by many natural sources, such as thunder, earthquakes, waves and wind. They may also be produced by machinery including household appliances such as washing machines and air conditioning units, all forms of transport and by turbulence. The presence of low frequency sound and infrasound in our everyday lives is heightened by the fact that the attenuation of sound in air is significantly lower at low frequencies than at the mid to high frequencies. As a result, noise which has travelled over long distances is normally biased towards the low frequencies. However, the fact that human hearing naturally down-weights, or filters out, sounds of such low frequencies means we are generally not aware of its presence. It is only under circumstances when it reaches a sufficiently high level, for example in the 'rumble' of distant thunder or the sound of large waves crashing on a shore, that we become aware of its presence.

A-weighting

A.58. It is because the human ear increasingly filters out sounds of lower frequencies that environmental noise measurements are undertaken as standard using sound level meters that apply the A-weighting curve, as it filters out lower frequency sounds to the same degree as the hearing of a healthy person with unimpaired hearing. The A-weighted sound level is used as a measure of subjective perception of sound unless there exists such a predominance of low frequency sound or infrasound relative to the

level of sound at higher frequencies that the use of the A-weighting curve would down-weight the actual source of the problem to such a degree that the resultant objective noise levels do not truly reflect the potential subjective effects of the noise. It is for this reason that a number of alternative weighting curves have been developed, specifically aimed at better accounting for the assessment of low frequency sound and infrasound.

Alternative frequency weightings

A.59. One such curve is denoted C-weighting. Unlike the A weighting curve, which gradually reduces the significance of frequencies below 1000 Hz until at 10 Hz the attenuation is 70 dB, the C-weighting curve is flat to within 1 dB down to about 50 Hz and then drops by 3 dB at 31.5 Hz and 14 dB at 10 Hz. The C weighting curve was originally developed to reflect the fact that, at higher overall noise levels, low frequencies can have a greater subjective effect than at lower overall noise levels.

A.60. One relatively simple measure of undertaking a first-pass assessment as to whether low frequency sound is likely to be an issue is to determine the difference between the overall C weighted noise level and the overall A weighted noise level. The C weighted level includes contributions from low frequency sound, whereas the A weighted level filters it out. It has been suggested in that a level difference of more than 20 dB indicates that low frequency sound may be subjectively significant, but more detailed investigations are in practice required to determine whether or not this is actually the case.

A.61. Another curve, termed the G weighting curve, has been specifically derived to provide a measure of the audibility of infrasound when considered separately from higher frequency noise. The G weighting curve falls off rapidly above 20 Hz and below 20 Hz it follows assumed hearing contours with a slope of 12 dB per octave down to 2 Hz.

Wind-farm ground-borne vibration

A.62. As early as 1997 a report by Snow[29] gave details of a comprehensive study of infrasound and low frequency sound (up to around 100 Hz) and vibration measurements made in the vicinity of a wind farm. Measurements were made both on the wind farm site, and at distances of up to 1 kilometre. During the experiments a wide range of wind speeds and directions were recorded. It was found that the vibration levels at 100 metres from the nearest turbine itself were a factor of 10 lower than those recommended for human exposure in the most critical buildings (i.e. laboratories for precision measurements), and lower again than the limits specified for residential premises. A similar comparison with recognised limits for assessing structural damage showed that the measured vibrations were a factor of 100 below the recommended guidelines at 100 metres from the turbines. Vibration levels were found to comply with recommended residential criteria even on the wind turbine site itself.

A.63. In 2004/2005 researchers from Keele University investigated the effects of the extremely low levels of vibration resulting from wind farms on the operation of a seismic array installed at Eskdalemuir in Scotland. This is one of the most sensitive ground-borne vibration detection stations in the world. The results of this study were initially misinterpreted, as just discussed for the DEFRA/Leventhall report, in that if infrasonic vibrations from wind farms can be measured, then they must consequentially have some potential effect on humans. In order to clarify their position, the authors subsequently explained[30] that:

> 'The levels of vibration from wind turbines are so small that only the most sophisticated instrumentation and data processing can reveal their presence, and they are almost impossible to detect'.

A.64. They then continue:

29 'Low frequency noise and vibration measurements at a modern wind farm', D. Snow, ETSU Report ETSU W/13/00392/REP, 1997
30 'Wind farm noise', P. Styles, letter by Prof P Styles and S Toon printed in The Scotsman, August 2005.

> 'Vibrations at this level and in this frequency range will be available from all kinds of sources such as traffic and background noise – they are not confined to wind turbines. To put the level of vibration into context, they are ground vibrations with amplitudes of about one millionth of a millimetre. There is no possibility of humans sensing the vibration and absolutely no risk to human health'.

Wind turbine infrasound

A.65. In the Snow[29] study, low level infrasonic (i.e. below 20 Hz) periodic noise from the wind farm was detected by instrumentation at distances up to 1 kilometre, the measuring instruments used were much more sensitive than human hearing. Based on his measurements, Snow concluded that subjective detection of the wind turbines may be apparent at this distance, but if this is the case it will be due to higher frequency components (which are more readily masked by general ambient environmental noise) and not the low frequency components which lie below the threshold of audibility.

A.66. In 2003, findings on both low frequency sound and infrasound have been compiled into the previously referenced extensive review report commissioned by DEFRA and prepared by Dr G Leventhall[31]. Dr Leventhall notes that despite the numerous published studies there is little or no agreement about the biological effects of infrasound or low frequency sound on human health. Leventhall notes that direct evidence of adverse effects of exposure to low-intensity levels of infrasound (less than 90 dB) is lacking. He goes on to describe the low frequency hearing threshold i.e. the lowest levels which are audible to an average person with normal hearing. He notes the threshold at 4 Hz is about 107 dB, at 10 Hz it is about 97 dB and at 20 Hz it is 79 dB. As such, high levels of infrasound are required to exceed the hearing thresholds at such low frequencies. Leventhall therefore concluded that most people can be reassured that there will be no serious consequences to peoples' health from infrasound exposure.

A.67. Indeed, specifically in relation to wind farms and infrasound, Leventhall went further still with his statement of reassurance. This additional reassurance followed the voicing of concerns by some interested parties that, because infrasound and very low frequency vibrations could be measured from wind farms, then it must follow that these were a potential hazard and source of annoyance. In fact, what those concerned observers failed to account for is that highly sensitive electronic measuring equipment designed solely to detect such infrasonic sounds and vibrations is orders of magnitude more sensitive than even the most sensitive human. Thus, whilst such measurement systems may be able to detect such low-level phenomena, the same stimuli can have no effect on humans. Typical levels of infrasound produced by a wind turbine at representative separation distances would not exceed 70 dB, and clearly below the perception thresholds discussed above. In the light of this, Leventhall issued an open statement:

> 'I can state quite categorically that there is no significant infrasound from current designs of wind turbines. To say that there is an infrasound problem is one of the hares which objectors to wind farms like to run. There will not be any effects from infrasound from the turbines'.

A.68. In 2006, the results of a study specifically commissioned by the UK Department of Trade and industry (DTI) to look at the effects of infrasound and low frequency noise (LFN) arising from the operation of wind farms have been published in what is commonly referred to as the DTI LFN Report[32]. This Report is quite categorical in its findings: infrasound is not the perceived health threat suggested by some observers, nor should it even be considered a potential source of disturbance. Quoting from the Executive Summary to the DTI LFN Report:

> '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.

31 'A review of published research on low frequency noise and its effects', G. Leventhall, report for DEFRA, 2003
32 'The measurement of low frequency noise at three UK wind farms', M. Hayes, DTI Report W/45/00656/00, 2006

The document "Community Noise" prepared for the World Health Organisation, states that "there is no reliable evidence that infrasound below the hearing threshold produce physiological or psychological effects". Other detection mechanisms of infrasound only occur at levels well above the threshold of audibility.

It may therefore be concluded that infrasound associated with modern wind turbines is not a source which will result in noise levels which may be injurious to the health of a wind farm neighbour'.

A.69. The same report noted that low frequency sound in the greater than 20 Hz frequency range may, under some circumstances, be measured to be of a comparable or higher level than the threshold of audibility. On such occasions this low frequency sound may become audible to low frequency sensitive persons who may already be awake inside nearby properties, but not to the degree that it will cause awakenings. However, such noise should still be assessed for its potential subjective effects in the conventional manner in which environmental noise is generally assessed. In particular, the subjective effects of this audible low frequency sound should not be confused with the claimed adverse health effect arguments concerning infrasound which, in any event, have now been shown from the results of the DTI LFN Report to be wholly unsubstantiated.

