Technical Appendix 13.1

Environmental Noise Assessment

SCOTTISHPOWER RENEWABLES

Technical Appendix 13.1

HOARE LEA

Euchanhead Renewable Energy Development.

Technical Appendix 13.1 - Environmental noise assessment.

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Contents.

Non-Technical Summary

Hoare Lea (HL) have been commissioned by ScottishPower Renewables to undertake a noise assessment for the construction and operation of the proposed Euchanhead Renewable Energy Development (the proposed Development). Noise will be emitted by equipment and vehicles used during construction and decommissioning of the proposed Development and by the wind 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. Various mitigation methods have been suggested to reduce the effects of construction noise, the most important of these being suggested restrictions of hours of working. It is concluded that noise generated through construction activities will have a minor effect that is not significant in EIA terms.

De-commissioning is likely to result in less noise than during construction of the proposed Development. The construction phase has been considered to have minor noise effects, therefore de-commissioning will, in the worst case, also have minor noise effects in EIA terms.

Operational Noise

Operational wind 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. Noise surveys for adjacent wind energy developments have already sufficiently established 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. Predicted noise levels take full account of the potential combined effect of the noise from the proposed Development along with Afton Windfarm (operational), Harehill Windfarm (operational), Harehill Windfarm Extension (operational), Lorg Windfarm (consented but not built), Sanqhuar Windfarm (operational), Sanquhar Six Windfarm (consented but not built), Sanquhar II Windfarm (proposed), Whiteside Hill Windfarm (operational), and Windy Rig Windfarm (consented and under construction). Other, more distant windfarms 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 turbines will be within levels deemed, by national guidance, to be acceptable for developments with wind turbines, therefore the effects of operational wind turbine noise are considered not significant in EIA terms.

The proposed Development would also include a substation and an energy storage facility, which would emit some noise during operation. Based on experience of similar installations and professional judgement, in conjunction with the large separation distances to the nearest receptor locations, the associated levels of operational noise would be negligible and are considered not significant in EIA terms.

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

1. Introduction

1.1.1 This report presents an assessment of the potential construction and operational noise effects of the Euchanhead Renewable Energy Development (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 effects of its de-commissioning. Assessment of the operational noise effects accounts for the cumulative effect of the proposed Development as well as other windfarms nearby. Other windfarms considered were those closest and consisted of: Afton Windfarm (operational, approximately 2.8 km west), Harehill and Harehill Extension Windfarms (operational, approximately 2 km north), Lorg Windfarm (consented but not built, adjacent to the south west), Sanqhuar Windfarm (operational, approximately 1.1 km north east), Sanquhar Six Windfarm (consented but not built, adjacent to the north), Sanquhar II Windfarm (proposed, adjacent to the north and east), Whiteside Hill Windfarm (operational, approximately 3 km east), and Windy Rig Windfarm (consented and under construction, approximately 4.5 km west). Some of these windfarms are existing or consented, whilst others are proposed. Other, more distant windfarms were not considered because their potential noise contribution was not considered acoustically important. The proposed Development would also include a substation and ancillary services/energy storage facility which would emit some noise during operation (e.g. electrical plant and air conditioning systems).

1.1.2 Noise and vibration which arises from the construction of a windfarm is a factor which should be taken into account when considering the total effect of the proposed Development. However, in assessing the effects of construction noise, it is accepted that the associated works are of a temporary nature. The main work locations for construction of the wind turbines are distant from nearest noise sensitive residences and are unlikely to cause significant effects. The construction and use of access tracks may, however, occur at lesser separation distances. Assessment of the temporary effects of construction noise is primarily aimed at understanding the need for dedicated management measures and, if so, the types of measures that are required.

1.1.3 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 windfarm. 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.

1.1.4 The proposed Development would also include a substation and an energy storage facility, with a capacity of around 31 MW. These facilities would emit noise during operation (e.g. electrical plant and air conditioning systems).

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

2. Policy and Guidance Documents

2.1 Planning Policy and Advice Relating to Noise

2.1.1 Scottish Planning Policy (SPP)[i] provides advice on how the planning system should manage the process of encouraging, approving and implementing renewable energy proposals including onshore windfarms. Whilst SPP suggests noise impacts are one of the aspects that will need to be considered it provides no specific advice. Planning Advice Note PAN1/2011[ii] 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 windfarms. In relation to operational noise from windfarms, 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[iii] provides further advice on noise, and confirms that the recommendations of 'The Assessment and Rating of Noise from Wind Farms' (ETSU-R-97)[iv] "*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 The recommendations contained in ETSU-R-97 provide a robust basis for assessing the noise implications of a windfarm. ETSU-R-97 has become the accepted standard for such developments within the UK. Guidance on good practice on the application of ETSU-R-97 has been provided by the Institute of Acoustics (IOA Good Practice Guide or GPG)[v]. This was subsequently endorsed by the Scottish Government[vi] 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.

