HOARE LEA H.

Glenvernoch wind farm
Environmental noise assessment.

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Contents.

Executive Summary

Hoare Lea (HL) have been commissioned by Energiekontor UK to undertake a noise assessment for the construction and operation of the proposed Glenvernoch Wind Farm (the Proposed Development). Noise will be emitted by equipment and vehicles used during construction and decommissioning of the wind farm and by the turbines during operation. 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 has been assessed by a desk-based study of a potential construction programme and by assuming the Proposed Development 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 negligible impact. Worst-case traffic increases associated with the construction could correspond to an increase on traffic noise along parts of the construction route which would correspond to a minor impact at most.

Decommissioning is likely to result in less noise than during construction of the Proposed Development. The construction phase has been considered to have negligible to minor noise impacts, therefore decommissioning will, in the worst case, also have negligible to 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. Surveys have been performed to establish existing baseline noise levels at a number of these properties. Noise limits have been derived from data about the existing noise environment following the method stipulated in national planning guidance and have also been derived following the simplified assessment method, also stipulated in national planning guidance, for some properties. Predicted noise levels take full account of the potential combination of the noise from the Proposed Development along with Kilgallioch Wind Farm and Kilgallioch Extension Wind Farm. The proposed Blair Hill Wind Farm has been considered separately as it has not yet been submitted and there is therefore limited environmental information that would not allow a complete cumulative noise assessment to be undertaken. Other, more distant wind farms were not considered as they do not make an acoustically relevant contribution to cumulative noise levels.

Predicted operational 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.

The potential noise from the substation and battery storage infrastructure for the Proposed Development was assessed in line with the relevant standard and could be associated with a minor impact at most. The addition of these sources to that of the wind turbines would not affect the outcome of the above assessment.

This Executive Summary contains an overview of the noise assessment and its conclusions. No reliance should be placed on the content of this Executive Summary until this report has been read in its entirety.

1. Introduction

1.1 This report presents an assessment of the potential construction and operational noise impacts of the Glenvernoch Wind Farm (the Proposed Development) on the residents of nearby dwellings. The assessment considers both the construction and operation of the Proposed Development and also the likely impacts of its decommissioning. Assessment of operational noise accounts for the cumulative total of the Proposed Development as well as the nearby operational Kilgallioch Wind Farm and consented Kilgallioch Extension Wind Farm, both located west of the Proposed Development. The application for the Blair Hill Wind Farm has not yet been submitted, but an indicative cumulative assessment is presented based on preliminary information for that development. Other, more distant Wind Farms were not considered, because 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 Proposed Development. 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, substation and battery storage infrastructure 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 Statement.

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 Proposed Development will therefore generally form the basis of the assessment of the levels of noise against accepted standards.

1.4 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 - Scotland

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 noise impacts on communities and dwellings are one of the aspects that will need to be considered; however, it provides no specific advice. Planning Advice Note

1 Scottish National Planning Framework 4, Scottish Government. Adopted 13 February 2023.

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 Online Renewables Planning Advice on Onshore wind turbines[3] provides further advice on noise, and confirms that the recommendations of 'The Assessment and Rating of Noise from Wind Farms' (ETSU-R-97)[4] "*should be followed by applicants and consultees, and used by planning authorities 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 With regard to infrasound and low-frequency noise, the above-referenced online planning advice note, Onshore wind turbines refers to a report for the UK Government which concluded that *'there is no evidence of health effects arising from infrasound or low frequency noise generated by the wind turbines that were tested'*.

2.1.4 The recently published Scottish Government Onshore Wind Policy Statement 2022[5] 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. Although a report on this topic commissioned by the UK Government has been published (WSP BEIS Report)[6], its recommendations for updates to some aspects of the ETSU-R-97 methodology 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.

2.1.5 The recommendations contained in ETSU-R-97 therefore provide a robust basis for assessing the noise implications of a wind farm. ETSU-R-97 has become the accepted standard for such developments

2 Planning Advice Note 1/2011: Planning & Noise, Scottish Government, March 2011.
3 Scottish Government, Online Renewables Planning Advice, Onshore Wind Turbines (https://www.gov.scot/publications/onshore-wind-turbines-planning-advice). Updated 28 May 2014.
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 Scottish Government (2021) - Onshore wind - policy statement 2022, December 2022.
6 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).

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)[7]. This was subsequently endorsed by the Scottish Government[8] which advised in the web-based planning advice note that this *'should be used by all IOA members and those undertaking assessments to ETSU-R-97',* The methodology of ETSU-R-97 and the IOA GPG has therefore been adopted for the present assessment and is described in greater detail below.

2.1.6 For assessing operational noise from non-wind turbines sources associated with the Proposed Development, such as fixed plant associated with the substation and battery storage elements, 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.

2.1.7 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.

2.1.8 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.

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

2.1.10 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.

7 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.
8 Letter from John Swinney MSP, Scottish Government, 29/05/2013
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'.
15 Planning Advice Note 50: Controlling The Environmental Effects of Surface Mineral Workings, 1996.

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. 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/major impacts in this instance. Accordingly, vibration impacts do not warrant detailed assessment and are therefore not discussed further in this assessment.

3.1.6 The analysis of the related potential impacts has been made in accordance with PAN50, BS 6472-2 2008 and BS 5228.

3.2 Methodology for Assessing Wind Farm 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 F 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

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.

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 <u>or</u> 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 5.6 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 <u>or</u> 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 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 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.

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

3.2.7 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.

3.2.8 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 Proposed Development 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.

3.2.9 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.

3.2.10 The foregoing steps, as applied to the Proposed Development, are set out subsequently in this assessment.

3.2.11 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 Proposed Development.

3.2.12 Noise from non-wind turbines sources associated with the Proposed Development, such as fixed plant associated with the substation and Battery Energy Storage System (BESS) elements, 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 noise. The impact is then determined on this basis from negligible through minor to moderate and major. Table 1 outlines the impact magnitude criteria from the BS 4142 standard to assess operational noise from the substation and BESS equipment.

Table 1 – Substation and BESS operational noise impact assessment criteria

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 and less than 35 dB(A)

3.2.13 In Table 1, a lower level of 35 dB L_{Ar} is applied on the basis that this represents a very low absolute noise level, which was consistent with the description applied in the 1997 version of the BS 4142 standard which is referenced in PAN1/2011. Consideration of the levels set out in Table A1 in Appendix 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 (as discussed above in 3.2.5).

3.3 Construction Noise Criteria

3.3.1 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.

3.3.2 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.

3.3.3 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 2 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 2 - 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 Proposed Development 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.			

3.3.4 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 2.

3.3.5 Blasting operations will not take place on this site, as materials will be imported therefore blasting operations are not considered further in this assessment.

3.4 Operational Noise Criteria

3.4.1 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 Proposed Development will still be within levels considered acceptable under the ETSU-R-97 assessment method.

3.4.2 Table 1 sets out the BS 4142 magnitude assessment criteria for operational noise from non-turbine elements of the Proposed Development such as the BESS and substation.

3.5 Consultation

3.5.1 Prior to undertaking the background surveys, a summary of the likely proposed monitoring locations was forwarded to the Environmental Health Department of Dumfries and Galloway for comment on

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.

17/08/2023, and no adverse comments were received. This consultation was based on a preliminary project layout which was of a similar form to the layout currently proposed.

3.5.2 Descriptions of the four installed noise monitoring positions were issued to the Environmental Health Department of Dumfries and Galloway on 27/10/2023 and no adverse comments were received in response.

3.5.3 The four installed noise monitoring locations are shown on the plan in Annex B. Further information about the monitoring locations, the equipment used and pictures of the survey positions are presented in Annex C.

4. Baseline

4.1 General Description

4.1.1 The Proposed Development is located in an area of relatively low population density, with a number of isolated properties surrounding the Proposed Development. The noise environment in the surrounding area is generally characterised by 'natural' sources, such as wind disturbed vegetation, birds, livestock and to the east and north of the site, intermittent local road traffic noise and agricultural/All Terrain Vehicle (ATV) movements in the area.

4.2 Details of the Baseline Background Noise Survey

4.2.1 A total of five proposed noise monitoring locations were proposed to the Local Authority (Dumfries & Galloway Council) as representative of the background noise environment in areas and properties surrounding to the Proposed Development site, prior to commencement of the background noise survey.

4.2.2 However, access was refused by landowners at an initially proposed measurement location at Larg Farm. Access was also refused at Old Larg House, Brigton, Shepherds Cottage, Cordorcan Cottage and Low Cordorcan Cottage properties, all along the River Cree. In all cases the purpose of the measurements was clearly explained. For these properties, measurements undertaken at Knockville were referenced instead which is considered precautionary as Knockville was distanced further from the River Cree and the A714 main road. Therefore, no watercourse noise and reduced road traffic noise was observed at this property.

4.2.3 Therefore, background noise measurements at four of the five locations initially proposed surrounding the Proposed Development were installed. The four measurement locations are shown on the map figure in Annex B and listed in Table 3.

Table 3 - Background Noise Monitoring Locations (approximate Easting / Northing)

No.	Property	Easting	Northing
1	Glenvernoch	234582	575284
2	Knockville	236177	572416
3	Ochiltree	232312	574331
4	Glenruther	232373	573194

4.2.4 The assessment has considered operational noise from the Proposed Development at the measurement locations noted above, as well as other residential properties: these assessment locations are listed in Table 4.

4.2.5 In some instances, the results obtained at the survey positions have been used to represent the background environment expected to occur at other nearby assessment locations. The use of the data in this way is justified by the relatively similar nature of the terrain, the shared influence of 'natural' sources on background noise levels throughout the area (particularly at increased wind speeds) and the shared exposure to road traffic noise at the measurement and assessment properties located along the A714 road, running along the River Cree from the north to southeast of the Proposed Development. This approach is consistent with the guidance provided by ETSU-R-97 and current good practice as set out in the IOA GPG. Locations where such representations have been made, and the source of the representations, are represented in Table 4. It is noted that where such representations have been made, the distance between the assessment location and nearest turbine is comparable to, if not greater than, the distance between the reference monitoring location and the nearest turbine.

4.2.6 At some properties located further away from the proposed turbines, the simplified ETSU-R-97 noise limit (as outlined in paragraph 3.2.7 above) of 35 dB(A) was considered instead, as shown in Table 4.

4.2.7 A consent (application ref. 21/1078/FUL) for two recreational huts near the Clachaneasy property and situated in the Crungie Woods, has been granted on 22/11/2021 to construct the huts near the northeastern site boundary of the Proposed Development. The current consent is for recreational use of the huts, not for residential use and therefore they are considered as less sensitive to noise. However, on a precautionary basis the recreational hut 1, located closest to the Proposed Development turbines, is included in the noise assessment and treated as noise sensitive, as outlined in Table 4 below.

Table 4 - Assessment properties in the vicinity of the Proposed Development

Property	Easting	Northing	Approximate Distance to Closest Turbine (m)	Closest Turbine (ID)	Survey Location
Beoch	232189	571731	2480	T9	Simplified 35 dB(A) limit
Brigton	236003	574481	1290	T10	Knockville
Clachaneasy	235456	574930	1270	T10	Glenvernoch
Cordorcan Cottage	236958	572544	1220	T1	Knockville
Glassoch	233694	569591	2410	T2	Simplified 35 dB(A) limit
Glenhapple	237404	571348	1280	T1	Knockville
Glenruther	232373	573194	1560	T13	Glenruther
Glenruther Lodge	232221	572520	2010	T13	Ochiltree
Glenvernoch*	234582	575284	1420	T12	Glenvernoch
Glenvernoch Bungalow	234569	575436	1560	T12	Glenvernoch
Knockville*	236177	572416	610	T4	Knockville
Larg Farm	236069	574075	1180	T10	Knockville
North Lodge	237932	570526	2090	T1	Knockville
Ochiltree	232312	574331	1660	T13	Ochiltree
Old Larg House	236009	574220	1170	T10	Knockville
Shepherds Cottage	236540	573170	1230	T4	Knockville
Recreational Hut 1	235423	574725	1070	T10	Glenvernoch
** Financially involved with the Proposed Development*					

4.2.8 The background noise monitoring exercise was conducted over a period of just over six weeks, however the first two weeks of survey data were discarded as the LIDAR wind measurement device was in operation for four weeks only. Therefore four-weeks of survey data was used for the assessment and is in excess of the minimum of one week suggested by ETSU-R-97. The equipment used for the survey comprised four Rion NL-52 logging sound level meters. All meters were enclosed in environmental cases 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 1.2 to 1.4 metres above ground level, consistent with the requirements of ETSU-R-97.

4.2.9 The sound level meters were located on a side of the property in question facing the wind farm where possible, never closer than 3.5 metres from the façade of the property and as far away as was practical from obvious atypical localised sources of noise such as running water, trees or boiler flues. Details and photographs of the measurement locations are presented in Annex C.

4.2.10 All measurement systems were calibrated on their deployment on 24/10/2023, during interim servicing visits on 09/11/2023, 21/11/2023 and upon collection of the equipment on 05/12/2023. 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 26 days for each location, which is in excess of the minimum of one week suggested by ETSU-R-97 and is compliant with the IOA GPG requirements.

4.2.11 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) by the use of a Global Positioning System (GPS) receiver. The clock on the LIDAR 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.

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 Proposed Development to account for the potential effect of site-specific wind shear. This method is consistent with method C described in the IOA GPG. Values of wind speed at a standardised height of ten metres were calculated from those measured using a LIDAR at a measurement height of 114 m, located at approximate easting and northing: 233854/573685. Full details of the standardised wind speed calculation method are given in Annex F.

4.3.2 Figures D1 and D2 reproduced at Annex D show the range of wind conditions experienced during the noise survey period. During the quiet day-time and night-time periods wind speeds were up to a maximum of 13 m/s and 11 m/s respectively. The wind speeds were observed to be strongest from the northwest, with moderate to high wind speeds from the southeast and southwest directions during the survey period. Therefore, a suitably representative range of wind conditions were measured during the survey period, including south westerly wind directions typical for the UK.

4.3.3 Figures E1 to E10 of Annex E show the results of the background noise measurements at each of the four survey locations, in addition to the Shepherds cottage assessment 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 during the noise survey period at the Glenvernoch measurement location, positioned away from tall vegetation and buildings to maximise exposure to the sky; data from this gauge were therefore used to exclude those periods where rain was indicated, including 10 minutes prior and 10 minutes following a period of rainfall.

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 as a result of wet roads which increase tyre noise emissions or dissipating flow noise in water courses and drainage systems. Observations whilst on-site indicated traffic noise to be a distant influence on background sound levels at properties located to the north and east of the Proposed Development, and thus there was a limited effect of increased tyre noise from wet roads. In terms of water flow noise, there were no water courses noted in the immediate vicinity of the measurement locations that were considered likely to influence background noise levels. The monitoring locations were also positioned as far as practically possible from any residential drainage systems to minimise any associated noise influence from site observations, however there is still a potential for audible water drainage noise localised to the measurement positions, i.e. falling water from roofs and guttering during rainfall periods. Based on the above source considerations, rainfall is considered to have a limited effect on background sound levels.

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. For example, likely boiler flue noise at Glenruther was evident at low to medium wind speeds and excluded, detailed further in Appendix C. This was also observed from the time history, as a reoccurring sustained noisy event unrelated to the typical background noise occurred daily from around 18:00 to 19:40 GMT. 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 Existing wind turbine noise from the operational Kilgallioch Wind Farm, located 6 km west from Glenruther and Ochiltree, was not observed during the installation or on subsequent servicing visits at these properties, and is likely to be minimal given the separation distances involved. Therefore, as required by ETSU-R-97 and the IOA GPG, existing turbine noise from cumulative sites did not appear to influence the background noise measurements for the Proposed Development.

4.3.8 Following removal of those data points, best-fit lines were generated using a polynomial fit of a maximum of 4th order. These lines of best-fit define the ETSU-R-97 background noise levels (see Table 5 and Table 6) which were then 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. The derivation of the relevant fixed lower limit value used for day-time periods (38 dB(A)) is described in a section 5.6. For involved properties the lower absolute limit becomes 45 dB(A).