A.70. This has been subsequently confirmed by many subsequent international studies and reviews, some of which are listed below:

- A study for the National Institute for Public Health and the Environment (RIVM) in the Netherlands[33] published in 2020 concluded in this regard that: 'Although low frequency sound and infrasound might have other effects than 'normal' sound has, these effects are highly unlikely at sound levels typical for wind turbines. Brain studies show that low frequency and infrasound are processed in the same parts of the brain as 'normal' sound and there is no evidence that infrasound elicits any reaction at sub-audible levels.'
- A 2010 review by the UK Health Protection Agency[34] noted: "The available data do not suggest that exposure to infrasound below the hearing threshold levels is capable of causing adverse effects."
- A study in Japan[35] determined that infrasound from wind turbines was inaudible and below relevant criteria.
- A study in Australia[36], based on a highly robust double-blind randomised controlled study, considered the effects, including on sleep, to exposing people to 72 hours of infrasound (designed to simulate a wind turbine infrasound signature). It concluded that: "High level, but inaudible, infrasound did not appear to perturb any physiological or psychological measure tested in these study participants."
- A large cross-sectional epidemiological study undertaken by Health Canada[37] found that assessment using metrics representing low-frequency noise was not necessary and did not identify association between noise-levels and chronic health conditions such as migraines, tinnitus or high blood pressure.
- Controlled experiments[38] from Germany, which included participants self-reported to be sensitive to wind turbine infrasound, demonstrated that exposure to infrasound at levels

33 Health effects related to wind turbine sound: an update, I. van Kamp, G.P. van den Berg, National Institute for Public Health and the Environment (RIVM), RIVM report 2020-0150, October 2020.
34 UK Health Protection Agency, Health Effects of Exposure to Ultrasound and Infrasound, Report of the independent Advisory Group on Non-ionising Radiation (2010).
35 Shimada A, Nameki M (2017), Evaluation of Wind Turbine Noise in Japan, 12th ICBEN Congress on Noise as a Public Health Problem.
36 Marshall et. al., The Health Effects of 72 Hours of Simulated Wind Turbine Infrasound: A Double-Blind Randomized Crossover Study in Noise-Sensitive, Healthy Adults. Environmental Health Perspectives (EHP), 131(3) March 2023.
37 D. Michaud, Wind Turbine Noise and Health Study: Summary of Results, 6th International Meeting on Wind Turbine Noise, 2015.
38 Krahé, D, Alaimo Di Loro, A, Müller, U, Elmenhorst, E, De Gioannis, R, Schmitt, S, Belke, C, Benz, S, Großarth, S, Schreckenberg, D, Eulitz, C, Wiercinski, B & Möhler, U, 2020. Lärmwirkungen von Infraschallimmissionen (Noise Effects from Infrasound Immissions, in German, with abstract in English).

representative of those experienced at dwellings was not associated with physiological or psychological health effects.

- A study in Finland[39] was undertaken in assessing whether wind turbine infrasound has harmful effects on human health and found that wind turbine infrasound exposure did not cause physiological responses in any of the participant groups in the study.
- Other reviews of health effects, such as by Harrsion RV in 2014[40], Tonin et al (2016)[41], Nelson et al (2019)[42], and Maijala et al (2021)[43], showed that infrasound emission from wind turbines at ranges relevant to neighbouring dwellings were typically too low to expect any adverse effects, even for people with heightened sensitivity due to medical conditions.
- A report commissioned by the UK Government[44] published in February 2023 concludes that controlling A-weighted noise levels from wind turbines provides sufficient control of low-frequency noise, and that, based on the latest available evidence, "exposure to infrasound at levels representative of wind turbine immissions at dwellings is not associated with physiological or psychological health effects."

A.71. The Institute of Acoustics (IOA) also published a position statement[45] which noted that:

The IOA is aware that there is some information presented at planning inquiries suggesting the potential for physiological health effects from low frequency noise from wind turbines. It is current advice to members that there is no need to assess low frequency noise as part of the noise impact assessment process, as the absolute levels, whilst potentially audible at typical receptor distances, are well below those reported to trigger physiological health effects based on peer reviewed research to date.

A.72. In conclusion, whilst is known that infrasound can have an adverse effect on people (potential adverse health impacts are listed by the World Health Organisation as stress, irritation, unease, fatigue, headache, possible nausea and disturbed sleep), these effects can only come into play when the infrasound reaches a sufficiently high level. This is a level above the threshold of audibility. However, all available information from measurements on current wind turbines reveals that the level of infrasound emitted by these wind turbines lies below the threshold of human perception. Consequently, there is no reason to treat noise from wind farm development any differently to noise from any other form of development.

Blade swish (amplitude modulation)

A.73. The noise assessment methodology presented in ETSU-R-97, sets out noise limits which already account for typically encountered levels of blade swish. Notwithstanding the conclusions and advice presented in the preceding paragraphs concerning both infrasound and low frequency sound, the DTI LFN Report went on to suggest that, where complaints of noise at night had occurred, these had most likely resulted from an increased amplitude modulation of the blade passing noise, making the 'swish, swish, swish' sound (often referred to as 'blade swish') more prominent than normal. Whilst it was therefore acknowledged that this effect of enhanced amplitude modulation of blade aerodynamic noise may occur, it was also concluded that there were a number of factors that should be borne in mind

39 Infrasound Does Not Explain Symptoms Related to Wind Turbines, Maijala et al, Government's Analysis, Assessment and Research Activities, Helsinki, Finland, 2020
40 Harrison, RV, 2014. On the biological plausibility of Wind Turbine Syndrome. International Journal of Environmental Health Research.
41 Tonin, R, Brett, J & Colagiuri, B, 2016. The effect of infrasound and negative expectations to adverse pathological symptoms from wind farms. Journal of Low Frequency Noise, Vibration and Active Control.
42 Nelson, P, Bryne, A, Waggenspack, M, Lueker, M, Feist, C, Herb, B & Marr, J, 2019. Testing the human response to wind turbine emissions. Wind Turbine Noise 2019, 12-14 June, Lisbon. INCE-Europe
43 Maijala, PP, Kurki, I, Vainio, L, Pakarinen, S, Kuuramo, C, Lukander, K, Virkkala, J, Tiippana, K, Stickler, EA & Sainio, M, 2021. Annoyance, perception, and physiological effects of wind turbine infrasound. Journal of the Acoustical Society of America.
44 WSP, A Review of Noise Guidance for Onshore Wind Turbines, report for the UK Department for Business, Energy & Industrial Strategy, October 2022 (published 10 February 2023).
45 Institute of Acoustics, Statement in Respect of Wind Farm Noise Assessment, December 2024. https://www.ioa.org.uk/publications/wind-turbine-noise [accessed December 2025]

when considering the importance to be placed on the issue when considering present and proposed wind farm installations:

- it appeared that the effect had only been reported as a problem at a very limited number of sites (the DTI report looked at the 3 out of 5 U.K. sites where it has been reported to be an issue out of the 126 onshore wind farms reported to be operational at the time in 2006);
- the effect occurred only under certain conditions at these sites (the DTI LFN Report was significantly delayed while those involved in taking the measurements waited for the situation to occur at each location);
- at one of the sites concerned it had been demonstrated that the effect can be reduced to an acceptable level by the introduction of a Noise Reduction Management System (NRMS) which controls the operation of the necessary turbines under the relevant wind conditions (this NRMS had to be switched off in order to gain the data necessary to inform the DTI LFN Report);
- whilst still under review, it appeared that the most likely cause of the increased amplitude modulation was related to an increase in the stability of the atmosphere during evening and night time periods, hence the increased occurrence of such an effect at these times, but this effect had been shown by measurement of wind speed profiles to be extremely site specific;
- internal noise levels were below all accepted night time criteria limits and insufficient to wake residents, it was only when woken by other sources of a higher level (such as local road traffic) that there were self-reported difficulties in returning to sleep.

A.74. The Government then commissioned an independent research project to further investigate the prevalence of the impact of enhanced levels of amplitude modulation across UK wind farms. This research work was awarded to the University of Salford who reported on their findings in July 2007[46]. The Salford study concluded that that the occurrence of increased levels of 'blade swish' was infrequent, but suggested it would be useful to undertake further work to understand and assess this feature of wind turbine noise.

A.75. As a consequence of the findings of the report by the University of Salford, the UK Department for Business, Enterprise and Regulatory Reform (BERR formerly the DTI) issued a statement in August 2007[47] which concluded:-

> 'A comprehensive study by Salford University has concluded that the noise phenomenon known as aerodynamic modulation (AM) is not an issue for the UK's wind farm fleet.
>
> AM indicates aerodynamic noise from wind turbines that is greater than the normal degree of regular fluctuation of blade swoosh. It is sometimes described as sounding like a distant train or distant piling operation.
>
> The Government commissioned work assessed 133 operational wind projects across Britain and found that although the occurrence of AM cannot be fully predicted, the incidence of it from operational turbines is low'.

A.76. The statement then concludes with the advice:

> 'Government continues to support the approach set out in Planning Policy Statement (PPS) 22 – Renewable Energy. This approach is for local planning authorities to "ensure that renewable energy developments have been located and designed in such a way to minimise increases in ambient noise levels", through the use of the 1997 report by ETSU to assess and rate noise from wind energy development'.

46 'Research into Aerodynamic Modulation of Wind Turbine Noise', Report by University of Salford, URN 07/1235 (July 2007)
47 'Government statement regarding the findings of the Salford University report into Aerodynamic Modulation of Wind Turbine Noise', BERR, Ref: 2007/033 (1st August 2007)

A.77. This represents an aspect of wind turbine noise which has become the subject of considerable research in the UK and abroad in the past years and the state of knowledge on the subject is rapidly evolving. An extensive research programme entitled 'Wind Turbine Amplitude Modulation: Research to Improve Understanding as to its Cause and Effect' was published in 2013[48]. This research, commissioned by RenewableUK (ReUK) was specifically aimed at identifying and explaining some of the key features of wind turbine AM noise.

A.78. Claims have emerged from different researchers that wind turbines were capable of generating noise with characteristics out with that expected of them. This characteristic was an enhanced level of modulated aerodynamic noise that resulted in the blade swish becoming more impulsive in character, such that those exposed to it would describe it more as a 'whoomp' or 'thump' than a 'swish'. It could also become audible at distances from the wind turbines that were considerably greater than the distances at which blade swish could ordinarily be perceived. It has since emerged that this may be similar to the character of the noise identified in the DTI LFN study. Hence for the purposes of the ReUK project, any such AM phenomena with characteristics falling outside those expected of this "normal" AM (NAM) were therefore termed 'Other AM' (OAM).

A.79. The research identified the most likely cause of OAM noise is transient stall on the wind turbine blade (i.e. stall which occurs over a small area of each turbine blade in one part of the blade's rotation only). The occurrence of transient stall will be dependent on a combination of factors, including the air inflow conditions onto the individual blades, how these inflow conditions may vary across the rotor disc, the design of the wind turbine blades and the manner in which the wind turbine is operated. Variable inflow conditions may arise, for example, from any combination of wind shear, wind veer, yaw errors, turbine wake effects, topographic effects, large scale turbulence, etc. However, the occurrence of OAM on any particular site cannot be predicted at this stage.

A.80. As a consequence of the combined results of the ReUK research, and most notably the development of objective techniques for identifying and quantifying AM noise and the ability to relate such an objective measure to the subjective response to AM noise, ReUK has proposed an AM test[49] for implementation as a planning condition, although this was subject to discussion.

A.81. The Institute of Acoustics (IOA) published in 2016 a standardised methodology[50] for the assessment and rating of AM magnitude. The method provides a decibel level each 10 minute which represents the magnitude of the modulation in the noise, and minimises the influence of sources not related to wind turbines. The proposed method, unlike other methods that have previously been proposed, utilises as the core of its detection capability the fact that AM noise from wind turbines, by definition, exhibits periodicity at a rate that is directly related to the rotational speed of the source wind turbine. The IOA document does not however provide any thresholds or criteria methodology for using the resulting AM values.

A.82. The UK Government (DECC or Department of Energy and Climate Change, now obsolete) commissioned a review focused on the subjective response to AM with a view to recommend how this feature may be controlled. The outcome of this research has been published[51] in October 2016 by the Department for Business, Energy & Industrial Strategy (DBEIS). This report recommends the use of a "character penalty" approach, in which a correction is applied to the overall A-weighted noise level to account for AM in the noise in a manner similar to that used to assess tonality in the noise according to ETSU-R-97. This penalty is based on the above IOA methodology for detecting AM. The researchers make a number of recommendations for local authorities to consider and qualifications for the use of

48 Wind Turbine Amplitude Modulation: Research to Improve Understanding as to its Cause and Effect, Renewable UK, December 2013.
49 Template Planning Condition on Amplitude Modulation (guidance notes), RenewableUK, December 2013.
50 Institute of Acoustics (IOA) Amplitude Modulation Working Group, Final Report, A Method for Rating Amplitude Modulation in Wind Turbine Noise, June 2016.
51 Review of the evidence on the response to amplitude modulation from wind turbines, WSP for Department for Business, Energy & Industrial Strategy. https://www.gov.uk/government/publications/review-of-the-evidence-on-the-response-to-amplitude-modulation-from-wind-turbines

such controls, and note that the current state of knowledge on the subject and the implications of their proposed control is limited and that a period of testing and review over the next few years would be beneficial. The authors were however unable to provide clarity on how exactly the recommendations would operate in practice for any particular wind farm. On publication of the report, DBEIS encouraged local authorities in England to consider the research but provided limited guidance on how the outcomes were to be accounted for within the planning system.

A.83. Subsequently, a report commissioned by the UK Department for Business, Energy & Industrial Strategy was published[52] in February 2023 and concludes that the noise limits in ETSU-R-97 should be reviewed and that updated guidance on amplitude modulation should be included but makes no firm recommendations with regards to any update. Therefore, until the UK or Scottish governments conclude such a review, the ETSU-R-97 methodology continues to be applicable. The UK Government has also confirmed[53] that ETSU-R-97 should continue to apply until the review recommendations are considered in further detail. The UK Government most recently published[54] in July 2025 a draft for consultation of a revision of the ETSU-R-97 guidelines but noted that this draft guidance should not be used until a response to this consultation is published.

52 WSP, A Review of Noise Guidance for Onshore Wind Turbines, report for the UK Department for Business, Energy & Industrial Strategy, October 2022 (published 10 February 2023).
53 Government Response to the House of Lords Science and Technology Committee Report: The neglected pollutants: the effects of artificial light and noise on human health, December 2023. https://committees.parliament.uk/publications/42401/documents/210714/default/ [accessed September 2024]
54 https://www.gov.uk/government/consultations/assessment-and-rating-of-wind-turbine-noise-guidance-proposed-updates [accessed December 2025]

Glossary of Acoustics Terminology

Terminology	Description
A-weighting	A filter that down-weights low frequency and high frequency sound to better represent the frequency response of the human ear when assessing the likely effects of noise on humans
Acoustic character	One or more distinctive features of a sound (e.g. Tones, whines, whistles, impulses) that set it apart from the background noise against which it is being judged, possibly leading to a greater subjective effect than the level of the sound alone might suggest
Acoustic screening	The presence of a solid barrier (natural landform or manmade) between a source of sound and a receiver that interrupts the direct line of sight between the two, thus reducing the sound level at the receiver compared to that in the absence of the barrier
Ambient noise	All-encompassing noise associated with a given environment, usually a composite of sounds from many sources both far and near, often with no particular sound being dominant
Annoyance	A feeling of displeasure in this case evoked by noise
Attenuation	The reduction in level of a sound between the source and a receiver due to any combination of effects including: distance, atmospheric absorption, acoustic screening, the presence of a building façade, etc.
Audio frequency	Any frequency of a sound wave that lies within the frequency limits of audibility of a healthy human ear, generally accepted as being from 20 Hz To 20,000 Hz
Background noise	The noise level rarely fallen below in any given location over any given time period, often classed according to day time, evening or night time periods (for the majority of the population of the UK the lower limiting noise level is usually controlled by noise emanating from distant road, rail or air traffic)
Db	Abbreviation for 'decibel'
Db(a)	Abbreviation for the decibel level of a sound that has been a-weighted
Decibel	The unit normally employed to measure the magnitude of sound
Directivity	The property of a sound source that causes more sound to be radiated in one direction than another
Equivalent continuous sound pressure level	The steady sound level which has the same energy as a time varying sound signal when averaged over the same time interval, t, denoted by $L_{Aeq,t}$
External noise level	The noise level, in decibels, measured outside a building
Filter	A device for separating components of an acoustic signal on the basis of their frequencies
Frequency	The number of acoustic pressure fluctuations per second occurring about the atmospheric mean pressure (also known as the 'pitch' of a sound)
Frequency analysis	The analysis of a sound into its frequency components
Ground effects	The modification of sound at a receiver location due to the interaction of the sound wave with the ground along its propagation path from source to receiver
Hertz	The unit normally employed to measure the frequency of a sound, equal to cycles per second of acoustic pressure fluctuations about the atmospheric mean pressure
Impulsive sound	A sound having all its energy concentrated in a very short time period
Instantaneous sound pressure	At a given point in space and at a given instant in time, the difference between the instantaneous pressure and the mean atmospheric pressure
Internal noise level	The noise level, in decibels, measured inside a building
L_{Aeq}	The abbreviation of the a-weighted equivalent continuous sound pressure level
L_{A10}	The abbreviation of the 10 percentile noise indicator, often used for the measurement of road traffic noise
L_{A90}	The abbreviation of the 90 percentile noise indicator, often used for the measurement of background noise
Level	The general term used to describe a sound once it has been converted into decibels
Loudness	The attribute of human auditory response in which sound may be ordered on a subjective scale that typically extends from barely audible to painfully loud
Noise	Physically: a regular and ordered oscillation of air molecules that travels away from the source of vibration and creates fluctuating positive and negative acoustic pressure above and below atmospheric pressure.

Terminology	Description
	Subjectively: sound that evokes a feeling of displeasure in the environment in which it is heard, and is therefore unwelcomed by the receiver
Noise emission	The noise emitted by a source of sound
Noise immission	The noise to which a receiver is exposed
Noise nuisance	An unlawful interference with a person's use or enjoyment of land, or of some right over, or in connection with it
Octave band frequency analysis	A frequency analysis using a filter that is an octave wide (the upper limit of the filter's frequency band is exactly twice that of its lower frequency limit)
Percentile exceeded sound level	The noise level exceeded for n% of the time over a given time period, t, denoted by $L_{An,t}$
Receiver	A person or property exposed to the noise being considered
Residual noise	The ambient noise that remains in the absence of the specific noise whose effects are being assessed
Sound	Physically: a regular and ordered oscillation of air molecules that travels away from the source of vibration and creates fluctuating positive and negative acoustic pressure above and below atmospheric pressure
	Subjectively: the sensation of hearing excited by the acoustic oscillations described above (see also 'noise')
Sound level meter	An instrument for measuring sound pressure level
Sound pressure amplitude	The root mean square of the amplitude of the acoustic pressure fluctuations in a sound wave around the atmospheric mean pressure, usually measured in pascals (Pa)
Sound pressure level	A measure of the sound pressure at a point, in decibels
Sound power level	The total sound power radiated by a source, in decibels
Spectrum	A description of the amplitude of a sound as a function of frequency
Standardised wind speed	Values of wind speed at hub height corrected to a standardised height of ten metres using the same procedure as used in wind turbine emission testing
Threshold of hearing	The lowest amplitude sound capable of evoking the sensation of hearing in the average healthy human ear (0.00002 Pa)
Tone	The concentration of acoustic energy into a very narrow frequency range

Annex B – Location Maps and Turbine Coordinates

Figure 10.1.1 - Map showing the layout of the repowered wind farm, the Wyvis Lodge noise monitoring location and the noise assessment locations.