4.3.9 Simplified 35 dB(A) noise limits up to 10 m/s were applied to the Beoch and Glassoch assessment locations.

Table 5 - Day time L_{A90} (dB) background noise levels from the baseline noise survey 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
Glenvernoch	27.2	27.5	28.1	29.0	30.2	31.6	33.1	34.8	36.5	38.2	39.8	41.4
Knockville	24.1	22.2	21.7	22.3	23.9	26.2	29.1	32.3	35.6	38.9	41.9	44.4
Ochiltree	21.1	21.1	21.9	23.3	25.2	27.5	30.1	32.8	35.5	38.0	40.3	42.1
Glenruther	19.5	19.2	20.4	22.7	26.0	29.8	34.1	38.4	42.5	46.1	49.0	50.9

Table 6 - Night time L_{A90} (dB) background noise levels from the baseline noise survey 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
Glenvernoch	28.3	28.1	28.2	28.4	28.9	29.5	30.4	31.4	32.7	34.1	-	-
Knockville	23.3	23.1	22.1	21.3	21.7	23.5	27.0	31.7	37.1	42.2	-	-
Ochiltree	21.3	20.1	20.4	21.9	24.2	27.2	30.5	33.8	36.9	-	-	-
Glenruther	19.7	19.3	20.0	21.6	24.2	27.8	32.5	38.1	44.8	-	-	-

Table 7 - Day time L_{A90} (dB) noise limits derived from the baseline noise survey 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
Beoch**	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	#N/A	#N/A
Brigton	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	40.6	43.9	46.9	46.9
Clachaneasy	38.0	38.0	38.0	38.0	38.0	38.0	38.1	39.8	41.5	43.2	44.8	46.4
Cordorcan Cottage	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	40.6	43.9	46.9	46.9
Glassoch**	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	#N/A	#N/A
Glenhapple	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	40.6	43.9	46.9	46.9
Glenruther	38.0	38.0	38.0	38.0	38.0	38.0	39.1	43.4	47.5	51.1	54.0	54.0
Glenruther Lodge	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	40.5	43.0	45.3	47.1
Glenvernoch*	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	46.4
Glenvernoch Bungalow	38.0	38.0	38.0	38.0	38.0	38.0	38.1	39.8	41.5	43.2	44.8	46.4
Knockville*	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	46.9	46.9
Larg Farm	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	40.6	43.9	46.9	46.9
North Lodge	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	40.6	43.9	46.9	46.9
Ochiltree	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	40.5	43.0	45.3	47.1
Old Larg House	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	40.6	43.9	46.9	46.9
Shepherds Cottage	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	40.6	43.9	46.9	46.9

Property	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Recreational Hut 1	38.0	38.0	38.0	38.0	38.0	38.0	38.1	39.8	41.5	43.2	44.8	46.4

* Indicates the property is financially involved with the Proposed Development.
** Indicates the property is subject to a simplified noise limit.

Table 8 - Night time L_{A90} (dB) noise limits derived from the baseline noise survey 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
Beoch**	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	#N/A	#N/A
Brigton	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	47.2	47.2	47.2
Clachaneasy	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0
Cordorcan Cottage	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	47.2	47.2	47.2
Glassoch**	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	#N/A	#N/A
Glenhapple	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	47.2	47.2	47.2
Glenruther	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.1	49.8	49.8	49.8	49.8
Glenruther Lodge	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0
Glenvernoch*	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0
Glenvernoch Bungalow	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0
Knockville*	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	47.2	47.2	47.2
Larg Farm	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	47.2	47.2	47.2
North Lodge	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	47.2	47.2	47.2
Ochiltree	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0
Old Larg House	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	47.2	47.2	47.2
Shepherds Cottage	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	47.2	47.2	47.2
Recreational Hut 1	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0

* Indicates the property is financially involved with the Proposed Development.
** Indicates the property is subject to a simplified noise limit.

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.

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 non-financially involved property which would be closest to the activity for a portion of construction, and the predicted noise level. Table 10 only lists the construction activities for the nearest financially involved property, if the activity occurs closer to a financially involved property compared to a non-involved property. 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 for the nearest non-involved assessment locations

Task Name	Plant/Equipment	Upper Collective Sound Emission Over Working Day $L_{WA,T}$ dB(A)	Nearest Receiver	Minimum Distance to Nearest Receiver	Predicted Upper Day-Time L_{Aeq}
Construct temporary site compounds	excavator / dump truck / tippers / rollers/ delivery trucks	120	Cordorcan Cottage	720	52
Construct site tracks	excavators / dump trucks / tippers / dozers / vibrating rollers	120	Cordorcan Cottage	350	59
Construct Sub-Station	excavator / concrete truck / delivery truck	110	Cordorcan Cottage	820	40
Construct Battery Energy Storage Solution (BESS)	excavator / concrete truck / delivery truck	110	Cordorcan Cottage	720	42
Construct crane hardstandings	excavators / dump trucks	120	Larg Farm	1180	47
Construct turbine foundations	Piling Rigs / excavators / tippers / concrete trucks / mobile cranes / water pumps / pneumatic hammers	120	Larg Farm	1180	47

Task Name	Plant/Equipment	Upper Collective Sound Emission Over Working Day $L_{WA,T}$ dB(A)	Nearest Receiver	Minimum Distance to Nearest Receiver	Predicted Upper Day-Time L_{Aeq}
	/ compressors / vibratory pokers				
Erect turbines	cranes / turbine delivery vehicles / artics for crane movement / generators / torque guns	120	Larg Farm	1180	47
Reinstate crane bases	excavator / dump truck	115	Larg Farm	1180	42
Reinstate road verges	excavator / dump truck	115	Cordorcan Cottage	350	54
Excavate and lay site cables/ Lay cable to sub-stations and BESS	JCB / saws / hydraulic breaker / dump truck/ tipper / wacker plate / tandem roller / tractor & cable drum trailer / delivery truck	115	Cordorcan Cottage	720	47
Concrete Batching	Batching Plant	110	Cordorcan Cottage	720	42
Forestry felling around turbines and access tracks	Harvesters and forwarders, characterised by saw noise diesel engine noise emissions commonly associated with tractors and excavation noise	115	Cordorcan Cottage	350	54

Table 10 - Predicted construction noise levels for the nearest financially-involved assessment locations, if the activity lies closer to a financially involved location compared to a non-involved location.

Task Name	Plant/Equipment	Upper Collective Sound Emission Over Working Day $L_{WA,T}$ dB(A)	Nearest Receiver	Minimum Distance to Nearest Receiver	Predicted Upper Day-Time L_{Aeq}
Construct temporary site compounds	excavator / dump truck / tippers / rollers/ delivery trucks	120	Knockville	550	54
Construct Sub-Station	excavator / concrete truck / delivery truck	110	Knockville	570	44
Construct Battery Energy Storage Solution (BESS)	excavator / concrete truck / delivery truck	110	Knockville	550	44
Construct crane hardstandings	excavators / dump trucks	120	Knockville	610	53
Construct turbine foundations	Piling Rigs / excavators / tippers / concrete trucks /	120	Knockville	610	53

Task Name	Plant/Equipment	Upper Collective Sound Emission Over Working Day $L_{WA,T}$ dB(A)	Nearest Receiver	Minimum Distance to Nearest Receiver	Predicted Upper Day-Time L_{Aeq}
	mobile cranes / water pumps / pneumatic hammers / compressors / vibratory pokers				
Excavate and lay site cables/ Lay cable to sub-stations and BESS	JCB / saws / hydraulic breaker / dump truck/ tipper / wacker plate / tandem roller / tractor & cable drum trailer / delivery truck	115	Knockville	600	48
Erect turbines	cranes / turbine delivery vehicles / artics for crane movement / generators / torque guns	120	Knockville	620	53
Reinstate crane bases	excavator / dump truck	115	Knockville	610	48
Concrete Batching	Batching Plant	110	Knockville	610	43

5.1.5 Comparing the above predicted noise levels in Table 9 to the range of background noise levels measured around the Proposed Development 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 construction activities will have impacts of negligible magnitude. For the site access construction activity which is closest to Cordorcan Cottage, predicted noise levels (59 dB(A)) are likely to represent those for a very short term period when activity is closest to the receptor. Noise levels will diminish as access track construction progresses, moving the activity further from the site entrance away from the property. The short-term nature of this activity closest to Cordorcan Cottage consequently categorises the impact to be of negligible magnitude.

5.1.6 Comparing the levels for construction activity noise nearest the financially involved locations in Table 10 to the significance criteria, indicates that the construction activities will have impacts of negligible magnitude.

5.1.7 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 presented in Chapter 11: Traffic and Transportation has identified that the most intensive traffic will occur in the 6^{th} month of construction, with a maximum generation of 172 construction vehicles movements per day (including 112 HGV), or an average maximum of 9 HGV vehicle movements each hour, based on a 11-hour working day.

5.1.8 Table 11-11 of Chapter 11 has been used to ascertain the 2030 daily projected traffic flows for scenarios with and without the Proposed Development. These total daily vehicle counts are summarised in Table 11 below.

Table 11 - Projected traffic flows

Road	Without Development		With Development	
	Annual Average Daily Traffic Flow	% Heavy Goods Vehicles	Annual Average Daily Traffic Flow	% Heavy Goods Vehicles
A75 west	4116	32.1%	4288	33.4%
A75 east	4520	35.2%	4692	36.3%
U52W	1065	22.6%	1237	28.5%
A714	1202	24.1%	1374	29.3%

5.1.9 The methodology set out in CRTN has been used to determine the associated maximum total change in the average day time traffic noise level at any given location due to construction of the Proposed Development: see Table 12.

Table 12 - CRTN predicted increase in day-time average traffic noise levels ($L_{A10,18hour}$)

Road	Maximum Change in Traffic Noise Level, dB(A)
A75 west	0.3
A75 east	0.3
U52W	2.2
A714	1.8

5.1.10 Table 12 indicates a maximum potential increase of around 2 dB(A) in the day-time average noise level during the worst-case phase of the construction programme at locations adjoining the U52W or A714. Based on the criteria set out in the DMRB, the associated change in traffic noise level along these routes would correspond to a minor impact. However, these roads carry traffic levels which are close to the minimum value of 1000 vehicles per day that is required by the CRTN methodology to enable reliable prediction. Therefore, even worst-case traffic flows will remain low in absolute terms. At all other locations and proposed routes, the predicted increase is of 0.3 dB(A). Based on the criteria set out in the DMRB, this would correspond to a negligible impact.

5.1.11 Chapter 11 also considered potential cumulative wind farm developments but concluded that there are no current consented or proposed developments that would share both common access routes and potentially peak construction traffic periods, and that there would therefore not be a risk of additional cumulative construction traffic increases.

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

5.1.13 This conclusion is based on construction activities generally being limited to the following working hours: from 07:00 to 19:00 on weekdays, and 07:00 to 13:00 on Saturdays. However, activities that are unlikely to give rise to noise audible at the site boundary may continue outside of the stated hours. Other activities that may take place outside these hours are limited to emergency works and dust suppression, unless otherwise agreed in writing by the local authority. 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 Decommissioning Noise

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

5.3 Operational Wind Turbine Emissions Data

5.3.1 The exact model of turbine to be used at the site will be the result of a future tendering process and therefore a representative worst-case turbine model has been assumed for this noise assessment. This operational noise assessment is based upon the noise specification of the Vestas V172-7.2 MW wind turbine. 13 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 172 metres, a hub height of 114 metres and a tip height of 200 metres. Due to its variable speed operation, the sound power output of the turbine varies considerably with wind speed, being quieter at the lower wind speeds when the blades are rotating more slowly and reaching a maximum sound power level output at a standardised 10-metre-high wind speed of 7 m/s. The candidate turbine also incorporates the use of Serrated Trailing Edges (or STE), which reduce noise emissions, as standard.

5.3.2 In addition to its general low noise characteristic at lower wind speeds, the Vestas V172-7.2 MW turbine also incorporates noise control technology. This allows the sound power output of the turbine to be reduced across a range of operational wind speeds, albeit with some loss of electrical power generation, to enable the best compromise to be achieved in any given situation between emitted noise and electrical power generation. Noise control of the candidate turbine is provided in a number of noise control modes with various noise/power output combinations. Similar noise reduction management systems are also offered by other wind turbine manufacturers. These systems are generally similar in that they rely on the turbine's computer-based controller adjusting either the pitch of the blades or holding back the rotational speed of the blades to reduce emitted noise under selected wind conditions (direction, speed or some combination of the two). In this manner, noise management only comes into play (and therefore potential power generation capacity is only lost) for those conditions under which it is required. For the purposes of the present assessment, turbines 1, 3 and 10 have been assumed to operate in the “SO1” mode of the turbine and turbines 4, 7 and 8 have been assumed to operate in the “SO2” mode. The remaining seven turbines operate in their standard unconstrained operational mode “PO7200”. This is one example of an operational strategy to demonstrate achievable compliance with the proposed noise limits at the nearest surrounding properties. Other turbine models may be used with similar levels at neighbouring receptors, requiring less or no use of reduced noise modes.

5.3.3 Vestas have supplied specified noise emission data for the V172-7.2 MW turbine which has been derived from various 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 absence of availability of a representative sound power spectrum for the Vestas V172-7.2 MW turbine model, reference has been made to test reports for the Vestas V162-6.2 MW turbine model to derive a representative octave sound spectrum for the turbine, based on an energetic average of the available information at each one-third octave band, at a hub height wind speed (v_{hub}) of 11 m/s and normalised to a sound power level (L_{WA}) of 106.9 dB, to match the maximum L_{WA} emission level of the V172-7.2 MW turbine model. The overall sound power and spectral data are presented in Table B3 and B4 in Annex B.

5.3.4 Assessment of the cumulative noise from operating the Proposed Development together with the Kilgallioch Wind Farm and the Kilgallioch Extension Wind Farm also requires source information for their turbine types. The data assumed for the operational Kilgallioch Wind Farm is for 94 Gamesa G114 2.5MW and two Gamesa G90-2000 turbines, which are consistent with the installed turbine models. The data assumed for the consented Kilgallioch Extension Wind Farm is for 11 Vestas V150-6.0MW turbines with a tip height of 180m, consistent with the candidate turbine specified in the Environmental Statement noise assessment for Kilgallioch Extension Wind Farm[20], as it has not been constructed yet. Specified noise emission data for these turbine models running unconstrained are also presented in Annex B. In addition, representative sound power spectra for the turbine models are also presented in Annex B.

5.3.5 No additional increases to the cumulative sites predicted emmission levels were considered, however predictions have been made assuming worst case downwind propagation from every turbine to every receptor at the same time, as a precautionary assumption. The IOA good practice guidance (GPG) 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. The noise assessment receptors closest to the Kilgallioch and Kilgallioch Extension Wind Farm, and therefore where cumulative effects may potentially arise, cannot lie downwind from the Proposed Development and cumulative sites simultaneously, this precautionary downwind assumption is therefore particularly robust, and therefore no further allowances are required in line with the IOA GPG guidance.

5.4 Choice of Wind Farm Operational Noise Propagation Model

5.4.1 The ISO 9613-2 model[21] 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.

5.4.2 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.

5.4.3 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. As stated in the previous section, predictions have been made assuming downwind propagation from every turbine to every receptor at the same time as a worst-case.

5.5 Predicted Wind Farm Operational Noise Immission Levels

5.5.1 Table 13 shows predicted noise immission levels 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. As

[20] Kilgallioch Extension Environmental Impact Assessment Report Volume 1, Scottishpower Renewables, December 2019

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

discussed above the predictions assume the Proposed Development operates with reduced noise modes assumed for turbines T1, T3, T4, T7, T8 and T10.

Table 13 - 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 Proposed Development alone.