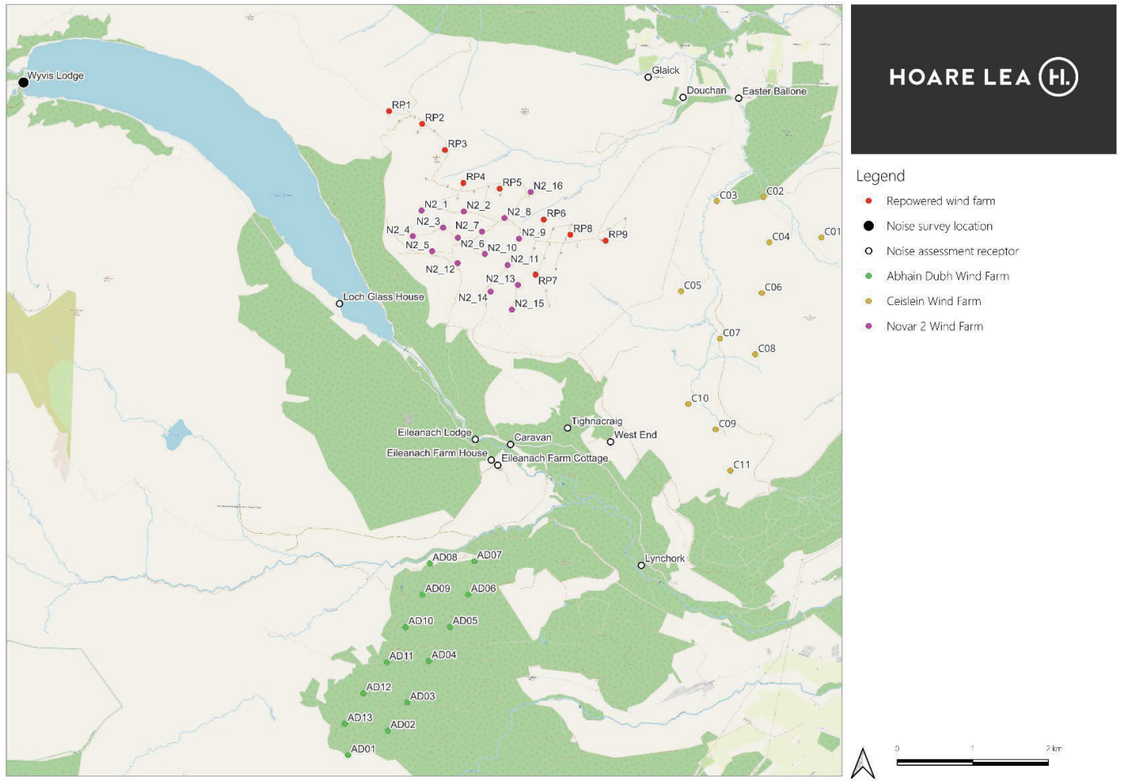


Table B1 – Repowered wind farm turbine coordinates

Turbine	Easting	Northing
RP_1	253365	873288
RP_2	253803	873120
RP_3	254105	872773
RP_4	254348	872337
RP_5	254829	872262
RP_6	255414	871851
RP_7	255304	871123
RP_8	255765	871651
RP_9	256232	871572
All Repowered wind farm turbines are modelled with a hub height of 98.5 metres and operating unconstrained at all times		

Table B2 – repowered wind farm propagation attenuation effects due to terrain (dB) – positive numbers are due to terrain shielding barrier effects (e.g. 2), representing a decrease in noise levels, and negative numbers (e.g. -3) represent an increase in predicted noise levels due to concave ground effects. Where there is a zero shown, neither terrain shielding nor concave ground were found.

Property	Turbine ID								
	RP_1	RP_2	RP_3	RP_4	RP_5	RP_6	RP_7	RP_8	RP_9
Douchan	2	2	0	0	0	0	0	0	0
Glaick	2	2	2	2	2	2	2	2	0
Loch Glass House	-3	0	0	0	0	0	0	0	0
Eileanach Lodge	0	0	0	0	0	2	2	2	2
West End	2	2	2	2	2	2	-3	-3	-3
Tighnacraig	2	2	2	2	2	2	2	0	-3
Easter Ballone	2	0	-3	0	-3	0	0	0	0
Wyvis Lodge	-3	-3	-3	-3	-3	2	-3	-3	2
Eileanach Farm Cottage	0	0	0	2	2	2	2	2	2
Caravan	2	2	2	2	2	2	2	2	2
Eileanach Farm House	0	0	0	0	2	2	2	2	2

Turbine source details: the repowered wind farm and Ceislein Wind Farm

Table B3 - Wind turbine sound power levels (dB L_{Aeq}) used in the noise assessment - the repowered wind farm and Ceislein Wind Farm

Turbine make / model	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Repowered wind farm Nordex N163 6.X VPC (STE variant) Mode 0.b (unconstrained) Source data hub height 98 m	-	-	97.8	99.1	103.7	108.1	109.4	109.4	109.4	109.4	109.4	109.4
Ceislein Wind Farm Nordex N163 6.X VPC (STE variant) Mode 0.b (unconstrained) Source hub height 118 m	-	-	97.8	99.4	104.2	108.6	109.4	109.4	109.4	109.4	109.4	109.4
Derived from: Nordex N163 6.X VPC document 'Third octave sound power levels', reference F008_277a_A17_EN, Rev 05, 03/05/2024, Doc. 9007485. With +2dB added for uncertainties in absence of specified uncertainty information.												

Table B4 - Octave band sound power spectrum (dB L_{Aeq}) for reference wind speed conditions (v_{10} = 8 m/s) - the repowered wind farm and Ceislein Wind Farm

Turbine make / model	Octave Band Centre Frequency (Hz)								
	63	125	250	500	1000	2000	4000	8000	A
Nordex N163 6.X VPC	90.6	98.2	100.3	101.5	103.3	104.0	98.4	84.0	109.4
Derived from: Nordex document 'Octave sound power levels', reference F008_277a_A19_IN, Rev 05, Doc 9007486 (data for *STE variant*), with +2dB added to match dB(A) values in Table B3									

Turbine & Propagation Details: Novar 1 Wind Farm

B.1. The existing Novar 1 Wind Farm is built and operating. Coordinates for the 34 Novar 1 turbines are outlined below in Table B5. The repowered wind farm would replace all of these turbines if consented.

B.2. Sound power levels for the Bonus B600 Mk IV wind turbines modelled are taken from test report documents made available to ourselves as referenced in the tables below, available between 6 m/s to 10 m/s. These overall sound power levels include an additional 2 dB(A) uncertainty margin to the sound power levels at each wind speed in the absence of specified uncertainty information, included in the values presented in Table B6 and Table B7.

Table B5 - Turbine coordinates – Novar 1 Wind Farm

Turbine	Easting	Northing	**Turbine**	Easting	Northing
NV1	255488	870709	**NV18**	255208	871260
NV2	255442	870913	**NV19**	254831	872179
NV3	255330	871110	**NV20**	254912	872347
NV4	255419	871339	**NV21**	254681	872281
NV5	255489	871531	**NV22**	254621	872076
NV6	255573	871196	**NV23**	254489	872220
NV7	255642	871407	**NV24**	254271	872128
NV8	255699	871599	**NV25**	254341	872339
NV9	255780	871790	**NV26**	254089	872105
NV10	255850	871488	**NV27**	254139	872295
NV11	256180	871578	**NV28**	253850	872389
NV12	256260	871729	**NV29**	253962	873032
NV13	256490	871868	**NV30**	253741	873008
NV14	256407	871653	**NV31**	253700	873210
NV15	255539	871727	**NV32**	253492	873159
NV16	255349	871679	**NV33**	253550	873339
NV17	255287	871470	**NV34**	253365	873285
All turbines modelled assuming a hub height of 42 m					

Table B6a - Propagation attenuation effects due to terrain (dB) – Novar 1 Wind Farm. Positive numbers are due to terrain shielding barrier effects (e.g. 2), representing a decrease in noise levels, and negative numbers (e.g. -3) represent an increase in predicted noise levels due to concave ground effects. Where there is a zero shown, neither terrain shielding nor concave ground were found.

Property	Turbine ID															
	NV1	NV2	NV3	NV4	NV5	NV6	NV7	NV8	NV9	NV10	NV11	NV12	NV13	NV14	NV15	NV16
Douchan	2	2	2	2	2	2	2	0	0	0	0	0	-3	0	2	2
Glaick	2	2	2	2	2	2	2	2	2	2	2	2	-3	2	2	2
Loch Glass House	-3	-3	-3	-3	0	-3	0	0	2	2	2	2	2	2	0	0
Eileanach Lodge	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
West End	-3	-3	2	2	2	-3	-3	-3	-3	-3	-3	-3	-3	-3	2	2
Tighnacraig	-3	2	2	2	2	2	2	2	2	2	-3	-3	-3	-3	2	2
Easter Ballone	2	2	2	2	0	2	2	0	-3	2	2	2	-3	-3	0	0
Wyvis Lodge	2	2	-3	-3	2	-3	2	2	2	2	2	2	2	2	2	2

Property	Turbine ID															
	NV1	NV2	NV3	NV4	NV5	NV6	NV7	NV8	NV9	NV10	NV11	NV12	NV13	NV14	NV15	NV16
Eileanach Farm Cottage	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Caravan	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Eileanach Farm House	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2

Table B6b – as above B6a, continued numbering of Novar 1 turbines

Property	Turbine ID																	
	NV17	NV18	NV19	NV20	NV21	NV22	NV23	NV24	NV25	NV26	NV27	NV28	NV29	NV30	NV31	NV32	NV33	NV34
Douchan	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Glaick	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Loch Glass House	-3	-3	2	2	2	0	0	-3	2	-3	-3	-3	2	-3	-3	-3	-3	-3
Eileanach Lodge	2	2	2	2	2	2	2	2	2	2	2	-3	2	2	2	2	2	2
West End	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Tighnacraig	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Easter Ballone	0	2	-3	-3	-3	-3	-3	0	-3	2	-3	-3	2	2	2	2	2	2
Wyvis Lodge	2	-3	2	2	2	2	2	-3	2	-3	-3	-3	-3	-3	-3	-3	2	-3
Eileanach Farm Cottage	2	2	2	2	2	2	2	2	2	2	2	-3	2	2	2	2	2	2
Caravan	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Eileanach Farm House	2	2	2	2	2	2	2	2	2	-3	-3	-3	2	2	2	2	2	2

Table B7 - Wind turbine sound power levels (dB L_{Aeq}) used in the noise assessment – Novar 1 Wind Farm - Bonus - B 600 Mk IV.

Turbine mode	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Mode 'High Speed'	-	-	-	-	-	97.8	98.8	99.8	100.8	101.8	-	-
Derived from: Danak 1825 - KAP 877100 8/10/1999 test report, 97.8 dB at 8 m/s for a 48 m hub height and an octave band spectrum. Warranty information indicated 99 dB(A) sound power level with a slope of 1 dB/m/s for the high speed mode. Database values are based on the test report plus a 2 dB margin for uncertainty and using the warranted slope between 6 m/s and 10 m/s.												

Table B8 - Octave band sound power spectrum (dB L_{Aeq}) for reference wind speed conditions (v_{10} = 8 m/s) - Novar 1 Wind Farm.

Turbine make / model	Octave Band Centre Frequency (Hz)								
	63	125	250	500	1000	2000	4000	8000	A
Bonus - B 600 Mk IV	78.9	86.3	91.4	93.7	94.3	91.7	89.9	82.5	99.8
Derived from: Danak 1825 - KAP 877100 8/10/1999 test report octave band spectrum.									

Turbine & Propagation Details: Novar 2 Wind Farm

B.3. The Novar 2 Wind Farm is adjacent to the south of the repowered wind farm (and the existing Novar 1 Wind Farm) is built and operating. Coordinates for the 16 Novar 2 turbines are outlined below in Table B5.

B.4. Sound power levels for the Enercon E70 wind turbines are taken from warranty documents made available to ourselves as referenced in the tables below. These overall sound power levels include an additional 1 dB(A) uncertainty margin to the sound power levels at each wind speed as advised by Enercon, included in the values presented in Table B6 and Table B7.

B.5. For the Novar 2 Wind Farm, an additional uplift of +2 dB, included in the assessment calculations, is considered as a reasonable allowance in the absence of specific restrictions associated with its consent and a nearby controlling properties. However, this additional uplift is not shown in the sound power values in Table B7 below.

Table B9 - Turbine coordinates – Novar 2 Wind Farm

Turbine	Easting	Northing	**Turbine**	Easting	Northing
NVE1	254358	871958	**NVE9**	254277	871271
NVE2	254992	870660	**NVE10**	254636	871394
NVE3	255087	871598	**NVE11**	254279	871609
NVE4	253796	871971	**NVE12**	254936	871247
NVE5	254712	870897	**NVE13**	254598	871690
NVE6	254084	871744	**NVE14**	255241	872224
NVE7	253681	871633	**NVE15**	255075	870985
NVE8	253940	871431	**NVE16**	254895	871872
All turbines modelled assuming a hub height of 65 m					

Table B10 - Propagation attenuation effects due to terrain (dB)– Novar 2 Wind Farm. Positive numbers are due to terrain shielding barrier effects (e.g. 2), representing a decrease in noise levels, and negative numbers (e.g. -3) represent an increase in predicted noise levels due to concave ground effects. Where there is a zero shown, neither terrain shielding nor concave ground were found.

Property	Turbine ID															
	NVE1	NVE2	NVE3	NVE4	NVE5	NVE6	NVE7	NVE8	NVE9	NVE10	NVE11	NVE12	NVE13	NVE14	NVE15	NVE16
Douchan	2	2	2	2	2	2	2	2	2	2	2	2	2	0	2	2
Glaick	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Loch Glass House	-3	-3	0	-3	0	-3	-3	-3	-3	0	-3	0	0	2	-3	0
Eileanach Lodge	2	2	2	-3	0	0	-3	0	2	2	2	2	2	2	2	2
West End	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Tighnacraig	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Easter Ballone	2	2	0	2	2	2	2	2	2	2	2	2	0	-3	2	0
Wyvis Lodge	-3	2	-3	-3	2	-3	-3	2	2	-3	-3	-3	-3	2	2	2
Eileanach Farm Cottage	2	2	2	-3	2	0	-3	0	2	2	2	2	2	2	2	2
Caravan	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Eileanach Farm House	2	2	2	-3	2	0	-3	0	0	2	0	2	2	2	2	2

Table B11 - Wind turbine sound power levels (dB L_{Aeq}) used in the noise assessment – Novar 2 Wind Farm - Enercon - E70 (2.3MW).

Turbine mode	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Mode 2.3MW (Mode III – unconstrained) Source data hub height 64 m	-	-	-	89.4	91.9	96.7	101.1	104.2	106.0	106.0	106.0	106.0
Derived from: Guaranteed Values of the Sound Power Level for the E-70 with 2.3 MW rated power (rev 1.0 / 20.02.06 - Mode III, rev 1.0 / 19.10.05 - Mode II) with 1dB(A) added to allow for uncertainty as advised by Enercon. An additional uplift of +2 dB was added to the above sound power values in the calculations, not shown in the above values.												

Table B12 - Octave band sound power spectrum (dB L_{Aeq}) for reference wind speed conditions (v_{10} = 8 m/s) - Novar 2 Wind Farm.

Turbine make / model	Octave Band Centre Frequency (Hz)								
	63	125	250	500	1000	2000	4000	8000	A
Enercon - E70 (2.3MW)	88.5	95.9	99.7	98.7	95.2	91.1	85.2	78.3	104.2
Derived from: WINDTest WICO 314SEA05/02 at 8m/s for the 2.3MW version, adjusted to match Table B11 values at 8 m/s.									

Turbine & Propagation Details: Abhainn Dubh Wind Farm

B.6. For the Abhainn Dubh Wind Farm a candidate wind turbine has been chosen which is typical of the type and size which would be installed, with relevant noise emission data shown below in Tables B15 and B16. Data have been provided by Vestas for their V136-4.0/4.2 MW turbine, which is offered as standard with serrated trailing edge blades. Sound power levels have been derived for a hub height of 82 m, operating in Mode SO1 for turbine AD06, Mode SO2 for turbines AD04 and AD05 and Mode 0 (unconstrained) assumed for the remaining turbines, in order to meet its proposed noise limits[55] and keep consistent with the Abhainn Dubh noise assessment.

Table B13 – Turbine coordinates and assumed operational modes – the Abhainn Dubh Wind Farm.

Turbine	Easting	Northing	**Turbine**	Easting	Northing
AD01	252824	864759	**AD08**	253904	867297
AD02	253348	865081	**AD09**	253808	866884
AD03	253607	865457	**AD10**	253585	866454
AD04	253891	866005	**AD11**	253334	865990
AD05	254171	866456	**AD12**	253026	865578
AD06	254413	866886	**AD13**	252778	865173
AD07	254494	867329			
All turbines modelled operating in Mode 0 for a hub height of 82 m					

Table B14 - Propagation attenuation effects due to terrain (dB) – the Abhainn Dubh Wind Farm – positive numbers are due to terrain shielding barrier effects (e.g. 2), representing a decrease in noise levels, and negative numbers (e.g. -3) represent an increase in predicted noise levels due to concave ground effects. Where there is a zero shown, neither terrain shielding nor concave ground were found.