Property	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Beoch	-	-	20.7	23.9	29.0	32.0	32.3	32.3	32.3	32.3	32.3	32.3
Brigton	-	-	25.6	28.8	33.7	36.5	36.7	36.7	36.7	36.7	36.7	36.7
Clachaneasy	-	-	25.4	28.6	33.6	36.5	36.7	36.7	36.7	36.7	36.7	36.7
Cordorcan Cottage	-	-	26.3	29.4	34.3	36.9	37.1	37.1	37.1	37.1	37.1	37.1
Glassoch	-	-	19.4	22.6	27.6	30.6	30.9	30.9	30.9	30.9	30.9	30.9
Glenhapple	-	-	23.8	27.0	31.8	34.5	34.8	34.8	34.8	34.8	34.8	34.8
Glenruther	-	-	23.5	26.8	31.9	35.0	35.2	35.2	35.2	35.2	35.2	35.2
Glenruther Lodge	-	-	22.1	25.3	30.4	33.5	33.8	33.8	33.8	33.8	33.8	33.8
Glenvernoch	-	-	24.7	27.9	32.9	35.9	36.2	36.2	36.2	36.2	36.2	36.2
Glenvernoch Bungalow	-	-	23.7	27.0	32.0	35.0	35.3	35.3	35.3	35.3	35.3	35.3
Knockville	-	-	32.4	35.5	40.3	42.7	42.9	42.9	42.9	42.9	42.9	42.9
Larg Farm	-	-	27.0	30.2	35.0	37.7	37.9	37.9	37.9	37.9	37.9	37.9
North Lodge	-	-	19.5	22.7	27.6	30.4	30.6	30.6	30.6	30.6	30.6	30.6
Ochiltree	-	-	20.2	23.4	28.5	31.6	31.9	31.9	31.9	31.9	31.9	31.9
Old Larg House	-	-	26.7	29.9	34.8	37.5	37.7	37.7	37.7	37.7	37.7	37.7
Shepherds Cottage	-	-	27.3	30.5	35.3	37.8	38.0	38.0	38.0	38.0	38.0	38.0
Recreational Hut 1	-	-	26.8	30.0	34.9	37.8	38.0	38.0	38.0	38.0	38.0	38.0

5.5.2 Table 14 below shows the predicted noise immission levels from the combined operation of the Kilgallioch Wind Farm and Kilgallioch Extension Wind Farm. At the assessment locations to the east and north of the Proposed Development, the predicted contribution from the Killgallioch Wind Farm and Killgallioch Extension Wind Farm are all more than 10 dB below the contribution of the Proposed Development operating in isolation when comparing the results from Table 13 and Table 14, assuming simultaneous downwind propagation from all three sites. Therefore, these assessment locations are not considered further[22] in the cumulative assessment.

[22] 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 or more. The addition of a noise source 10 dB(A) below that of another theoretically adds 0.4 dB to the total but is not considered to require assessment according to the IOA GPG. Therefore, any increase of cumulative total noise levels by 0.4 dB or less is not considered acoustically relevant.

Table 14 – Predicted L_{A90} (dB) wind farm noise immission levels at each of the noise assessment locations as a function of standardised wind speed from the combined levels from the Kilgallioch Wind Farm and Kilgallioch Extension Wind Farm.

Property	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Beoch	-	-	15.0	16.9	22.1	25.3	25.4	25.4	25.4	25.4	25.4	25.4
Brigton	-	-	9.0	10.9	16.1	19.3	19.4	19.5	19.5	19.5	19.5	19.5
Clachaneasy	-	-	9.6	11.5	16.7	19.9	20.0	20.0	20.0	20.0	20.0	20.0
Cordorcan Cottage	-	-	8.1	10.0	15.2	18.5	18.6	18.6	18.6	18.6	18.6	18.6
Glassoch	-	-	11.8	13.7	18.9	22.1	22.3	22.3	22.3	22.3	22.3	22.3
Glenhapple	-	-	7.8	9.7	14.9	18.1	18.2	18.3	18.3	18.3	18.3	18.3
Glenruther	-	-	16.6	18.5	23.7	27.0	27.0	27.1	27.1	27.1	27.1	27.1
Glenruther Lodge	-	-	16.0	17.9	23.1	26.3	26.4	26.4	26.4	26.4	26.4	26.4
Glenvernoch	-	-	10.8	12.7	17.9	21.1	21.2	21.2	21.2	21.2	21.2	21.2
Glenvernoch Bungalow	-	-	10.9	12.7	17.9	21.2	21.3	21.3	21.3	21.3	21.3	21.3
Knockville	-	-	9.2	11.1	16.3	19.5	19.6	19.6	19.6	19.6	19.6	19.6
Larg Farm	-	-	9.0	10.9	16.0	19.3	19.4	19.4	19.4	19.4	19.4	19.4
North Lodge	-	-	7.1	9.0	14.2	17.4	17.6	17.6	17.6	17.6	17.6	17.6
Ochiltree	-	-	16.1	17.9	23.2	26.4	26.4	26.5	26.5	26.5	26.5	26.5
Old Larg House	-	-	9.0	10.9	16.1	19.4	19.5	19.5	19.5	19.5	19.5	19.5
Shepherds Cottage	-	-	8.5	10.5	15.6	18.9	19.0	19.0	19.0	19.0	19.0	19.0
Recreational Hut 1	-	-	9.8	11.7	16.9	20.1	20.2	20.2	20.2	20.2	20.2	20.2

5.5.3 Table 15 below shows predicted cumulative noise immission levels at the relevant cumulative assessment locations, where the difference between the Proposed Development and the cumulative sites considered is within 10 dB, west of the Proposed Development. The predictions in Table 15 are cumulative assuming the Proposed Development, Killgallioch Wind Farm and Killgallioch Extension Wind Farm are operating with the turbine models as set out in section 5.4 and that all receptors are downwind of all wind turbines at the same time. These cumulative noise levels are therefore unlikely to occur in practice.

Table 15 - Predicted L_{A90} (dB) wind farm cumulative noise immission levels at each of the cumulative 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
Beoch	-	-	21.7	24.7	29.8	32.9	33.1	33.1	33.1	33.1	33.1	33.1
Glassoch	-	-	20.1	23.1	28.2	31.2	31.4	31.4	31.4	31.4	31.4	31.4
Glenruther	-	-	24.3	27.4	32.5	35.6	35.9	35.9	35.9	35.9	35.9	35.9
Glenruther Lodge	-	-	23.0	26.1	31.2	34.3	34.5	34.5	34.5	34.5	34.5	34.5
Ochiltree	-	-	23.1	26.1	31.2	34.4	34.6	34.6	34.6	34.6	34.6	34.6

5.5.4 The prediction results in Table 15 shows the L_{A90} (dB) cumulative noise levels to lie below 35 dB(A) in the standardised wind speed range considered at four of the cumulative assessment properties above, except at Glenruther. Therefore, these four properties are not considered further in the cumulative noise assessment.

5.6 ETSU-R-97 assessment

5.6.1 Figures E1 to E8 (Annex E) show the calculated wind farm noise immission levels at relevant four background noise measurement and noise assessment locations, which correspond to the four locations already presented in Table 5 and Table 6 plotted as a function of standardised wind speed. For each noise measurement location, the corresponding noise assessment locations having the highest predicted noise levels are shown and so these charts represent assessment locations with the greatest impacts. The calculated noise immission levels are shown overlaid on the day-time and night-time noise limit curves. These limits curves have been derived by calculating best-fit regression lines through the measured background noise data to give the prevailing background noise curve required by ETSU-R-97. The noise limits have then been set either at the prevailing measured background level plus 5 dB or at the relevant fixed lower limit whichever is the greater.

5.6.2 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.

5.6.3 The assessment, shown in tabular form in Table 16 and Table 17 shows that the predicted wind farm noise immission levels from the Proposed Development in isolation lie below the simplified ETSU-R-97 noise criterion of 35 dB(A) up to the standardised wind speed of 10 m/s at the Glassoch and Beoch noise assessment locations. The assessment also shows that the predicted wind farm noise immission levels from the Proposed Development in isolation meet the ETSU-R-97 derived noise limits under the wind speed range considered at the noise assessment locations, based on a lower day-time limit of 38 dB(A) and lower night time limit of 43 dB(A). Glenvernoch and Knockville are both considered as involved properties and the lower absolute limits are therefore 45 dB(A).

Table 16 - Difference between the ETSU-R-97 derived day time noise limits and the predicted L_{A90} (dB) wind farm Noise immission levels at each noise assessment location from the Proposed Development. 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
Beoch	-	-	-14.3	-11.1	-6.0	-3.0	-2.7	-2.7	-2.7	-2.7	-	-
Brigton	-	-	-12.4	-9.2	-4.3	-1.6	-1.3	-1.3	-3.9	-7.2	-10.2	-10.2
Clachaneasy	-	-	-12.6	-9.4	-4.4	-1.6	-1.4	-3.1	-4.8	-6.5	-8.1	-9.7
Cordorcan Cottage	-	-	-11.7	-8.6	-3.8	-1.2	-0.9	-0.9	-3.6	-6.8	-9.8	-9.8
Glassoch	-	-	-15.6	-12.4	-7.4	-4.4	-4.1	-4.1	-4.1	-4.1	-	-
Glenhapple	-	-	-14.2	-11.0	-6.2	-3.5	-3.2	-3.2	-5.9	-9.1	-12.1	-12.1
Glenruther	-	-	-14.5	-11.3	-6.2	-3.0	-3.8	-8.1	-12.2	-15.9	-18.8	-18.8

Property	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Glenruther Lodge	-	-	-15.9	-12.7	-7.6	-4.5	-4.2	-4.2	-6.7	-9.2	-11.5	-13.4
Glenvernoch	-	-	-20.4	-17.1	-12.1	-9.1	-8.8	-8.8	-8.8	-8.8	-8.8	-10.3
Glenvernoch Bungalow	-	-	-14.3	-11.0	-6.0	-3.0	-2.9	-4.5	-6.2	-7.9	-9.6	-11.2
Knockville	-	-	-12.6	-9.5	-4.8	-2.3	-2.1	-2.1	-2.1	-2.1	-4.0	-4.0
Larg Farm	-	-	-11.0	-7.8	-3.0	-0.3	-0.1	-0.1	-2.7	-6.0	-9.0	-9.0
North Lodge	-	-	-18.5	-15.3	-10.4	-7.6	-7.4	-7.4	-10.0	-13.3	-16.3	-16.3
Ochiltree	-	-	-17.9	-14.6	-9.5	-6.4	-6.1	-6.1	-8.6	-11.1	-13.4	-15.2
Old Larg House	-	-	-11.3	-8.1	-3.2	-0.5	-0.3	-0.3	-2.9	-6.2	-9.2	-9.2
Shepherds Cottage	-	-	-10.7	-7.5	-2.7	-0.2	0.0	0.0	-2.6	-5.9	-8.8	-8.8
Recreational Hut 1	-	-	-11.2	-8.0	-3.1	-0.2	-0.1	-1.7	-3.4	-5.1	-6.8	-8.4

Table 17 - Difference between the ETSU-R-97 derived night time noise limits (or simplified 35 dB(A) noise limits where applicable) and the predicted L_{A90} (dB) wind farm Noise immission levels at each noise assessment location. 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
Beoch	-	-	-14.3	-11.1	-6.0	-3.0	-2.7	-2.7	-2.7	-2.7	-	-
Brigton	-	-	-17.4	-14.2	-9.3	-6.6	-6.3	-6.3	-6.3	-10.5	-10.5	-10.5
Clachaneasy	-	-	-17.6	-14.4	-9.4	-6.6	-6.3	-6.3	-6.3	-6.3	-6.3	-6.3
Cordorcan Cottage	-	-	-16.7	-13.6	-8.8	-6.2	-5.9	-5.9	-5.9	-10.1	-10.1	-10.1
Glassoch	-	-	-15.6	-12.4	-7.4	-4.4	-4.1	-4.1	-4.1	-4.1	-	-
Glenhapple	-	-	-19.2	-16.0	-11.2	-8.5	-8.2	-8.2	-8.2	-12.4	-12.4	-12.4
Glenruther	-	-	-19.5	-16.3	-11.2	-8.0	-7.8	-7.9	-14.5	-14.5	-14.5	-14.5
Glenruther Lodge	-	-	-20.9	-17.7	-12.6	-9.5	-9.2	-9.2	-9.2	-9.2	-9.2	-9.2
Glenvernoch	-	-	-20.4	-17.1	-12.1	-9.1	-8.8	-8.8	-8.8	-8.8	-8.8	-8.8
Glenvernoch Bungalow	-	-	-19.3	-16.0	-11.0	-8.0	-7.8	-7.8	-7.8	-7.8	-7.8	-7.8
Knockville	-	-	-12.6	-9.5	-4.8	-2.3	-2.1	-2.1	-2.1	-4.3	-4.3	-4.3
Larg Farm	-	-	-16.0	-12.8	-8.0	-5.3	-5.1	-5.1	-5.1	-9.3	-9.3	-9.3
North Lodge	-	-	-23.5	-20.3	-15.4	-12.6	-12.4	-12.4	-12.4	-16.6	-16.6	-16.6
Ochiltree	-	-	-22.9	-19.6	-14.5	-11.4	-11.1	-11.1	-11.1	-11.1	-11.1	-11.1
Old Larg House	-	-	-16.3	-13.1	-8.2	-5.5	-5.3	-5.3	-5.3	-9.5	-9.5	-9.5
Shepherds Cottage	-	-	-15.7	-12.5	-7.7	-5.2	-5.0	-5.0	-5.0	-9.2	-9.2	-9.2
Recreational Hut 1	-	-	-16.2	-13.0	-8.1	-5.2	-5.0	-5.0	-5.0	-5.0	-5.0	-5.0

5.6.4 Table 18 below outlines the cumulative noise assessment at Glenruther. As shown, the predicted cumulative wind farm noise immission levels from the Proposed Development, Kilgallioch Wind Farm and Kilgallioch Extension Wind Farm using simultaneous downwind propagation lie below the day time and night time background derived ETSU-R-97 noise limits at the Glenruther cumulative assessment location. This is also shown in Figures E9 and E10 in Annex E. At all other properties, cumulative levels are either negligible or such that cumulative levels are below the simplified limit of 35 dB as discussed in the previous section.

Table 18 - Difference between the ETSU-R-97 derived day time and night time noise limits and the predicted cumulative L_{A90} (dB) wind farm Noise immission levels at the Glenruther cumulative noise assessment location. Negative values indicate the immission level is below the limit

Glenruther cumulative noise assessment location, dB(A)	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Day time ETSU-R-97 limit	38.0	38.0	38.0	38.0	38.0	38.0	39.1	43.4	47.5	51.1	54.0	54.0
Night time ETSU-R-97 limit	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.1	49.8	49.8	49.8	49.8
Cumulative predicted noise level	-	-	-	27.4	32.5	35.6	35.9	35.9	35.9	35.9	35.9	35.9
Predicted level - Day Limit	-	-	-	-10.6	-5.5	-2.4	-3.2	-7.5	-11.6	-15.2	-18.1	-18.1
Predicted level - Night Limit	-	-	-	-15.6	-10.5	-7.4	-7.1	-7.2	-13.9	-13.9	-13.9	-13.9

5.6.5 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 discussed in turn below:

Number of properties: there is a relatively low number of isolated properties affected by noise from the Proposed Development. The area of the Proposed Development and its surroundings is generally of low population density, with a limited number of surrounding properties particularly to the south and west, with no immediate nearby villages surrounding the Proposed Development.

Duration and level of exposure: The properties to the south and west of the site experience low levels of background noise during the day and night time periods, particularly in calmer wind conditions. Whilst screened and distanced from road traffic noise compared to properties along the east of the site, these isolated properties to the west of the site are upwind of the windfarm under the prevailing south westerly wind direction of the UK. The charts of Annex E show that at Glenruther and Ochiltree, the level of exposure in terms of comparing the predicted turbine noise (from the Proposed Development) relative to background noise is comparable towards the upper middle range of measured baseline levels in quiet conditions during the day-time and night time at these properties. The predictions are based on downwind conditions (wind blowing from source to receiver), and the actual levels which occur in practice will be considerably lower (10 dB(A) to 15 dB(A)) under upwind conditions. Bearing in mind the prevailing south westerly wind direction of the UK further reduces the portion of the time for which the benefit of an increased lower limit is required at these properties.

Properties to the east of the site based on background measurements at Knockville also show reduced background noise levels during low wind speed conditions. However, predictions in the charts of Annexe E, for Knockville and Shepherds Cottage show more elevated turbine noise levels at these properties which are also located downwind from the Proposed Development, during prevailing south westerly UK winds. This suggests a higher level and duration of exposure at these properties. However, the use of background noise measurements at Knockville for most of the properties east of the site is considered precautionary, as Knockville is located further from the A road and river compared to properties at the bottom of the hill (such as Shepherds Cottage).

Reduced road noise and no watercourse noise aligns with observations at the Knockville measurement position.

Generation capacity: The effect that having a limit at the lower end of this range would have on the number of turbines installed would be detrimental to the overall large (>80 MW) energy generation of the scheme. Indeed, the generation capacity of the site is a relevant consideration. The power generating capacity of modern wind turbines has dramatically increased over that which was typical at the time the ETSU-R-97 guidelines were produced. For example at the time the guide was produced, a wind farm site comprising around 143 turbines would have been required to achieve a similar generating capacity to that of the Proposed Development (up to 86 MW depending on the installed turbine model), thus highlighting the national significance of the scheme.