Property	Turbine ID												
	AD01	AD02	AD03	AD04	AD05	AD06	AD07	AD08	AD09	AD10	AD11	AD12	AD13
Douchan	2	2	2	2	2	2	2	2	2	2	2	2	2
Glaick	2	2	2	2	2	2	2	2	2	2	2	2	2
Loch Glass House	2	2	2	2	2	0	0	0	2	2	2	2	2
Eileanach Lodge	2	0	0	0	0	0	0	0	0	0	0	0	0
West End	0	0	0	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3
Tighnacraig	0	0	0	-3	-3	-3	-3	-3	-3	-3	-3	-3	0
Easter Ballone	2	2	2	2	2	2	2	2	2	2	2	2	2
Wyvis Lodge	2	2	2	2	2	2	2	2	2	2	2	2	2
Eileanach Farm Cottage	2	0	0	0	0	0	0	0	0	0	0	0	0
Caravan	0	0	0	0	0	0	0	0	0	0	0	0	0
Eileanach Farm House	2	0	0	0	0	0	0	0	0	0	0	0	0

[55] Abhainn Dubh Wind Farm Technical Appendix 10.1: Environmental Noise Assessment – REV. 7 – 10/05/2023

Table B15 - Wind turbine sound power levels (dB L_{Aeq}) used in the noise assessment - Abhainn Dubh Wind Farm - Vestas V136-4.0/4.2 MW

Turbine mode	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Mode 0	-	-	93.4	96.6	101.5	105.2	105.9	105.9	105.9	105.9	105.9	105.9
Mode SO1	-	-	93.4	96.6	101.4	103.7	103.8	104.0	104.0	104.0	104.0	104.0
Mode SO2	-	-	93.4	96.6	101.0	101.4	101.5	101.5	101.5	101.5	101.5	101.5
Derived from: Vestas General Specification, Vestas V136-4.2 MW. Document no.: 0067-7066 V03 2018-05-02. Serrated trailing edges (standard). Converted from hub height data to standardised 10 m data for a hub height of 82 m, with +2 dB(A) added to the values provided by the manufacturer and included within the values shown above. The 4 MW Platform Brochure[56] confirms that maximum sound power levels for the V136-4.0/4.2 MW are the same as for the V136-4.5 MW, therefore the referenced specification data for the V136-4.0/4.2 MW are applicable to the V136-4.5 MW.											

Table B16 - Octave band sound power spectrum (dB L_{Aeq}) for reference wind speed conditions (v_{10} = 8 m/s) - the Abhainn Dubh Wind Farm

Turbine make / model	Octave Band Centre Frequency (Hz)								
	63	125	250	500	1000	2000	4000	8000	A
Vestas V136-4.5 MW	87.0	94.6	99.2	101.0	99.9	95.8	89.0	79.1	105.9
Derived from: Vestas V136-4.0/4.2 MW Third octave noise emission DMS 0067-4732 V02 2018-03-20. Mode 0, at 11 m/s hub height wind speed, converted to octave bands from one-third octave band values. The 4 MW Platform Brochure confirms that maximum sound power levels for the V136-4.5 MW are the same as for the V136-4.2 MW, therefore the referenced third octave emissions data for the V136-4.2 MW are used to represent the V136-4.5 MW.									

56 Vestas Brochure (https://nozebra.ipapercms.dk/Vestas/Communication/4mw-platform-brochure) accessed 12th Jan 2023.

Propagation Details: Ceislein Wind Farm

B.1. For the Ceislein Wind Farm a candidate wind turbine has been chosen which is typical of the type and size which would be installed and is consistent with the Ceislein Wind Farm applicant's noise assessment. The relevant noise emission data is shown above in Tables B3 and B4 above. Data have been provided by Nordex for their N163 6.X VPC 7MW turbine, with serrated trailing edge blades. Sound power levels have been derived from a source hub height of 118 m, operating in Mode 0.b (unconstrained). These overall sound power levels include an additional 2 dB(A) uncertainty margin to the sound power levels at each wind speed in the absence of specified uncertainty information, included in the values presented in Table B3 and Table B4 above.

Table B17 - Turbine coordinates – Ceislein Wind Farm

Turbine	Easting	Northing	Hub height (m)	**Turbine**	Easting	Northing	Hub height (m)
C01	259090	871616	118	**C07**	257746	870275	164
C02	258324	872151	118	**C08**	258213	870068	164
C03	257705	872097	164	**C09**	257690	869072	164
C04	258400	871550	118	**C10**	257327	869408	164
C05	257231	870903	164	**C11**	257884	868527	118
C06	258300	870879	164				

Table B18 - Propagation attenuation effects due to terrain (dB) – Ceislein Wind Farm – positive numbers are due to terrain shielding barrier effects (e.g. 2), representing a decrease in noise levels, and negative numbers (e.g. -3) represent an increase in predicted noise levels due to concave ground effects. Where there is a zero shown, neither terrain shielding nor concave ground were found.

Property	Turbine ID										
	C01	C02	C03	C04	C05	C06	C07	C08	C09	C10	C11
Douchan	0	0	0	0	2	0	2	0	2	2	2
Glaick	0	0	0	0	2	0	2	2	2	2	2
Eileanach Lodge	2	2	2	2	2	2	2	2	0	0	-3
West End	0	2	0	0	0	0	0	0	0	0	0
Tighnacraig	0	0	0	0	0	0	0	0	0	0	0
Easter Ballone	0	0	0	0	0	0	0	0	2	2	2
Eileanach Farm Cottage	0	2	2	0	0	0	0	0	0	0	-3
Caravan	2	2	2	2	2	2	2	0	0	0	0
Eileanach Farm House	2	2	2	2	2	0	0	0	0	0	-3
Lynchork	2	2	2	2	2	2	2	2	0	0	0

Annex C – Noise Monitoring Information Sheets

Table C1 - Information on the measurement location, equipment and noise data at Wyvis Lodge.

Measurement Location Name	Wyvis Lodge
Measurement Location Description	The Wyvis Lodge property was chosen as a suitable noise measurement proxy location without existing wind turbine noise, to represent the existing baseline noise levels at the uninhabited Loch Glass House. The Loch Glass House is located across Loch Glass from the repowered wind farm (where the operational Novar 1 and Novar 2 sites are located). However, at Wyvis Lodge further northwest, the existing wind turbine noise from the Novar 1 and Novar 2 operational schemes was not observed. At the Loch Glass House location, aside from wind turbine noise, few local noise sources were observed (on a calm day) except occasional wave noise lapping onto shore from the loch and local intermittent birdsong noise sources, both similar to observations at the Wyvis lodge proxy measurement position. Continuous aerodynamic noise from the Novar 1 and Novar 2 operational wind turbines were clearly present across the loch. Therefore, the baseline noise levels at Wyvis Lodge were measured without contamination from existing wind turbine noise sources, in line with ETSU-R-97 methodology. Additionally, both properties are located along different areas of the Loch Glass shoreline, however they share similar natural noise sources from wind disturbed tall vegetation in the surrounding forests, occasional birdsong and occasional waves from Loch Glass. At the Wyvis Lodge location, the logger was positioned on the lawn away from tall vegetation to minimize wind disturbed vegetation noise, as there was reduced vegetation surrounding the Loch Glass House in comparison. The logger was set back slightly from the water shoreline, to minimise wave breaking sounds if windy conditions occurred. A pool pump room in a basement was noted; however no plant noise was observed at the installed position. The landowner also requested the logger was positioned such that guest views from the lodge onto the logger in the garden were minimised. Overall, the install position at Wyvis Lodge was a suitably representative of the Loch Glass house location, without existing turbine noise and therefore in line with IOA GPG guidance. SLM Location: 248462 / 873682

Equipment	Type	Serial Number	Last Calibrated (UKAS)
Sound Level Meter	Rion NL-52	00832245	15/08/2025
Microphone	Rion UC-59	05472	15/08/2025
Pre-amplifier	Rion NH-25	44552	15/08/2025
Calibrator	Rion NC-75	34745899	27/07/2024
SLM Range	20 – 120 dB(A)		

File	Time Start (GMT)	Time End (GMT)	Cal Start	Cal End	Drift	Notes
01	01/10/2024 11:10	14/10/2024 12:10	94.0	93.9	-0.1	No significant drift
02	14/10/2024 11:20	01/11/2024 11:30	94.0	93.9	-0.1	No significant drift

Data Exclusions
Data during periods 10 minutes prior, during and 10 minutes following any rainfall were excluded from the analysis. Quiet Daytime exclusions: Atypical elevated noise levels from noise events outside of the background noise trend were excluded: - Data between 2 m/s to 4 m/s and above the L_{A90} noise level of 32.0 dB. - Data between 4 m/s to 5 m/s and above the L_{A90} noise level of 35.0 dB. - Data between 6 m/s to 8 m/s and above the L_{A90} noise level of 39.0 dB. Night time exclusions: Atypical elevated noise levels from noise events outside of the background noise trend were excluded: - Data between 0 m/s to 3.2 m/s and above the L_{A90} noise level of 25.0 dB. - Data between 4 m/s to 6 m/s and above the L_{A90} noise level of 33.7 dB. - Data between 6 m/s to 8 m/s and above the L_{A90} noise level of 39.0 dB.