5.6.6 Based on the above considerations, it is considered wholly appropriate on balance to set the lower fixed portion of the day-time ETSU-R-97 noise limit towards the middle of the range at 38 dB(A).

5.6.7 In conclusion, predicted noise from the Proposed Development including predicted noise from operating Kilgallioch Wind Farm and Kilgallioch Extension Wind Farm where relevant, is compliant with the ETSU-R-97 criteria at all locations and all wind speeds. This outcome has been achieved through use of operational reduced noise mode turbine constraints applied to six of the Proposed Development turbines assuming worst-case downwind predictions.

5.6.8 The selection of the final turbine to be installed at the site should be made on the basis of enabling the relevant ETSU-R-97 noise limits of Table 7 and Table 8 to be achieved at the surrounding assessment properties.

5.7 Blair Hill Wind Farm

5.7.1 The Blair Hill Wind Farm is a proposal located south-east of the Proposed Development (approximately 5 km away) which is currently at scoping stage. There is therefore limited environmental information which would not allow a complete cumulative noise assessment to be undertaken. This report however presents an indicative analysis based on a likely finalised wind turbine layout (obtained from the developer of Blair Hill Wind Farm) and an indicative wind turbine model (Vestas V172-7.2 MW), on a worst-case basis (see Appendix B for turbine model information) that is assumed to be representative of the likely turbine dimensions of the indicative Blair Hill turbine layout. This was modelled to provide an indication of potential cumulative noise implications of a future planning submission for this wind farm for the assessment properties considered in Table 4.

5.7.2 Using the derived noise model, noise immission levels from the Blair Hill Wind Farm in isolation at the assessment locations in Table 4 are predicted to be no more than 29 dB L_{A90} as shown in Table B12 in Appendix B.

5.7.3 Table B13 in Appendix B shows the estimated contribution from the Blair Hill Wind Farm is more than 10 dB below the predicted noise levels of Table 13 (from the Proposed Development operating alone) in most cases. Therefore, the contribution of noise from the Blair Hill Wind Farm is negligible at the majority of the noise assessment receptors identified for the Proposed Development.

5.7.4 For the remaining three assessment receptors highlighted in Table B13 of Appendix B where predicted noise from the Proposed Development in isolation are within 10 dB of the predicted levels for the Blair Hill Wind Farm, predicted cumulative noise emission levels from these two schemes at these locations, shown in Table B14 in Appendix B, are either below or closer to 35 dB and clearly below the ETSU-R-97 derived noise limits in Table 7 and Table 8. These predictions also assume worst case downwind effects from both schemes simultaneously, therefore these levels are unlikely to occur in practice.

5.7.5 The above indicative assessment therefore indicates that the Blair Hill Wind Farm is unlikely to affect the conclusions of the ETSU-R-97 assessment set out above.

5.8 Low Frequency Noise, Vibration and Amplitude Modulation

5.8.1 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. 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.

5.8.2 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.

5.9 Substation and battery storage operational noise

5.9.1 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.

5.9.2 Battery Energy Storage System (BESS) facilities also have a combination of electrical plant as well as temperature control equipment, such as cooling fans, but are less likely overall to have a noise which is strongly tonal in nature.

5.9.3 The operational noise from the substation and BESS equipment have been predicted at the nearest respective non-financially involved residential property following the methodology set out in ISO 9613-2. These operational noise level predictions have been undertaken using a receiver height of four metres above local ground level, soft ground (G=1) conditions away from the sources and an air absorption based on a temperature of 10°C and 70% relative humidity. No allowance has been included for screening provided by intervening buildings or equipment structures, which is likely to be precautionary. No allowance for terrain screening has been considered in the prediction model, also as a precautionary assumption.

5.9.4 The proposed BESS facility area is located approximately 720 m from the nearest non-financially involved residential property, Cordorcan Cottage. The design of the BESS facility and associated plant selection are not finalised at this stage, but an assessment has been undertaken using a representative plant selection assuming the BESS units are positioned in a worst case location within the BESS facility area, along the designated area boundary closest to Cordorcan Cottage, based on a 10 MW capacity. Noise specification data was made available for similarly rated units to those typically sited for a development of this scale, with total sound power output of 99 dB L_{wA} assuming five BESS/power units of 92 dB L_{wA} each. The corresponding predicted noise levels from the BESS at Cordorcan Cottage would be less than 26 dB L_{Aeq}.

5.9.5 The proposed substation is located approximately 820 m from the nearest non-involved residential property, Cordorcan Cottage. The substation area is also located adjacent to the west of the BESS facility area. Noise specification data was referenced based on those typically used for a development of this scale, with total sound power output of 96 dB L_{wA} for two transformer units. This is considered representative of two transformers operating at their maximum sound power level with forced air cooling (fans) operational. The corresponding predicted noise levels from the substation at Cordorcan Cottage would be less than 24 dB L_{Aeq}.

5.9.6 Therefore, the combined total operational noise from the assumed BESS units and substation predicted at Cordorcan Cottage, results in a specific noise level of less than 28 dB L_{Aeq}.

5.9.7 A representative background noise level of 23 dB L_{A90}, during quiet night time periods and low wind speed conditions between the standardised wind speeds from 1 to 4 m/s, was determined from Figure E2 in Annex E from the Knockville noise measurement location to represent background noise levels at Cordorcan Cottage.

5.9.8 In accordance with the method described in BS 4142 a correction for the potential acoustic features has also been included to provide the 'rating level'. Corrections can be applied for tonal, impulsive and /or intermittent characteristics that have the potential to lead to increased awareness of a sound. As a precaution +2 dB has been added to the total specific noise level of 28 dB(A) for a tone that is just perceptible, to account for potential noise from the substation transformers. Therefore, a total rated noise level of 30 dB L_{Ar} is determined.

5.9.9 This 'rating level' is compared against the typical L_{A90} background noise levels measured at Knockville during low wind speed conditions to estimate the likely impact of the BESS and substation operational noise at the nearest non-involved noise sensitive assessment location, Cordorcan Cottage.

5.9.10 The predicted rated level of 30 dB L_{Ar} at Cordorcan Cottage lies 7 dB above the representative background noise level of 23 dB L_{A90}, however is also clearly less than 35 dB(A). BS 4142 requires consideration of several contextual factors including the nature of the source and the environment, but also the absolute levels of the noise. Given these factors, when assessed against the criteria derived in Table 1, predicted noise from the BESS and substation transformers at the nearest non-involved noise assessment location (Cordorcan Cottage) would correspond to a minor impact.

5.9.11 Slightly higher L_{Ar} (dB) noise levels at Knockville, a property located approximately 560 m from the BESS and Substation facility areas were predicted, however considering the financial involvement of the property with the Proposed Development, a minor impact at this assessment location from the BESS and Substation operational noise is concluded.

5.9.12 Because of the above conclusions, the nature of the sources and the different guidance documents applicable in each case, it is considered based on professional judgement that there would be no additional in-combination operational noise impacts from the wind turbine noise in addition to that from the BESS and substation equipment.

6. Summary of Key Findings and Conclusions

6.1.1 This report has presented an assessment of the impacts of construction and operational noise from the Proposed Development on the residents of nearby dwellings.

6.1.2 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 assigned to 16 surrounding properties have used either a simplified fixed noise limit or have been derived from the existing background noise levels, as derived from measurements made over approximately four weeks at each measurement location.

6.1.3 The construction noise assessment has determined that associated levels are expected to be audible at various times throughout the construction programme but remain with acceptable limits such that their temporary impacts are considered of negligible magnitude. Worst-case traffic increases associated with the construction could correspond to an increase on traffic noise along parts of the construction route which would correspond to a minor impact at most.

6.1.4 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 Scottish Planning Policy.

6.1.5 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 specified sound power data for the Vestas V172-7.2 MW wind turbine which is robust and typical of the type and size of turbine which may be considered for this site for noise emissions, and assuming worst case downwind propagation. This outcome can be achieved through use of turbine constraints applied to six turbines in the case of the candidate assessment turbine model. For other available turbine models, different or no reduced noise constraint modes may be required.

6.1.6 Operational noise from the BESS and substation infrastructure equipment has been assessed in accordance with the methodology set out in BS-4142 and a minor impact was achieved. This assessment has been based on the use of available sound power data from components similarly rated to those likely to be installed, assuming a conservative case without screening from structures or terrain.

6.1.7 In summary, the overall levels of construction noise are considered to represent a negligible to minor impact. 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.

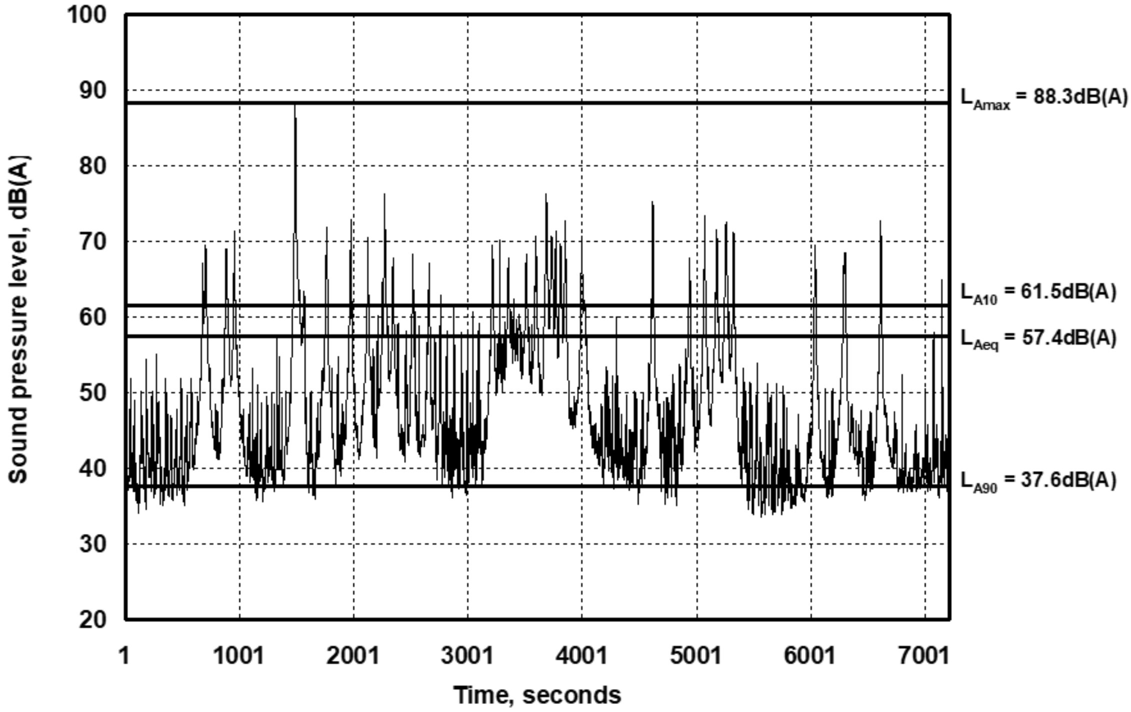
A.5. Before reviewing the potential effects of environmental sound on people, it is useful first to consider the means by which physical sound can be quantified.

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. Figure 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 Figure 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.

Figure 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 Figure 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 Figure 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. Figure 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'. 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.

A.55. 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.56. 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.57. 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.58. 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.59. 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.60. 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 infrasound and vibration

A.61. Over the past few years there has been considerable attention paid to the possibility that operational wind farms may radiate sufficiently high levels of infrasound or vibration to cause health problems. Dedicated research investigations have however repeatedly shown this not to be the case.

A.62. As early as 1997 a report by Snow[23] 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.

A.63. Noise and vibration levels were found to comply with recommended residential criteria even on the wind turbine site itself. Although 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.64. 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[24]. Dr Leventhall notes that despite the numerous published studies there is little or no agreement about the

23 'Low frequency noise and vibration measurements at a modern wind farm', D. Snow, ETSU Report ETSU W/13/00392/REP, 1997
24 'A review of published research on low frequency noise and its effects', G. Leventhall, report for DEFRA, 2003

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.65. 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.66. 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[25] 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.67. They then continue:

> *'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'.*

A.68. In relation to airborne infrasound as opposed to ground-borne vibrations, the researchers are equally robust in their conclusions, stating:

> *'The infrasound generated by wind turbines can only be detected by the most sensitive equipment, and again this is at levels far below that at which humans will detect low frequency sound. There is no scientific evidence to suggest that infrasound [at such an extremely low level] has an impact on human health'.*

A.69. 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[26]. This Report

25 'Wind farm noise', P. Styles, letter by Prof P Styles and S Toon printed in The Scotsman, August 2005.
26 'The measurement of low frequency noise at three UK wind farms', M. Hayes, DTI Report W/45/00656/00, 2006

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.*
>
> *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.70. This has been subsequently confirmed by many international studies and reviews. For example, a study for the National Institute for Public Health and the Environment (RIVM) in the Netherlands[27] 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.71. 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.

Low frequency sound

A.72. A report prepared for DEFRA by Casella Stanger[28] lists wind farms as a possible source of audible low frequency sound (20 Hz to 200 Hz). However, this is one possible source in a list of many commonly encountered sources such as pumps, boilers, fans, road, sea and rail traffic, the wind, thunder, the sea, etc. The report only considers the general issues associated with low frequency sound and makes no attempt to quantify the potential problem associated with each of these sources. This is in contrast to other reports which have considered the specific situation associated with wind farms.

A.73. In respect of low frequency sound as opposed to infrasound, the DTI LFN Report identified that wind farm noise levels at the studied properties were, under certain conditions, measured at a level just above the threshold of audibility. The report therefore concluded that 'for a low frequency sensitive person, this may mean that low frequency sound associated with the operation of the three wind farms could be audible within a dwelling'. This conclusion was, however, placed into some context with the qualifying statement that 'at all measurement sites, low frequency sound associated with traffic movements along local roads has been found to be greater than that from the neighbouring wind farm'. In particular, it was concluded that, although measurable and under some conditions may be audible, levels of low frequency sound were below permitted night time low frequency sound criteria, including the latest UK criteria resulting from the 2003 DEFRA study into the effects of low frequency sound.

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27 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.

28 'Low frequency noise', Report by Casella Stanger for DEFRA, 2001.

A.74. Based on the findings of the DTI LFN Report, 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.75. In November 2006, the UK Government released a statement[29] concerning low frequency sound, reiterating the conclusion of the DTI LFN report that:

> *'there is no evidence of health effects arising from infrasound or low frequency sound generated by wind turbines'.*

A.76. The Government statement concluded the position regarding low frequency sound from wind farms with the definitive advice to all English Local Planning Authorities and the Planning Inspectorate that PPS22 and ETSU-R-97 should continue to be followed for the assessment of noise from wind farms.

Blade swish (amplitude modulation)

A.77. 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 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.

29 'Advice on Findings of the Hayes McKenzie Report on Noise Arising from Wind Farms', URN 06/2162 (November 2006).

A.78. 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[30]. 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.79. 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[31] 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.80. 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'.*

A.81. 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[32]. This research, commissioned by RenewableUK (ReUK) was specifically aimed at identifying and explaining some of the key features of wind turbine AM noise.

A.82. 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.83. 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

30 'Research into Aerodynamic Modulation of Wind Turbine Noise', Report by University of Salford, URN 07/1235 (July 2007)

31 'Government statement regarding the findings of the Salford University report into Aerodynamic Modulation of Wind Turbine Noise', BERR, Ref: 2007/033 (1st August 2007)

32 Wind Turbine Amplitude Modulation: Research to Improve Understanding as to its Cause and Effect, Renewable UK, December 2013.

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.84. 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[33] for implementation as a planning condition, although this was subject to discussion.

A.85. The Institute of Acoustics (IOA) published in 2016 a standardised methodology[34] 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.86. 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[35] 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 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.87. A Scottish Government onshore wind policy statement[36] published in late 2022 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 "*until such time as new guidance is produced*". Subsequently, a report commissioned by the UK Department for Business, Energy & Industrial Strategy was published[37] 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 national governments conclude such a review, the ETSU-R-97 methodology continues to be applicable. The UK Government has also confirmed[38] that ETSU-R-97 should continue to apply until the review recommendations are considered in further detail.

33 Template Planning Condition on Amplitude Modulation (guidance notes), RenewableUK, December 2013.
34 Institute of Acoustics (IOA) Amplitude Modulation Working Group, Final Report, A Method for Rating Amplitude Modulation in Wind Turbine Noise, June 2016.
35 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
36 Scottish Government (2021) - Onshore wind - policy statement 2022, December 2022.
37 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).
38 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 January 2023]

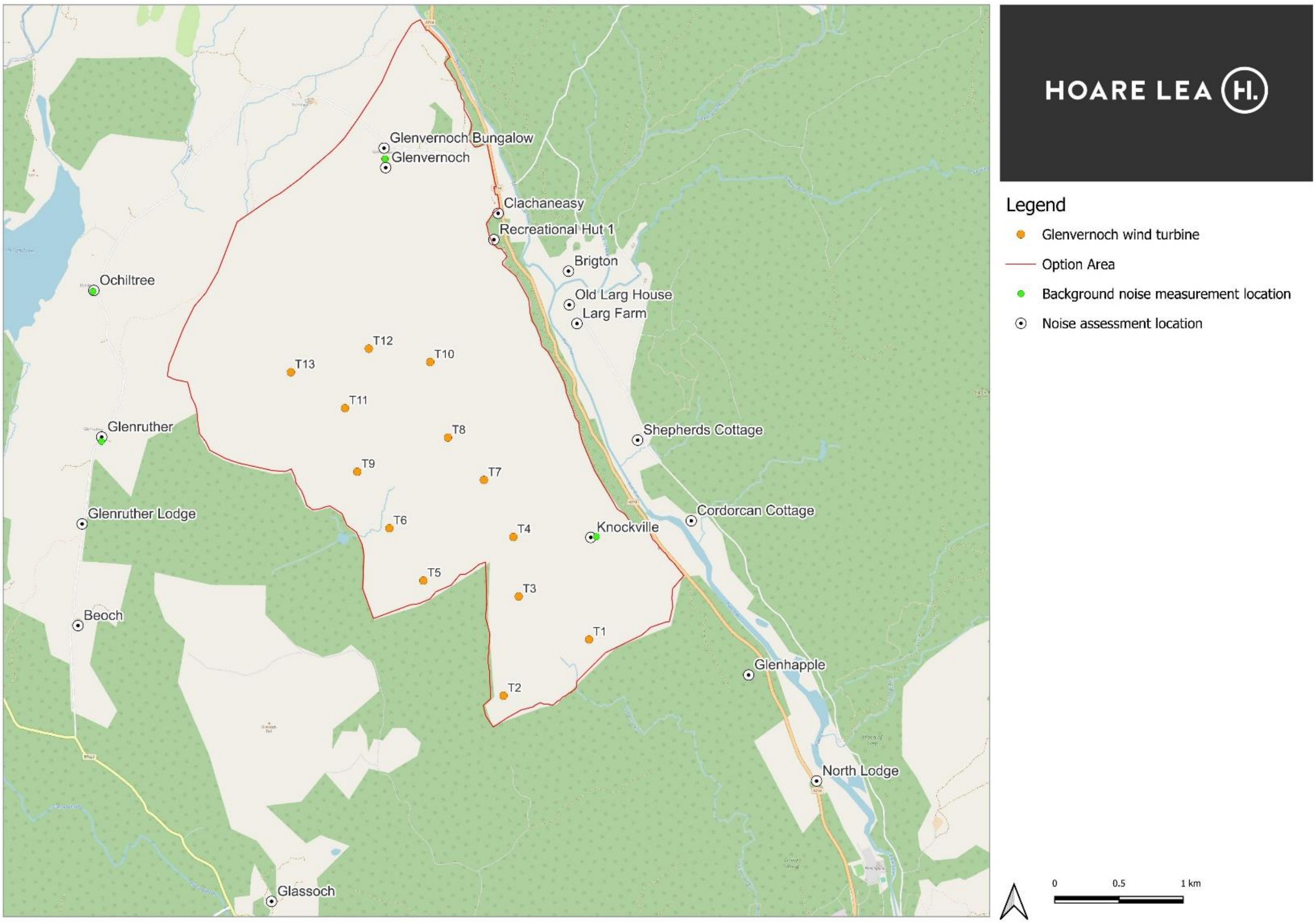
Glossary of Acoustics Terminology

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 Map & Turbine Information

Figure B1 - Map showing the layout of the Proposed Development (Glenvernoch wind turbines), noise assessment locations, background noise measurement locations and the redline option area.



Turbine & Propagation Details: the Proposed Development

Table B1 – Turbine coordinates – the Proposed Development

Turbine	Easting	Northing	Turbine	Easting	Northing
T1	236163	571623	T8	235065	573190
T2	235498	571188	T9	234360	572925
T3	235616	571957	T10	234928	573776
T4	235574	572419	T11	234265	573418
T5	234874	572081	T12	234450	573880
T6	234610	572487	T13	233844	573697
T7	235346	572861			
All turbines modelled using a hub height of 114 m, a rotor diameter of 172 m and a tip height of 200 m. With turbines 1, 3 and 10 operating in Mode SO1 and turbines 4, 7 and 8 operating in Mode SO2 at all times.					

Table B2 - Propagation attenuation effects due to terrain (dB) – the Proposed Development – 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 name	Turbine ID												
	1	2	3	4	5	6	7	8	9	10	11	12	13
Beoch	0	0	0	0	0	0	0	0	0	0	0	0	0
Brigton	0	0	0	0	0	0	0	0	0	0	0	0	0
Clachaneasy	0	0	0	0	0	0	0	0	0	0	0	0	0
Cordorcan Cottage	0	0	0	0	0	0	0	0	0	0	0	0	0
Glassoch	0	0	0	0	0	0	0	0	0	0	0	0	0
Glenhapple	0	0	0	0	0	0	0	0	0	0	0	0	0
Glenruther	0	0	0	0	0	0	0	0	0	0	0	0	0
Glenruther Lodge	0	0	0	0	0	0	0	0	0	0	0	0	0
Glenvernoch	0	0	0	0	0	0	0	0	0	0	0	0	0
Glenvernoch Bungalow	0	0	0	0	0	0	0	0	0	0	0	0	0
Knockville	0	0	0	0	0	0	0	0	0	0	0	0	0
Larg Farm	0	0	0	0	0	0	0	0	0	0	0	0	0
North Lodge	0	0	0	0	0	0	0	0	0	0	0	0	0
Ochiltree	2	2	2	2	2	2	2	2	2	2	2	2	2
Old Larg House	0	0	0	0	0	0	0	0	0	0	0	0	0
Shepherds Cottage	0	0	0	0	0	0	0	0	0	0	0	0	0

Table B3 - Wind turbine sound power levels (dB L_{Aeq}) used in the noise assessment - the Proposed Development

Turbine make / model	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Vestas V172-7.2 MW 117m hub height Mode PO7200	-	-	96.8	100.1	105.3	108.6	108.9	108.9	108.9	108.9	108.9	108.9
Mode SO1	-	-	96.4	99.5	104.2	106.8	107.0	107.0	107.0	107.0	107.0	107.0
Mode SO2	-	-	96.4	99.5	104.1	105.9	106.0	106.0	106.0	106.0	106.0	106.0
Derived from: Vestas specification documentation: '0127-1584_V01 - Performance Specification V172-7.2 MW.pdf', dated 07/08/2022. Values presented above are for the serrated trailing edge variant (STE) and include a +2dB uncertainty margin in the absence of uncertainty information in the available documentation.												

Table B4 - Octave band sound power spectrum (dB L_{Aeq}) for reference wind speed conditions (v_{10} = 8 m/s) - the Proposed Development

Turbine make / model	Octave Band Centre Frequency (Hz)								
	63	125	250	500	1000	2000	4000	8000	A
Vestas V162-6.2 MW	88.2	95.7	100.2	102.0	100.9	96.9	90.2	80.5	106.9
Derived from: Spectra currently unavailable for the V172-7.2MW turbine, therefore Lw Data from Document: V162-6.2MV Third Octaves, 0105-5200_00.pdf', Table 1: V162-PO6200, expected 1/3 octave band performance, (Blades with serrated trailing edges (STE)). Frequency spectrum converted from 1/3 octaves given by Vestas at a hub height wind speed of v_{hub} = 11 m/s, normalised to the V172-7.2 MW turbine, mode PO7200 with STE to a maximum L_{wA} output of 106.9 dB.									

Turbine & Propagation Details: Kilgallioch Wind Farm

B.1. Kilgallioch Wind Farm is built and operating. Installed coordinates for the turbines (numbered and prefixed ‘K##’) are outlined below.

B.2. Sound power levels for the Kilgallioch wind turbines are taken from documents made available to ourselves for the installed Gamesa G114 2.5MW turbines and the two Gamesa G90-2000 turbines (K21 and K23) turbines as referenced in the tables below. An additional +2dB margin in accordance with the Gamesa documentation was added to get to the 'Declared' L_{WA} values specified by Gamesa, for both turbine models.

Table B5 - Turbine coordinates – Kilgallioch Windfarm

Turbine	Easting	Northing	Turbine	Easting	Northing	Turbine	Easting	Northing
K01	221284	573400	K33	219210	571758	K65	221918	570112
K02	220072	571827	K34	219203	571191	K66	222295	569800
K03	220465	572195	K35	219598	570802	K67	223192	574519
K04	220731	571792	K36	220035	570428	K68	223644	574783
K05	220900	572396	K37	221495	575014	K69	223955	574311
K06	221247	572719	K38	221598	574380	K70	224402	574111
K07	221199	572116	K39	221574	573804	K71	224306	573543
K08	221608	571791	K40	221226	574707	K72	222864	574135
K09	221210	571510	K41	221199	575371	K73	222799	573434
K10	221179	570928	K42	221121	574061	K74	222798	572774
K11	220800	573102	K43	220828	574343	K75	223198	573124
K12	219695	571534	K44	220477	574663	K76	223186	573757
K13	219965	571108	K45	220827	574957	K77	223583	575959
K14	220294	571452	K46	220309	574003	K78	224010	575746
K15	220778	571135	K47	223205	576313	K79	223613	575445
K16	220429	570856	K48	222765	576211	K80	223223	575738
K17	220832	570468	K49	222150	576169	K81	223248	575133
K18	221199	570161	K50	222446	575756	K82	224078	575118
K19	220407	572794	K51	222795	575397	K83	224502	575413
K20	220401	570143	K52	222359	575141	K84	224895	575753
K21	220800	569809	K53	222000	574733	K85	224910	575156
K22	221144	569561	K54	222001	575362	K86	225581	575208
K23	221229	568759	K55	222478	574551	K87	225264	574811
K24	222009	569497	K56	222005	574092	K88	224916	574456
K25	222379	569253	K57	222408	573742	K89	224534	574857
K26	221696	569041	K58	222299	573074	K90	224899	573767
K27	220795	573770	K59	221970	572787	K91	225275	574090
K28	220426	573419	K60	222409	572360	K92	225647	574462
K29	219980	573695	K61	222006	570712	K93	226200	574760
K30	220007	573051	K62	221566	570520	K94	225954	574032
K31	219920	572490	K63	221608	571141	K95	226365	573720
K32	219573	572156	K64	222282	570371	K96	225656	573721

Turbine	Easting	Northing	Turbine	Easting	Northing	Turbine	Easting	Northing
All turbines modelled assuming a hub height of 88 m, except turbines K21 & K23 each modelled with a hub height of 78 m.								

Table B6 - Wind turbine sound power levels (dB L_{Aeq}) used in the noise assessment – Kilgallioch Windfarm.

Turbine make / model	Standardised 10 m Wind Speed (m/s)									
	3	4	5	6	7	8	9	10	11	12
Gamesa - G114 IIA 2.5MW[1] Basic unconstrained mode 93 m source data hub height	97.8	99.5	104.8	108.0	108.0	108.0	108.0	108.0	108.0	108.0
Gamesa G90 2 MW[2] Unconstrained mode 78 m source data hub height	93.4	97.9	102.7	106.6	107.0	107.0	107.0	107.0	107.0	107.0

[1] Derived from: Gamesa documentation: 'G114 IIA 2.5MW 50/60 Hz Wind Turbine Power Curve and noise emission level' - GD181659-en (25/10/2013) & 'G114 IIA 2.5MW 50/60 Hz Power and Noise curves for low noise operating mode (NRS)' - GD181660-en (03/12/2013)

[2] Derived from: Overall sound power levels from two documents, one for full power and the other for noise modes. From GD080626-en Rev0 12/04/10 and GD080632-en Rev0 12/04/10 documents.

Table B7 - Octave band sound power spectrum (dB L_{Aeq}) for reference wind speed conditions (v_{10} = 8 m/s) - Kilgallioch Windfarm.

Turbine make / model	Octave Band Centre Frequency (Hz)								
	63	125	250	500	1000	2000	4000	8000	A
Gamesa - G114 IIA 2.5MW[3]	79.2	86.3	91.9	95.0	94.9	91.2	85.4	74.5	100.0
Gamesa G90 2MW[4]	88.0	95.6	100.6	102.4	100.2	95.8	90.6	92.2	107.0

[3] Derived from: 'G114 2.5MW IIA 50/60Hz Noise Emission Analysis' document- GD208973-en (09/12/13). Provided in 1/3 octave bands normalised to 100dB, converted to octave bands.

[4] Derived from: Gamesa summary test report WT 6432/08 (extract from WT 6432/08), normalised to 107dBA.

Turbine & Propagation Details: Kilgallioch Extension Wind Farm

B.3. Kilgallioch Extension Wind Farm was consented on 08/12/2021 however it is not currently built. Coordinates for the turbines relate to the 11-turbine layout (numbered and prefixed 'Kext ##').

B.4. Sound power levels for the 11 wind turbines as specified in the Environmental Statement noise assessment are taken from documents made available for the Vestas V150-6.0 MW wind turbine as referenced in the tables below. 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 (v_{10}) of 3 m/s to 12 m/s inclusive. In addition to the overall sound power data, reference has been made to octave band specification documentation for the unit to derive a representative octave band sound spectrum for the turbine, based on an energetic average of the available information at each third octave band and normalised to 100 dB based on a hub height wind speed of 12 m/s.

Table B8 - Turbine coordinates – Kilgallioch Extension Wind Farm

Turbine	Easting	Northing	Turbine	Easting	Northing
Kext 1	224926	569849	Kext 9	224228	569777
Kext 2	222904	570588	Kext 10	223551	569794
Kext 3	223603	570349	Kext 11	224519	569291
Kext 4	222907	569869			
Kext 5	224015	570833			
Kext 6	224832	570361			
Kext 7	224572	570851			
Kext 8	223403	570880			
All turbines modelled assuming a hub height of 105 m					

Table B9 - Wind turbine sound power levels (dB L_{Aeq}) used in the noise assessment – Kilgallioch Extension Wind Farm

Turbine make / model	Standardised 10 m Wind Speed (m/s)									
	3	4	5	6	7	8	9	10	11	12
Vestas V150 6.0 MW Mode 0	94.8	98.2	102.5	106.0	106.8	106.9	106.9	106.9	106.9	106.9
Derived from: Vestas specification document: 'Performance Specification V150-6.0 MW'. Document ref. 0098-0749.V01. Dated 13/10/2020. The values shown above include +2 dB added for uncertainty and converted to standardised wind speeds.										

Table B10 - Octave band sound power spectrum (dB L_{Aeq}) for reference wind speed conditions (v_{10} = 12 m/s) - Kilgallioch Extension Wind Farm

Turbine make / model	Octave Band Centre Frequency (Hz)								
	63	125	250	500	1000	2000	4000	8000	A
Vestas V150-6.0 MW	81.1	88.7	93.4	95.1	94.0	89.9	82.9	72.9	99.9
Derived from: 'V150-6.0MW Third Octaves', Document ref. 0095-3747.V01. Dated 03/11/2020. Table 1: 'V150-PO6000, expected 1/3 octave band performance'. Frequency spectrum converted from 1/3 octaves given by Vestas and normalised to 100 dB at a hub height wind speed of 12 m/s.									

Turbine Details: Blair Hill Wind Farm

B.5. Although finalised details are not available, the likely finalised wind turbine layout of Table B11 was modelled for the Blair Hill Wind Farm. The noise emissions assumed were based on the Vestas V172 7.2 MW model as used for the Proposed Development, which is also considered representative of the turbine model which could be installed for this Wind Farm. All turbines were assumed to operate unconstrained. The resulting Vestas V172 7.2 MW model noise emission data is set out in Tables B3/B4 as above for the Proposed Development.