View of the monitoring location at Wyvis Lodge looking east



View of the monitoring location at Wyvis Lodge looking south



View of the monitoring location at Wyvis Lodge looking west



View of the monitoring location at Wyvis Lodge looking north

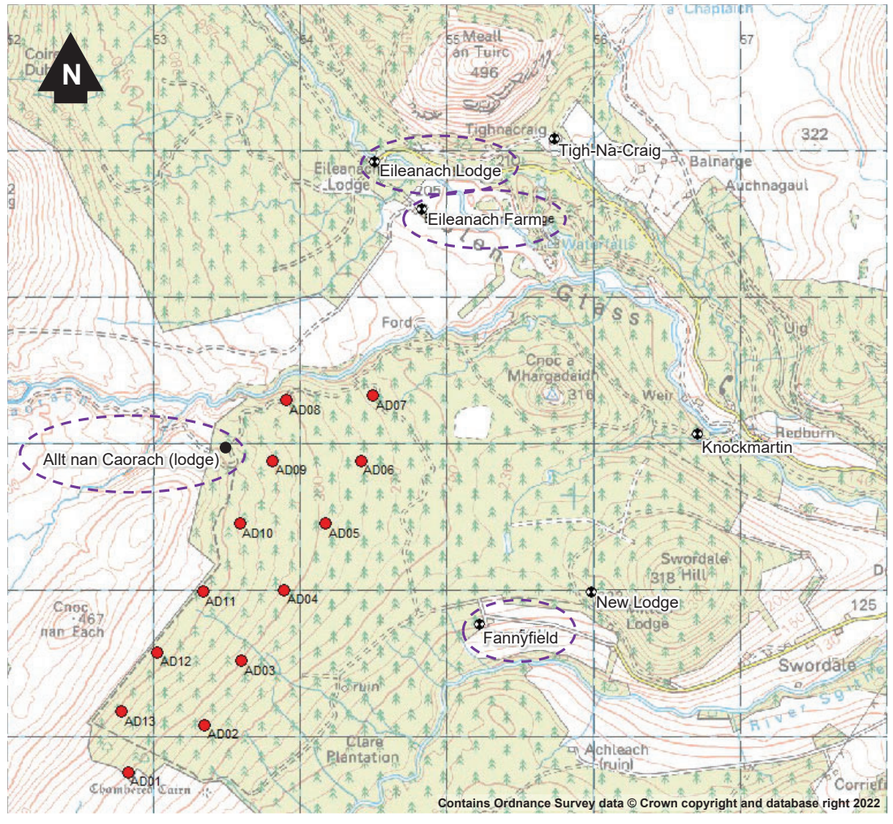


Annex D – Baseline Information & Derived Noise Limits/Criteria

Derivation of Background Noise Levels

D.1 A review of the EIA for the previously proposed Clach Liath Wind Farm (superseded since by the Abhainn Dubh Wind Farm application) shows that background noise levels have been measured at several locations (see Figure 10.1.2). Given that two relevant noise-sensitive receptor locations being assessed for the repowered wind farm have already been surveyed for baseline background noise levels, it was not considered necessary to undertake further baseline surveys at these properties.

Figure 10.1.2 – Map showing the layout of the Abhainn Dubh turbines (red circles, prefixed 'AD') located south of the repowered wind farm and the locations where baseline background levels were surveyed for the previously proposed Clach Liath Wind Farm (purple outlines).



D.2 Existing data have been reviewed to provide the required representative baseline background noise levels for the purposes of an ETSU-R-97 assessment. Table D1 shows the background noise survey results derived from the Clach Liath Wind Farm noise assessment, calculated from the equations given for the best fit lines on the assessment charts. The Clach Liath Wind Farm background noise survey was conducted at locations agreed in consultation with THC. The results from the survey are reasonable and consistent with the requirements of ETSU-R-97 and IOA GPG. The Clach Liath Wind Farm noise assessment noted that Novar 2 Wind Farm was being constructed at the time of the survey but that

the survey results were unlikely to be influenced by construction or operational noise from the wind turbines.

D.3 The IOA GPG suggests that baseline results measured for other wind farms can be referenced in this way, but that they should be based on standardised ten metre wind speeds related to those at the hub height of the candidate wind turbine for the repowered wind farm. Where these wind speed references differ, corrections may need to be applied to account for wind shear effects.

Table D1 – Original background noise levels at the four survey locations relevant to assessment of the Abhainn Dubh Wind Farm for both day-time and night-time periods, calculated from the lines of best fit shown in the Clach Liath Wind Farm noise assessment. Highlighted rows indicate the properties relevant for the assessment of the repowered wind farm.

Survey Locations (survey coordinates)	Standardised 10 m Wind Speed (m/s)									
	3	4	5	6	7	8	9	10	11	12
Day-time Periods										
Fannyfield (255232, 865728)	29.0	30.0	30.9	31.9	32.9	33.8	34.8	35.8	36.7	37.7
Eileanach Lodge (254494, 868916)	42.9	43.2	43.6	43.9	44.3	44.6	44.9	45.3	45.6	46.0
Eileanach Farm (254806, 868589)	30.9	31.5	32.2	32.8	33.5	34.1	34.7	35.4	36.0	36.7
Allt nan Caorach (253440, 867037)	22.1	24.3	26.6	28.8	31.0	33.3	35.5	37.7	40.0	42.2
Night-time Periods										
Fannyfield (255232, 865728)	28.4	29.1	29.9	30.6	31.4	32.1	32.9	33.7	34.4	35.2
Eileanach Lodge (254494, 868916)	43.3	43.6	43.9	44.2	44.5	44.8	45.1	45.4	45.7	46.0
Eileanach Farm (254806, 868589)	31.6	32.2	32.7	33.3	33.9	34.5	35.1	35.6	36.2	36.8
Allt nan Caorach (253440, 867037)	23.4	25.7	27.9	30.1	32.3	34.5	36.8	39.0	41.2	43.4
Locations and coordinates as stated in the Clach Liath Wind Farm noise assessment.										

D.4 The existing baseline data had been referenced to wind speeds measured at a height of 80 metres[57] that was used in the historical Clach Liath Wind Farm baseline survey. In the Abhainn Dubh noise assessment, the historical baseline levels were corrected to account for a hub height of 125 metres. This was the hub height for the proposed Abhainn Dubh Wind Farm turbines at the Scoping phase. The precautionary wind shear exponent values used for the correction were taken from the IOA GPG SGN4[58] and are typical of a rolling hilly terrain, which in our experience are most likely to be representative of the repowered wind farm (see Table D2).

Table D2 – Table of typical averaged wind shear exponents (m) for evening ('amenity') and night-time periods given in the IOA GPG SGN4.

Period	Shear exponent values (m) for standardised wind speed at 10 m									
	3	4	5	6	7	8	9	10	11	12
Amenity periods	0.25	0.24	0.22	0.20	0.18	0.17	0.15	0.15	0.14	0.13
Night-time periods	0.29	0.28	0.25	0.23	0.20	0.18	0.17	0.16	0.14	0.13

57 Baseline background noise surveys completed for Clach Liath Wind Farm were referenced to standardised ten metre wind speeds calculated from those directly measured at 80 m, which was the proposed hub height of the Clach Liath Wind Farm. The Clach Liath Wind Farm noise assessment states "No additional corrections were required to convert the measured wind speed data to hub height equivalent as the wind speed was measured at the proposed hub height".

58 A Good Practice Guide to the Application of ETSU-R-97 for the Assessment and Rating of Wind Turbine Noise - Supplementary Guidance Note SG4 – Wind Shear, Matthew Cand, Robert Davis, Chris Jordan, Malcolm Hayes, Richard Perkins, Institute of Acoustics, 1st July 2014, Issue 1.

D.5 Whilst the hub height of the repowered wind farm is modelled at 89.5 metres, the calculations presented relate to a taller hub height of 125 metres, to remain consistent with information presented to THC for the previous Abhainn Dubh Wind Farm consultation and agreement of the approach to determining background noise levels. The use of data related to a 125 metre hub height is therefore more precautionary, and this would compensate for differences between the wind speeds experienced by the two wind farm sites. Table D3 shows the magnitude of these wind speed corrections ('shifts'). The correction process applies these wind shear corrections to the whole integer values of wind speeds shown in Table D3, resulting in background noise levels related to non-integer values of wind speed.

Table D3 – Table of the wind speed correction (amount to move wind speeds to the right if value is positive) to correct the values using the wind shear exponents (m) shown in Table D2.

Period	Wind speed shift (m/s) for standardised wind speed at 10 m									
	3	4	5	6	7	8	9	10	11	12
Amenity periods	0.16	0.20	0.20	0.19	0.15	0.14	0.07	0.08	0.04	-0.01
Night-time periods	0.22	0.27	0.27	0.27	0.22	0.17	0.16	0.13	0.04	-0.01

D.6 A best-fit line is used for each set of values to define the relationship of background noise levels with wind speed, using the same order of best-fit line used in the original Clach Liath Wind Farm background noise assessment. These lines of best-fit enable values of background noise levels related to integer (whole value) wind speeds to be derived, with the resulting shear corrected historical background noise levels presented in Table D4 for relevant properties.

Table D4 – Wind shear corrected historical background noise levels at the two survey locations relevant to the assessment of the repowered wind farm, are shown for both day-time and night-time periods.