Table B11 – Turbine coordinates – Blair Hill Wind Farm

Turbine	Easting	Northing	Turbine	Easting	Northing
BH1	242473	574210	BH9	241652	571803
BH2	242694	573636	BH10	242193	571483
BH3	242305	573204	BH11	241546	571218
BH4	241753	572981	BH12	242327	570903
BH5	241238	572683	BH13	241607	570626
BH6	242474	572624	BH14	242166	570330
BH7	241874	572364	BH15	241645	570030
BH8	242455	572030			
All turbines modelled using a hub height of 164 m (250 m tip height), assuming a candidate turbine rotor diameter of 172 m.					

Table B12 – Predicted L_{A90} (dB) noise immission levels from indicative Blair Hill Wind Farm layout in isolation.

Property	Standardised 10 m Wind Speed (m/s)										
	1	2	3	4	5	6	7	8	9	10	11	12
Beoch	-	-	8.5	12.4	17.7	20.6	20.5	20.5	20.5	20.5	20.5	20.5
Brigton	-	-	10.9	14.8	20.1	23.0	22.9	22.9	22.9	22.9	22.9	22.9
Clachaneasy	-	-	10.0	13.9	19.2	22.1	22.0	22.0	22.0	22.0	22.0	22.0
Cordorcan Cottage	-	-	13.9	17.8	23.1	26.0	25.9	25.9	25.9	25.9	25.9	25.9
Glassoch	-	-	10.1	14.0	19.3	22.2	22.1	22.1	22.1	22.1	22.1	22.1
Glenhapple	-	-	15.4	19.3	24.6	27.5	27.4	27.4	27.4	27.4	27.4	27.4
Glenruther	-	-	8.6	12.5	17.8	20.7	20.6	20.6	20.6	20.6	20.6	20.6
Glenruther Lodge	-	-	8.5	12.4	17.7	20.6	20.5	20.5	20.5	20.5	20.5	20.5
Glenvernoch	-	-	9.4	13.3	18.6	21.5	21.4	21.4	21.4	21.4	21.4	21.4
Glenvernoch Bungalow	-	-	9.6	13.5	18.8	21.7	21.6	21.6	21.6	21.6	21.6	21.6
Knockville	-	-	13.3	17.2	22.5	25.4	25.3	25.3	25.3	25.3	25.3	25.3
Larg Farm	-	-	11.4	15.3	20.6	23.5	23.4	23.4	23.4	23.4	23.4	23.4
North Lodge	-	-	16.5	20.4	25.7	28.6	28.5	28.5	28.5	28.5	28.5	28.5
Ochiltree	-	-	3.3	7.2	12.5	15.4	15.3	15.3	15.3	15.3	15.3	15.3
Old Larg House	-	-	11.2	15.1	20.4	23.3	23.2	23.2	23.2	23.2	23.2	23.2
Shepherds Cottage	-	-	12.9	16.8	22.1	25.0	24.9	24.9	24.9	24.9	24.9	24.9

Property	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Recreational Hut 1	-	-	10.1	14.0	19.3	22.2	22.1	22.1	22.1	22.1	22.1	22.1

Table B13 – Difference between the predicted L_{A90} (dB) noise immission levels from indicative Blair Hill Wind Farm layout and the Proposed Development. Highlighted results indicate assessment locations where the contribution from the Proposed Development in isolation are below 35 dB(A), as shown in Table 13. Negative values indicate the contribution of Blair Hill Wind Farm is less than the contribution from the Proposed Development.

Property	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Beoch	-	-	-12.2	-11.6	-11.3	-11.5	-11.9	-11.9	-11.9	-11.9	-11.9	-11.9
Brigton	-	-	-14.7	-14.0	-13.6	-13.4	-13.8	-13.8	-13.8	-13.8	-13.8	-13.8
Clachaneasy	-	-	-15.4	-14.7	-14.4	-14.3	-14.7	-14.7	-14.7	-14.7	-14.7	-14.7
Cordorcan Cottage	-	-	-12.4	-11.6	-11.1	-10.8	-11.1	-11.1	-11.1	-11.1	-11.1	-11.1
Glassoch	-	-	-9.3	-8.6	-8.3	-8.4	-8.8	-8.8	-8.8	-8.8	-8.8	-8.8
Glenhapple	-	-	-8.4	-7.7	-7.2	-7.1	-7.4	-7.4	-7.4	-7.4	-7.4	-7.4
Glenruther	-	-	-14.9	-14.2	-14.0	-14.3	-14.6	-14.6	-14.6	-14.6	-14.6	-14.6
Glenruther Lodge	-	-	-13.6	-13.0	-12.7	-12.9	-13.3	-13.3	-13.3	-13.3	-13.3	-13.3
Glenvernoch	-	-	-15.2	-14.6	-14.3	-14.4	-14.8	-14.8	-14.8	-14.8	-14.8	-14.8
Glenvernoch Bungalow	-	-	-14.2	-13.5	-13.2	-13.3	-13.7	-13.7	-13.7	-13.7	-13.7	-13.7
Knockville	-	-	-19.1	-18.3	-17.7	-17.3	-17.6	-17.6	-17.6	-17.6	-17.6	-17.6
Larg Farm	-	-	-15.6	-14.9	-14.4	-14.2	-14.5	-14.5	-14.5	-14.5	-14.5	-14.5
North Lodge	-	-	-3.0	-2.3	-1.9	-1.8	-2.1	-2.1	-2.1	-2.1	-2.1	-2.1
Ochiltree	-	-	-16.9	-16.3	-16.1	-16.3	-16.6	-16.6	-16.6	-16.6	-16.6	-16.6
Old Larg House	-	-	-15.5	-14.8	-14.4	-14.2	-14.5	-14.5	-14.5	-14.5	-14.5	-14.5
Shepherds Cottage	-	-	-14.5	-13.7	-13.2	-12.9	-13.2	-13.2	-13.2	-13.2	-13.2	-13.2
Recreational Hut 1	-	-	-16.7	-16.0	-15.6	-15.6	-15.9	-15.9	-15.9	-15.9	-15.9	-15.9

Table B14 – Predicted L_{A90} (dB) cumulative noise immission levels from the Proposed Development and indicative Blair Hill Wind Farm.

Property	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Glassoch	-	-	19.9	23.2	28.2	31.2	31.4	31.4	31.4	31.4	31.4	31.4
Glenhapple	-	-	24.4	27.6	32.6	35.3	35.5	35.5	35.5	35.5	35.5	35.5
North Lodge	-	-	21.3	24.7	29.8	32.6	32.7	32.7	32.7	32.7	32.7	32.7

Annex C – Noise Monitoring Information Sheets

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

Measurement Location Name	Knockville
Measurement Location Description	Knockville is a residential farm cottage located near the south eastern area of the site. The property is located on the same hillside on top of which the Proposed Development is to be located. The logger was positioned in the rear garden to the west of the property, therefore facing the Proposed Development The installed position used the property's facade to help minimise distant road traffic noise from the A714 road, located along the bottom of the valley to the east of the property. Additionally the property screened the logger from flags flapping in front garden and from a boiler flue exhaust on the south façade of the property. Observed noise sources included local vegetation, livestock, and intermittent birdsong. Distant road traffic was also audible, despite minimising and partially screening this source using the cottage building. SLM Location: 236176 / 572415

Equipment	Type	Serial Number	Last Calibrated (UKAS)
Sound Level Meter	Rion NL-52	632045	22/05/2023
Pre-amplifier	Rion NH-25	32073	22/05/2023
Microphone	Rion UC-59	11317	22/05/2023
Calibrator	Rion NC-74	34172706	10/07/2023
SLM Range	20 – 120 dB(A)		

File	Time Start (GMT)	Time End (GMT)	Cal Start	Cal End	Drift	Notes
01	Fri 10/11/23 11:20	Tue 21/11/23 09:50	94.0	93.8	-0.2	No significant drift
02	Tue 21/11/23 10:30	Tue 05/12/23 15:10	94.0	93.8	-0.2	No significant drift

Data Exclusions
Periods 10 minutes prior to, during and 10 minutes following rainfall were excluded from the analysis. The following periods were excluded as atypical: - A snowfall and snow melting period over the weekend of 2nd to 3rd December 2023, excluded 02/12/2023 00:00 to 03/12/2023 23:50 GMT from the analysis. Quiet daytime exclusions: - Noise data above 30.0 dB(A) and between standardised wind speeds of 0.0 m/s to 5.0 m/s. - Noise data above 42.0 dB(A) and between standardised wind speeds of 8.0 m/s to 9.1 m/s. - Noise data above 46.0 dB(A) and between standardised wind speeds of 11.0 m/s to 12.0 m/s. Night exclusions: - Noise data between the 02/12/2023 23:00 GMT to 03/12/2023 00:40 GMT.

Figure C1 - View of the monitoring location at Knockville looking north

Figure C2 - View of the monitoring location at Knockville looking east

Figure C3 - View of the monitoring location at Knockville looking south

Figure C4 - View of the monitoring location at Knockville looking west

Table C2 - Information on the measurement location, equipment and noise data at Glenvernoch.

Measurement Location Name	Glenvernoch
Measurement Location Description	Glenvernoch is a residential property located near the northern area of the site. The logger was positioned in the front garden/driveway to the east of the property, which also faced the Proposed Development located to the south of the garden. During installation the land manager for the property mentioned a water pump was in the shed, used on some occasions. However this was located towards the rear of the property and no noise from the pump was observed during the installation or subsequent site visits to the property. The logger was positioned in front of the house, therefore screening from the shed was provided by the house façade in the case the pump was used. Additionally at this position the logger was distanced from any potential farm activity in the farmyard area to the south, during visits occasional distant ATV and farm activity noise was observed from the farm. The logger was also distanced from large vegetation at the garden borders, such that vegetation noise would not dominate the readings, however the installed position was still representative of the property and the surrounding area's noise climate. Additionally distant road traffic noise and local birdsong noise were observed. SLM Location: 234581 / 575284

Equipment	Type	Serial Number	Last Calibrated (UKAS)
Sound Level Meter	Rion NL-52	Rion NL-52	832244
Pre-amplifier	Rion NH-25	Rion NH-25	32272
Microphone	Rion UC-59	Rion UC-59	5471
Calibrator	Rion NC-74	34172706	10/07/2023
SLM Range	20 – 120 dB(A)		

File	Time Start (GMT)	Time End (GMT)	Cal Start	Cal End	Drift	Notes
01	Fri 10/11/23 11:20	Mon 20/11/23 16:00	94.0	93.8	-0.2	No significant drift
02	Mon 20/11/23 16:40	Tue 05/12/23 15:40	94.0	93.8	-0.2	No significant drift

Data Exclusions
Periods 10 minutes prior to, during and 10 minutes following rainfall were excluded from the analysis. The following periods were excluded as atypical: - A snowfall and snow melting period over the weekend of 2nd to 3rd December 2023, excluded 02/12/2023 00:00 to 03/12/2023 23:50 GMT from the analysis. Quiet daytime exclusions: - Noise data above 32.0 dB(A) and between standardised wind speeds of 0.0 m/s to 3.0 m/s. - Noise data above 35.0 dB(A) and between standardised wind speeds of 3.0 m/s to 5.0 m/s. - Noise data above 41.0 dB(A) and between standardised wind speeds of 7.4 m/s to 12.0 m/s. Night exclusions: - Noise data above 32.1 dB(A) and between standardised wind speeds of 0.0 m/s to 4.0 m/s. - Noise data above 35.0 dB(A) and between standardised wind speeds of 4.0 m/s to 7.0 m/s. - Noise data above 37.0 dB(A) and between standardised wind speeds of 7.0 m/s to 9.0 m/s.

Figure C5 - View of the monitoring location at Glenvernoch looking north east

Figure C6 - View of the monitoring location at Glenvernoch looking north west

Figure C7 - View of the monitoring location at Glenvernoch looking south

Figure C8 - View of the monitoring location at Glenvernoch looking west

Table C3 - Information on the measurement location, equipment and noise data at Ochiltree.

Measurement Location Name	Ochiltree
Measurement Location Description	Ochiltree is a remote residential property located near the north western area of the site, situated 250m east of Loch Ochiltree. The logger was positioned in the front driveway boundary, to the east (front) of the property which also faced the Proposed Development located to the south east of the property. The garden was avoided due to horses grazing. Additionally this location used the building façade to help screen potential distant water noise from the loch and any potential boiler flue outlet noise at the other side of the house. However neither of these sources were observed during the installation and subsequent service visits. The noise climate at the property was observed to be calm, with the occasional passing vehicle on the single lane road, occasional birdsong noise and light wind noise. SLM Location: 232312 / 574331

Equipment	Type	Serial Number	Last Calibrated (UKAS)
Sound Level Meter	Rion NL-52	331821	10/05/2023
Pre-amplifier	Rion NH-25	21772	10/05/2023
Microphone	Rion UC-59	18642	10/05/2023
Calibrator	Rion NC-74	34172706	10/07/2023
SLM Range	20 – 120 dB(A)		

File	Time Start (GMT)	Time End (GMT)	Cal Start	Cal End	Drift	Notes
01	Fri 10/11/23 11:20	Tue 21/11/23 11:00	94.0	93.8	-0.2	No significant drift
02	Tue 21/11/23 11:30	Wed 06/12/23 10:20	94.0	93.9	-0.1	No significant drift

Data Exclusions
Periods 10 minutes prior to, during and 10 minutes following rainfall were excluded from the analysis. The following periods were excluded as atypical: - A snowfall and snow melting period over the weekend of 2nd to 3rd December 2023, excluded 02/12/2023 00:00 to 03/12/2023 23:50 GMT from the analysis. Quiet daytime exclusions: - Noise data above 28.0 dB(A) and between standardised wind speeds of 0.0 m/s to 4.0 m/s. - Noise data above 35.0 dB(A) and between standardised wind speeds of 4.0 m/s to 7.0 m/s. - Noise data above 37.5 dB(A) and between standardised wind speeds of 7.0 m/s to 8.5 m/s. Night exclusions: - Noise data above 26.0 dB(A) and between standardised wind speeds of 0.0 m/s to 4.0 m/s. - Noise data above 27.0 dB(A) and between standardised wind speeds of 4.0 m/s to 5.0 m/s. - Noise data above 35.8 dB(A) and between standardised wind speeds of 5.0 m/s to 7.3 m/s.

Figure C9 - View of the monitoring location at Ochiltree looking east

Figure C10 - View of the monitoring location at Ochiltree looking west

Figure C11 - View of the monitoring location at Ochiltree looking south

Figure C12 - View of the monitoring location at Ochiltree looking north

Table C4 - Information on the measurement location, equipment and noise data at Glenruther.

Measurement Location Name	Glenruther
Measurement Location Description	Glenruther is a remote residential property located to the west of the site along a single lane road, situated 1 km south east of Loch Ochiltree. The logger was positioned in the front garden to the south of the property. The logger was also facing the Proposed Development to the east of the property and garden. The rear and east gardens were avoided due to dense vegetation coverage and to minimise potential farm activity and livestock noise to the rear of the property. The noise climate at the property was observed to be calm, with present vegetation noise increasing with wind speed, occasional birdsong noise and the occasional passing vehicle road traffic noise on the single lane road surrounding the property to the north, east and south. Potential boiler outlet noise was observed upon inspection of the data following the survey, however was not observed during the installation or site visits. As outlined below this noise source where apparent in the data was excluded from the analysis. SLM Location: 232373 / 573194

Equipment	Type	Serial Number	Last Calibrated (UKAS)
Sound Level Meter	Rion NL-52	721003	05/09/2022
Pre-amplifier	Rion NH-25	22109	05/09/2022
Microphone	Rion UC-59	21944	05/09/2022
Calibrator	Rion NC-74	34172706	10/07/2023
SLM Range	20 – 120 dB(A)		

File	Time Start (GMT)	Time End (GMT)	Cal Start	Cal End	Drift	Notes
01	Fri 10/11/23 11:20	Tue 21/11/23 11:50	94.0	93.8	-0.2	No significant drift
02	Tue 21/11/23 12:20	Wed 06/12/23 09:50	94.0	94.0	0.0	No drift

Data Exclusions
Periods 10 minutes prior to, during and 10 minutes following rainfall were excluded from the analysis. The following periods were excluded as atypical: - A snowfall and snow melting period over the weekend of 2nd to 3rd December 2023, excluded 02/12/2023 00:00 to 03/12/2023 23:50 GMT from the analysis. Quiet daytime exclusions: - Noise data above 24.6 dB(A) and between standardised wind speeds of 0.0 m/s to 4.0 m/s, to exclude both atypical shorter term elevated noise events and prolonged noise events (boiler noise) occurring from 18:00 to 19:40 GMT. - Noise data above 28.5 dB(A) and between standardised wind speeds of 4.0 m/s to 5.0 m/s, to exclude elevated prolonged noise events (boiler noise) occurring from 18:00 to 19:40 GMT. - Atypical outlier noise data above 42.9 dB(A) and between standardised wind speeds of 7.0 m/s to 8.0 m/s. Night exclusions: - Noise data above 25.0 dB(A) and between standardised wind speeds of 0.0 m/s to 3.1 m/s. - Noise data above 27.3 dB(A) and between standardised wind speeds of 3.1 m/s to 4.0 m/s. - Noise data above 36.8 dB(A) and between standardised wind speeds of 5.0 m/s to 7.0 m/s.

Figure C13 - View of the monitoring location at Glenruther looking east

Figure C14 - View of the monitoring location at Glenruther looking west

Figure C15 - View of the monitoring location at Glenruther looking south

Figure C16 - View of the monitoring location at Glenruther looking north

Annex D – Wind Speeds and Directions

Figure D1 - Wind speed and direction range during all quiet day-time periods (Knockville data shown; other data excluded at some of the other locations).

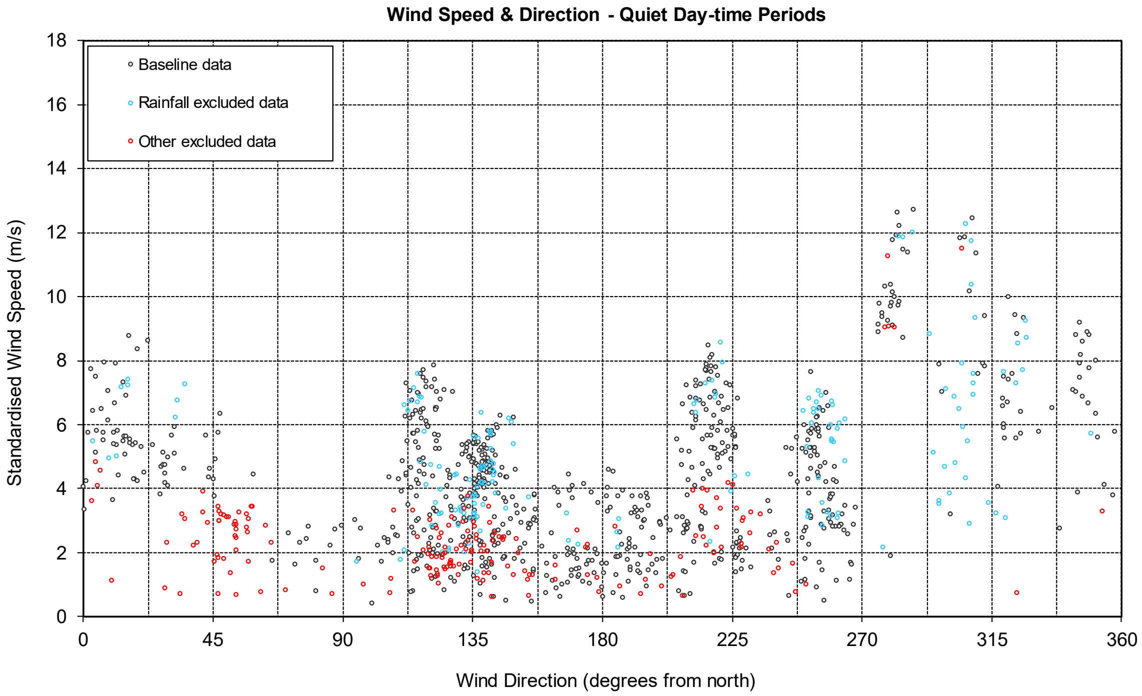
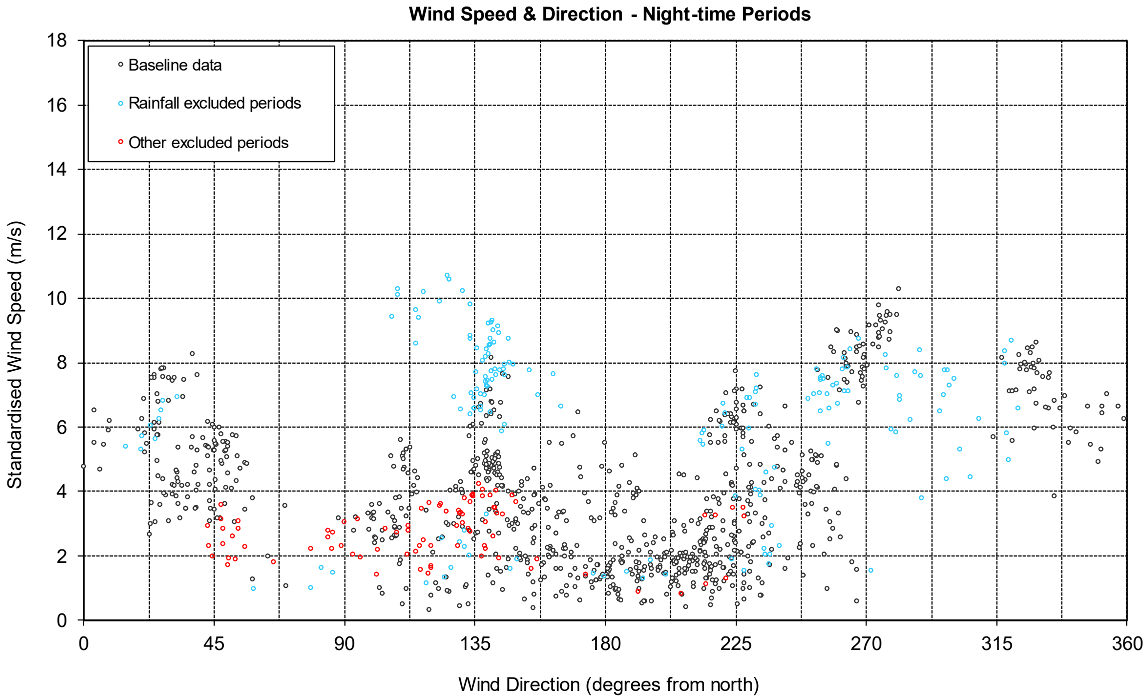


Figure D2 - Wind speed and direction range during all night-time periods (Knockville data shown; other data excluded at some of the other locations).



Annex E – Background Noise and Noise Limits

Figure E1 - Chart of background noise levels against wind speeds, the best fit curve to the data, the derived noise limit curve for Knockville during quiet day time periods. Predicted immission noise levels are also shown for the Proposed Development.

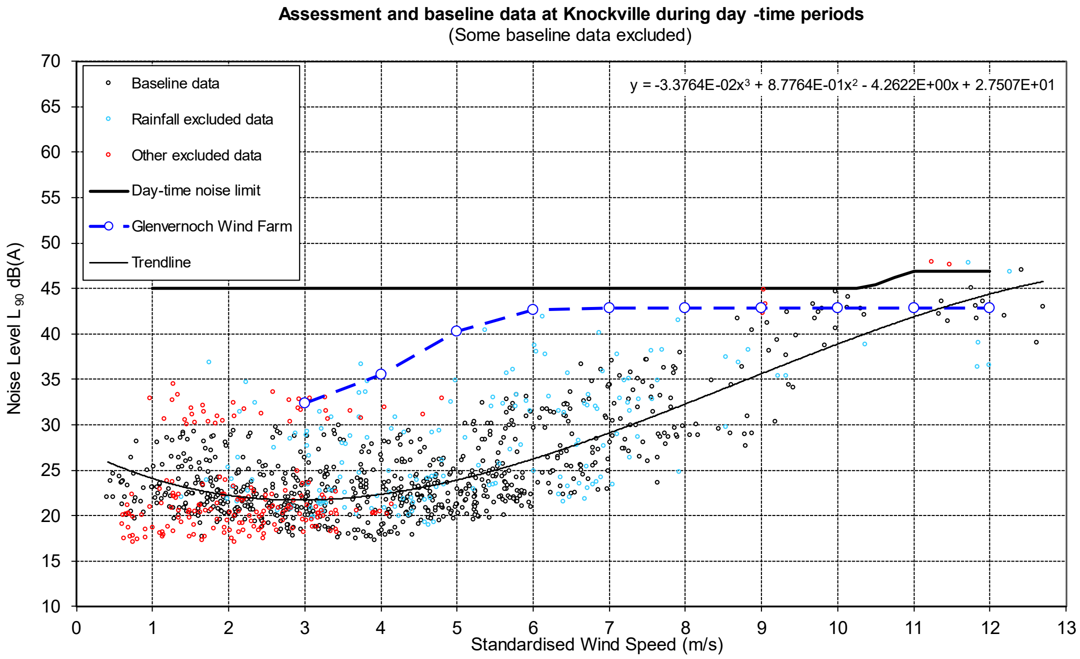


Figure E2 - Chart of background noise levels against wind speeds, the best fit curve to the data, the derived noise limit curve for Knockville during quiet day time periods. Predicted immission noise levels are also shown for the Proposed Development.

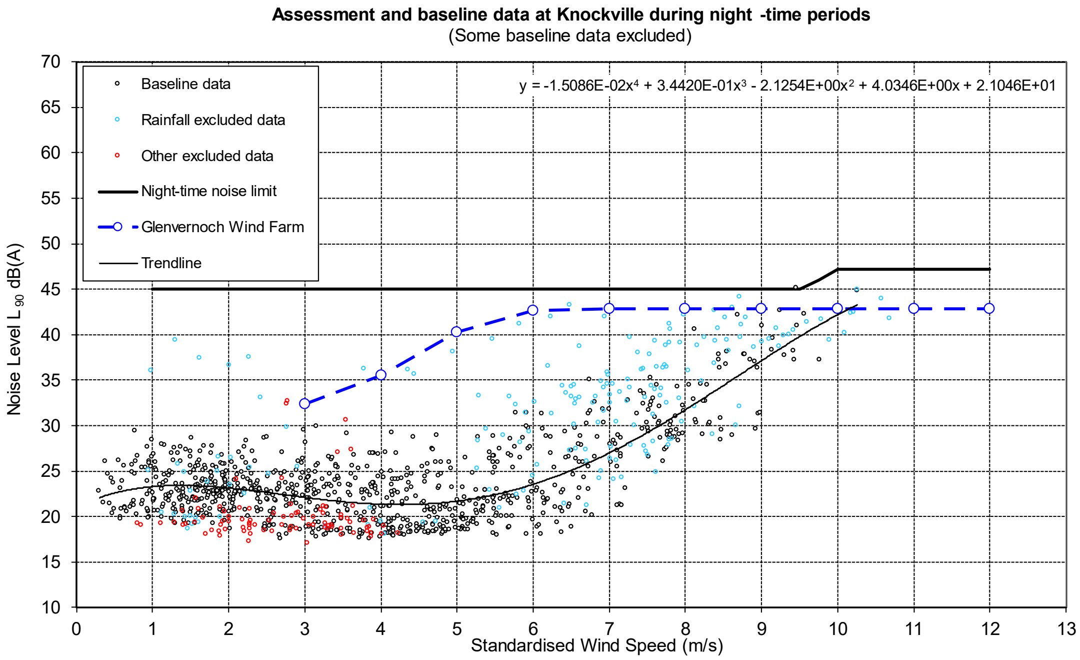


Figure E3 - Chart of background noise levels against wind speeds the best fit curve to the data measured at Knockville, the derived noise limit curve for Shepherds Cottage during quiet day time periods. Predicted immission noise levels are also shown for the Proposed Development at Shepherds Cottage.

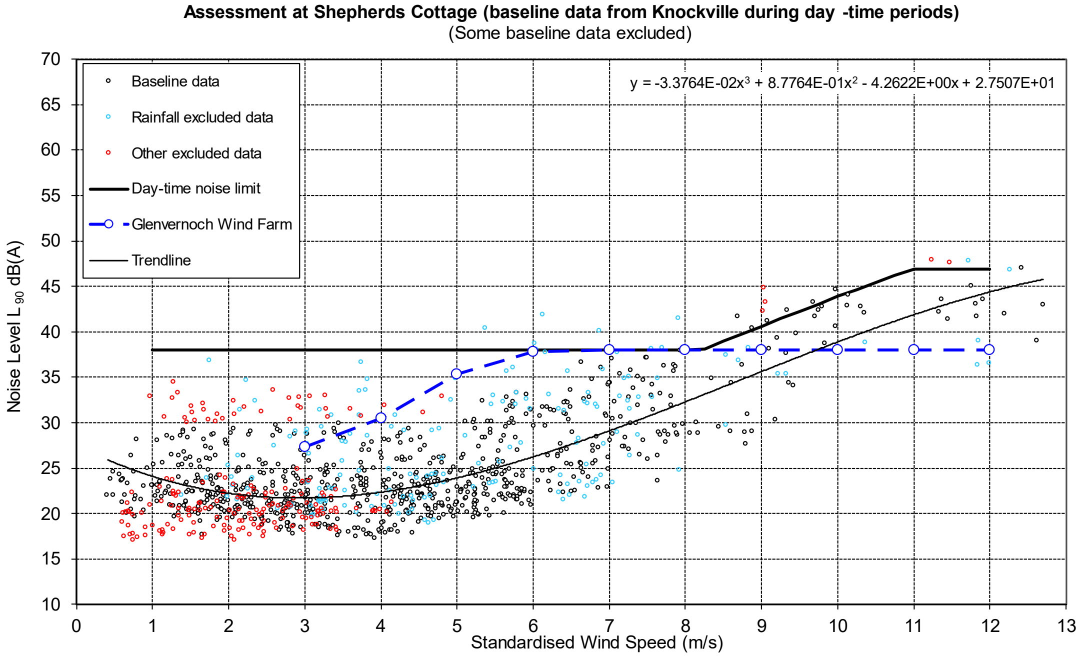


Figure E4 - Chart of background noise levels against wind speeds, the best fit curve to the data measured at Knockville, the derived noise limit curve for Shepherds Cottage during quiet day time periods. Predicted immission noise levels are also shown for the Proposed Development at Shepherds Cottage.

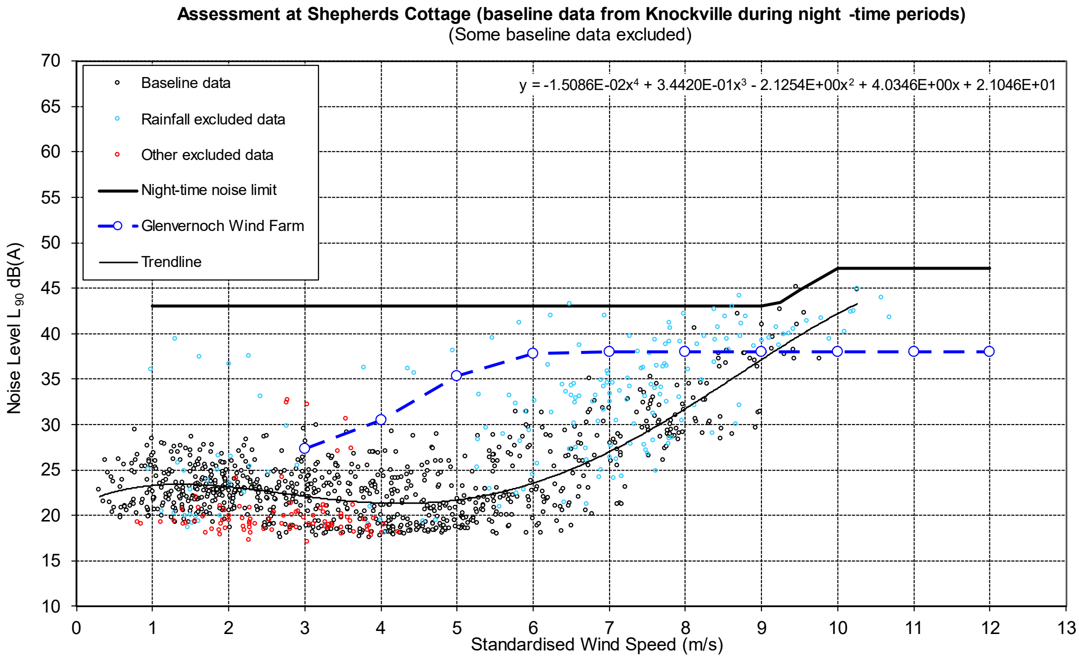


Figure E5 - Chart of background noise levels against wind speeds, the best fit curve to the data, the derived noise limit curve for Glenvernoch during quiet day time periods. Predicted immission noise levels are also shown for the Proposed Development.