Survey Locations	Standardised 10 m Wind Speed (m/s)									
	3	4	5	6	7	8	9	10	11	12
Day-time Periods										
Eileanach Lodge	42.8	43.2	43.5	43.9	44.2	44.6	44.9	45.3	45.6	45.9
Eileanach Farm	30.7	31.4	32.1	32.7	33.4	34.0	34.7	35.3	36.0	36.7
Night-time Periods										
Eileanach Lodge	43.2	43.5	43.9	44.2	44.5	44.8	45.1	45.4	45.7	46.0
Eileanach Farm	31.4	32.0	32.6	33.2	33.8	34.4	35.0	35.6	36.2	36.8

Annex E – Wind Speeds and Directions

Chart E1 - Wind speed and direction range during all quiet day-time periods (Wyvis Lodge data shown).

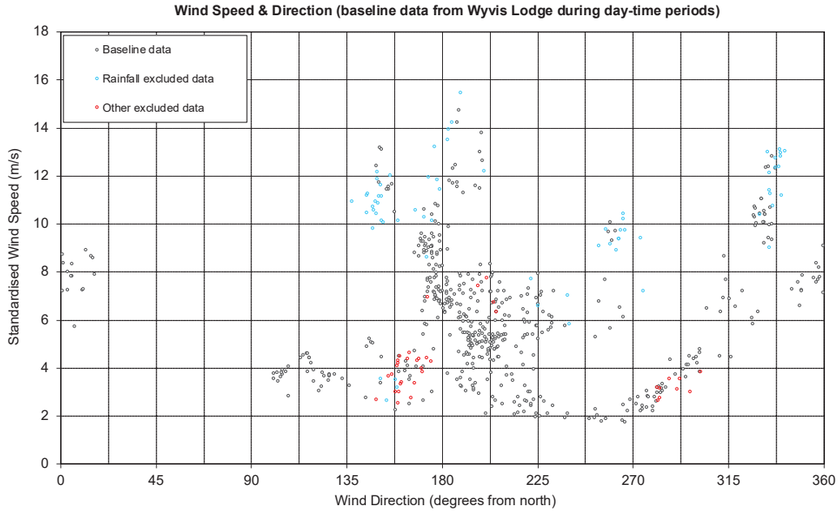
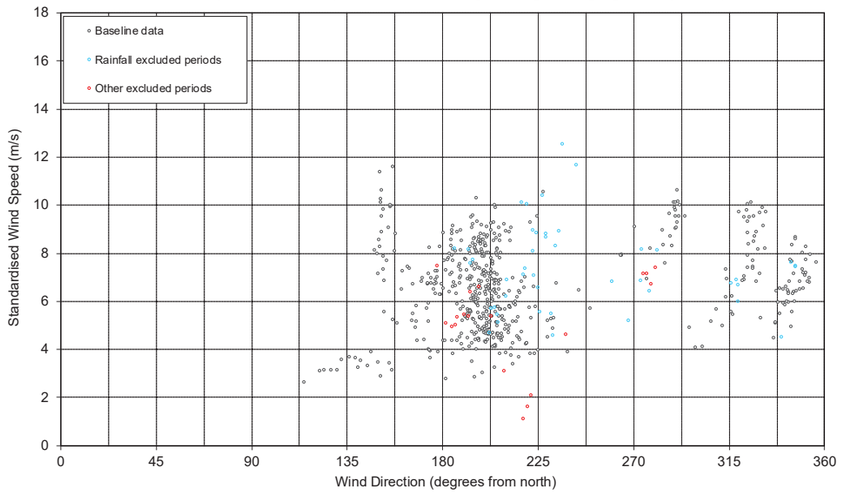


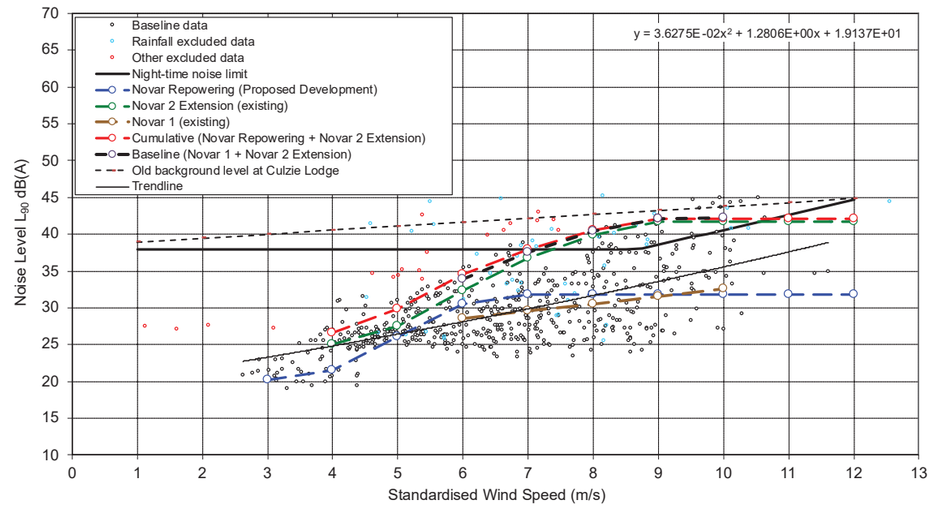
Chart E2 - Wind speed and direction range during all night-time periods (Wyvis Lodge data shown).



Annex F – Background Noise and Noise Limits

Chart F1 - Chart of background noise levels against wind speeds, the best fit curve to the data, the indicative noise limit curve for Loch Glass House during quiet day time periods. Predicted immission noise levels are also shown for the repowered wind farm, the existing Novar wind farms considered and the cumulative total of Novar 2 and the repowered wind farm.

Chart F2- Chart of background noise levels against wind speeds, the best fit curve to the data, the indicative noise limit curve for Loch Glass House during night-time periods. Predicted immission noise levels are also shown for the repowered wind farm and the other existing Novar wind farms considered and the cumulative total of Novar 2 and the repowered wind farm.



Annex G – Wind Speed Calculations

G.1 The IOA GPG[59] requires that noise data recorded every 10 minutes are related to standardised ten metre wind speeds experienced at the hub height of the turbines, at a location on the wind farm representative of the wind farm. These wind speeds can be either measured directly at the turbine hub height or derived by calculation from measurements at two heights, with measurements at the upper height not less than 60% of the turbine hub height and measurements at least 15 metres below that. These are referred to as 'Method A' or 'Method B' in the IOA GPG which describes these as the preferred methods to use. IOA GPG SGN4[60] provides additional guidance on these methods.

G.2 The site of the repowered wind farm has a temporary LIDAR remote sensing measuring system installed at the existing Novar 1 Wind Farm which measured wind conditions at various heights as follows:

- Wind speeds at 80m and 39m
- Wind directions at 80m.

G.3 These measurement heights meet the requirements of the IOA GPG: the 80m upper measurement height being at least 60% of the proposed candidate hub height of 98.5 metres and the 39m height anemometer being at least 15 metres lower than the upper measurement. The LIDAR meets the accuracy and calibration requirements of the IOA GPG, installed by competent individuals from ZX Measurement Services. The LIDAR install position was sufficiently distanced from nearby operational turbines, such that the risk of interference from wake effects were minimised at the LIDAR position.

G.4 Wind speed data were used to perform a calculation of the shear exponent found between the two wind speed measurement heights for every ten-minute period, by using Equation 3 of IOA GPG SGN4. Where wind speeds were the same at both heights or lower at greater height, the shear exponent was assumed to be zero. The shear exponent so calculated for every ten-minute period was then used to calculate the hub height wind speed using Equation 2 of SGN4 for each ten-minute period. Equation 1 of SGN4 was then used to calculate a standardised ten-metre height wind speed from the hub height wind speed every ten minutes assuming the reference roughness length of 0.05 metres.

G.5 Wind speeds are standardised to a height of ten metres assuming a reference ground roughness length of 0.05 metres as described in the IOA GPG. This approach is of the same form as that given in BS EN 61400-11:2003[61] for calculating ten metre wind speeds related to hub height wind speeds when providing source noise emission data for wind turbines.

G.6 By using this method, measured background noise levels were correlated to ten metre wind speeds calculated from wind speeds at hub height. Any likely difference in the shear profile during the 24 hours of the day will be accounted for within the method and be reflected in the resulting standardised ten metre wind speed data. The method used to calculate ten metre wind speeds from those at hub height is the same as that used when deriving noise emission data for the turbines. Because the same method has been used, direct comparison of background noise levels, noise limits and predicted turbine noise immission levels may be undertaken. This method is consistent with guidance published in the IOA GPG.

59 A Good Practice Guide to the Application of ETSU-R-97 for the Assessment and Rating of Wind Turbine Noise, M. Cand, R. Davis, C. Jordan, M. Hayes, R. Perkins, Institute of Acoustics, May 2013.
60 A Good Practice Guide to the Application of ETSU R 97 for the Assessment and Rating of Wind Turbine Noise - Supplementary Guidance Note 4: Wind Shear, M. Cand, R. Davis, C. Jordan, M. Hayes, R. Perkins, Institute of Acoustics, July 2014.
61 IEC 61400 11:2003 Wind turbine generator systems - Part 11: Acoustic noise measurement techniques.

HOARE LEA

RYLAN NORCROSS
SENIOR ACOUSTICS ENGINEER

+44 1454 806 668
rylannorcross@hoarelea.com

HOARELEA.COM

155 Aztec West
Almondsbury
Bristol
BS32 4UB
England