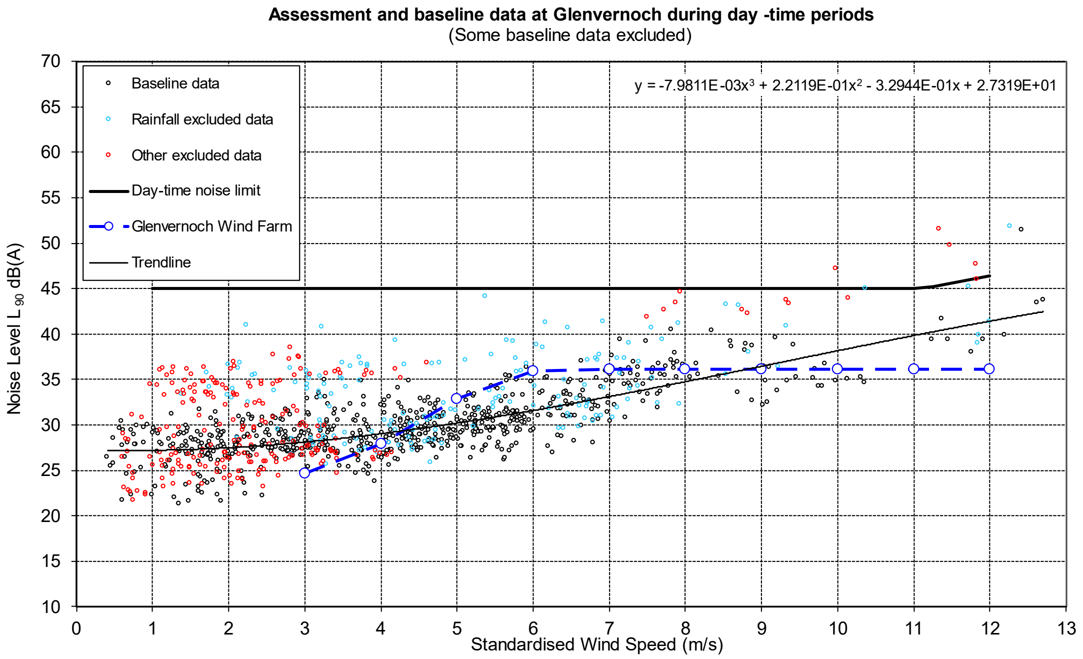


Figure E6 - Chart of background noise levels against wind speeds, the best fit curve to the data, the derived noise limit curve for Glenvernoch during quiet day time periods. Predicted immission noise levels are also shown for the Proposed Development.

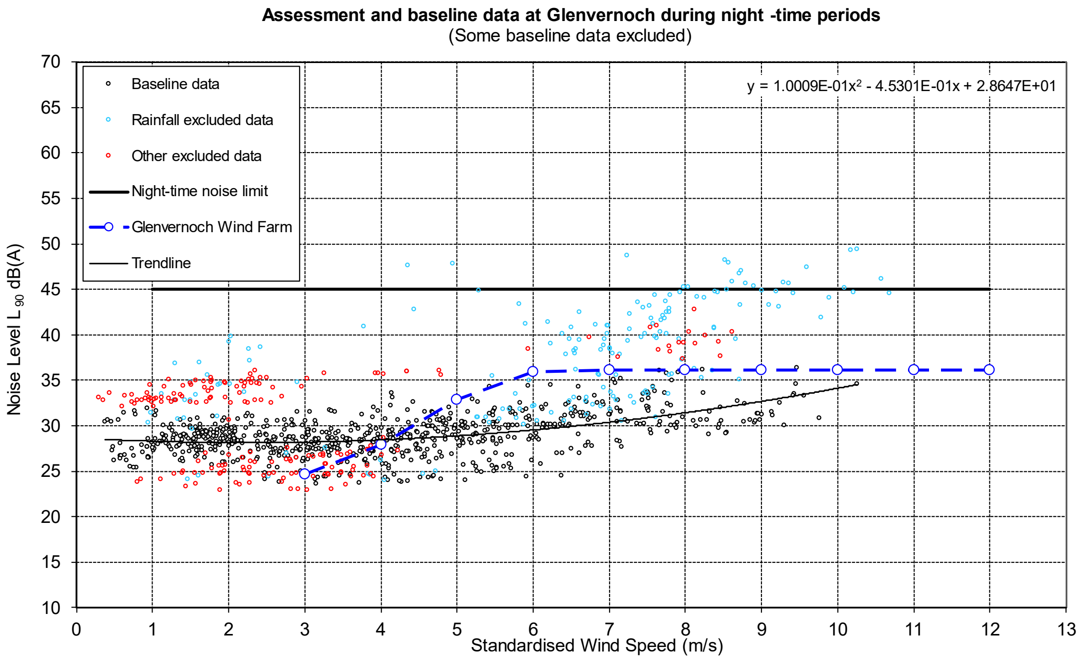


Figure E7 - Chart of background noise levels against wind speeds, the best fit curve to the data, the derived noise limit curve for Ochiltree during quiet day time periods. Predicted immission noise levels are also shown for the Proposed Development.

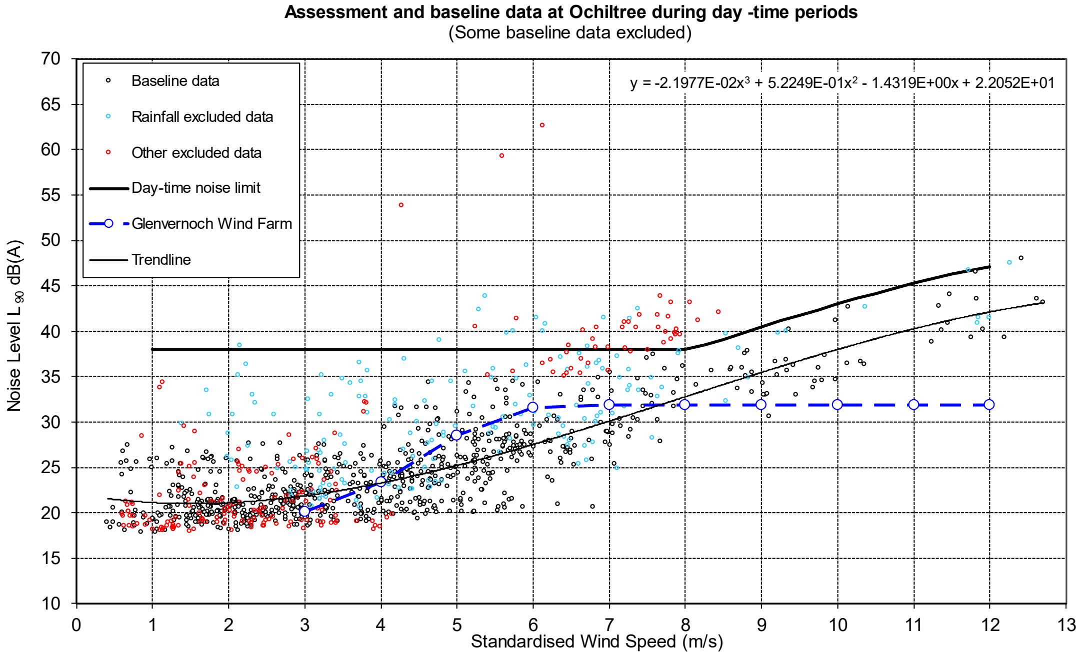


Figure E8 - Chart of background noise levels against wind speeds, the best fit curve to the data, the derived noise limit curve for Ochiltree during quiet day time periods. Predicted immission noise levels are also shown for the Proposed Development.

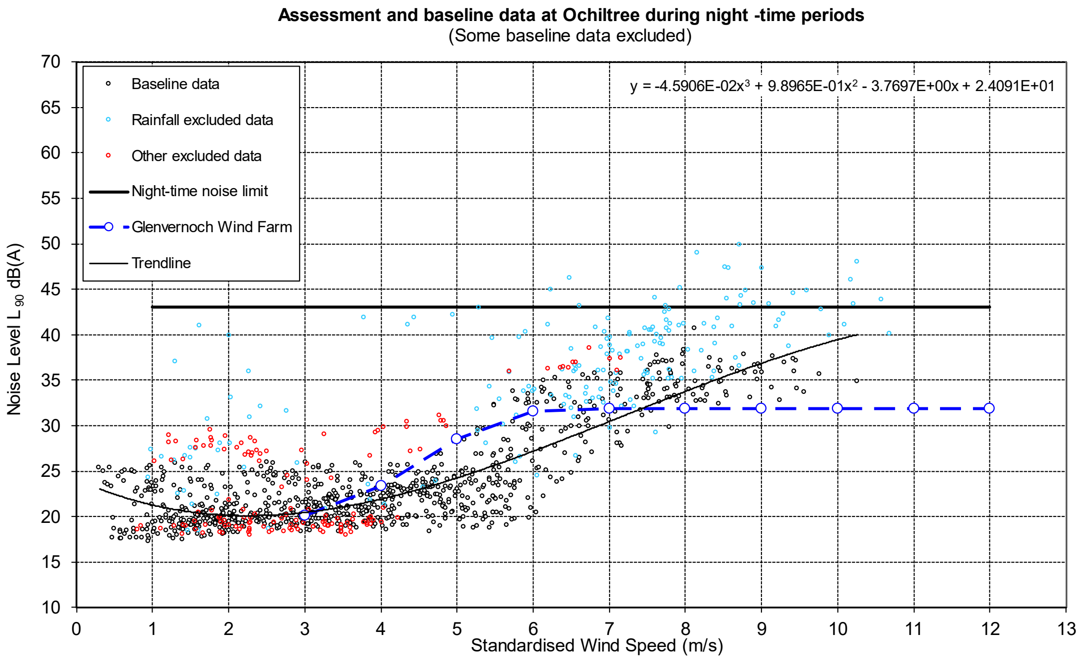


Figure E9 - Chart of background noise levels against wind speeds, the best fit curve to the data, the derived noise limit curve for Glenruther during quiet day time periods. Predicted immission noise levels are also shown for the Proposed Development, the Kilgallioch and Kilgallioch Extension Wind Farms and the cumulative total.

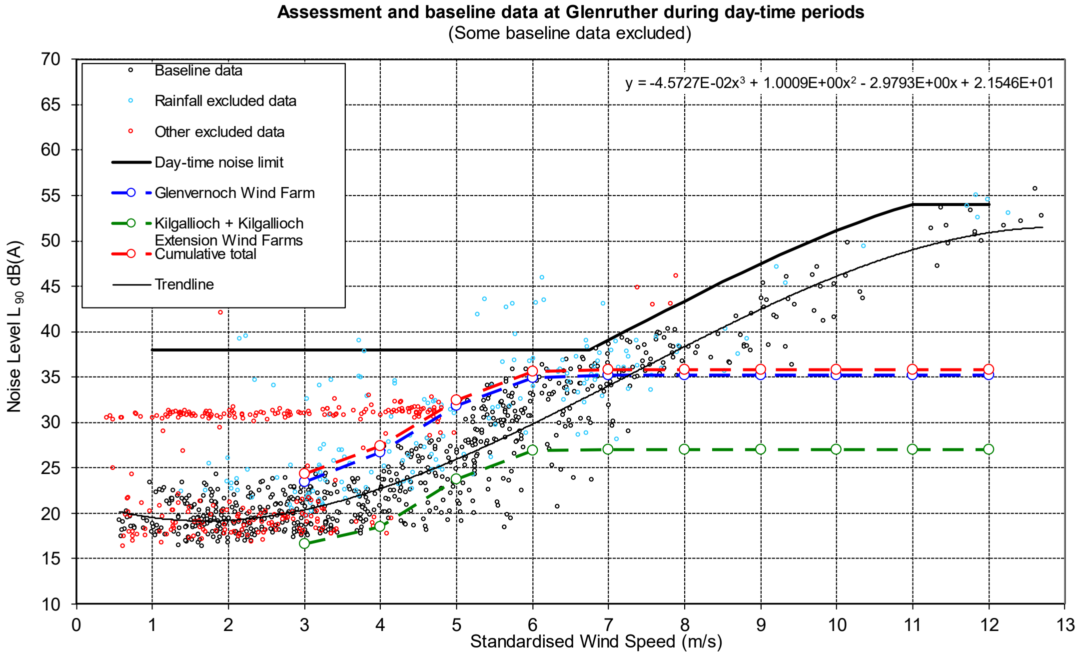
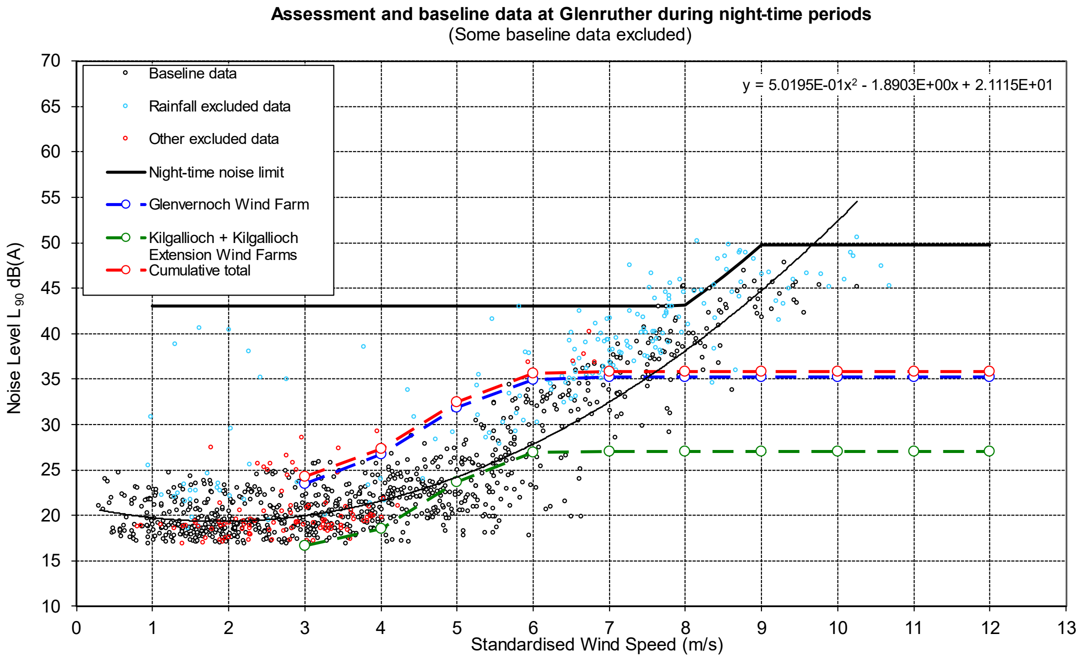


Figure E10 - Chart of background noise levels against wind speeds, the best fit curve to the data, the derived noise limit curve for Glenruther during quiet day time periods. Predicted immission noise levels are also shown for the Proposed Development, the Kilgallioch and Kilgallioch Extension Wind Farms and the cumulative total.



Annex F – Wind Speed Calculations

F.1 The IOA GPG[39] 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 referred to as 'Method C', 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[40] provides additional guidance on these methods.

F.2 The site of the Proposed Development has a temporary LIDAR remote sensing measuring system installed which measured wind conditions at various heights including in particular :

- 114 metre wind speed
- 114 metre wind direction

F.3 These measurement heights follows the requirements of the IOA GPG 'Method C': where the wind speed is measured directly at the proposed assessment turbine hub height of 114 m on the LIDAR, to determine a standardised 10 metre high wind speed. The LIDAR system meets the accuracy and calibration requirements of the IOA GPG and was installed at a suitable location (by others) on open moorland away from large vegetation.

F.4 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.

F.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[41] for calculating ten metre wind speeds related to hub height wind speeds when providing source noise emission data for wind turbines.

F.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.

39 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.

40 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.

41 IEC 61400 11:2003 Wind turbine generator systems - Part 11: Acoustic noise measurement techniques.

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