2.1.4 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'*.

2.1.5 PAN1/2011 and the Technical Advice Note[vii] 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[viii]. 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.

2.1.6 For detailed guidance on construction noise and its control, the Technical Advice Note refers to British Standard BS 5228[ix] '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)[x] (BS 5228-1) for airborne noise and BS 5228-2: 2009 (amended 2014)[xi] (BS 5228-2) for ground-borne vibration. These updated versions have therefore been adopted as the relevant versions upon which to base this assessment.

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

2.1.8 Planning Advice Note PAN50[xii] "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 effects associated with quarry blasting. BS 6472-2 2008[xiii] 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'[xiv] (CRTN).

3.1.5 The nature of works and distances involved in the construction of a renewable energy development with wind turbines are such that the risk of significant effects relating to ground borne vibration are very low (excluding blasting). Occasional momentary vibration can arise when heavy vehicles pass dwellings at very short separation distances, but again this is not sufficient to constitute a risk of significant impacts in this instance. Accordingly, vibration impacts do not warrant detailed assessment and are therefore not discussed further in this assessment.

3.1.6 It is anticipated that some rock extraction from borrow pits by means of blasting operations could be required in some instances. 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 Operational Wind Turbine 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.

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

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

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. Given the relatively large energy generating potential of the proposed Development (particularly when compared to the range of windfarm generating capacities considered at the time ETSU-R-97 was prepared) and the relatively low number of surrounding properties in the immediate vicinity of the scheme, the limit should tend towards the upper end of the 35 dB(A) to 40 dB(A) range. The appropriate choice of value is considered subsequently in this Report.

3.2.5 The night-time noise limit is derived from background noise data measured during the night-time periods (23:00 to 07:00) with no differentiation being made between weekdays and weekends. The ten minute $L_{A90,10min}$ noise levels measured over these night-time periods are again plotted against the concurrent wind speed data and a 'best-fit' correlation is established. As with the day-time limit, the night-time noise limit is also set as the greater of: a level 5 dB(A) above the best-fit background curve or a fixed level of 43 dB(A). This fixed lower night-time limit of 43 dB(A) was set in ETSU-R-97 on the basis of World Health Organization (WHO) guidance[xv] 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 development. Where this is the case then the lower fixed portion of the noise limit at that property may be increased to 45 dB(A) during both the day-time and the night-time periods alike.

3.2.7 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 operational, consented and proposed windfarms 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.

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

- specify the number and locations of the wind turbines on all windfarms;
- identify the locations of the nearest, or most noise sensitive, neighbours;
- determine 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 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 on the proposed Development and cumulatively in combination with other wind energy schemes as a function of site wind speed at the nearest neighbours; and
- compare the calculated wind turbine noise immission levels with the derived noise limits and assess in the light of planning requirements.

3.2.9 The foregoing steps, as applied to the proposed Development, are set out subsequently in this assessment. Similarly, assessment of the substation and ancillary services/energy storage has been made based on experience of similar installations.

3.2.10 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.

3.3 Methodology for Assessing Operational Non-wind Turbine Noise

3.3.1 Noise from fixed plant other than the wind turbines is assessed by comparing typical noise levels from these operational sources (based on the $L_{Aeq,t}$) with baseline $L_{A90,t}$ noise levels at relevant noise-sensitive receptors. Corrections for rating any noticeable characteristics in the source are also included.

3.4 Construction Noise Criteria

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

3.4.2 BS 5228-1 informative Annex E provides example criteria that may be used to consider the significance of any construction noise effects. 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 significant effect unless ambient noise levels (i.e. regularly occurring levels without construction) are sufficiently high to provide a degree of masking of construction noise.

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

Table 1 - Free-field noise criteria against which construction noise effects are assessed

Significance	Condition
Major	Construction noise is greater than 85 dB $L_{Aeq,T}$ for any part of the construction works or exceeds 75 dB $L_{Aeq,T}$ for more than 4 weeks in any 12 month period
Moderate	Construction noise is less than or equal to 75 dB $L_{Aeq,T}$ throughout the construction period, with periods of up to 75 dB $L_{Aeq,T}$ lasting not more than 4 weeks in any 12 month period.
Minor	Construction noise is generally less than or equal to 65 dB $L_{Aeq,T}$, with periods of up to 70 dB $L_{Aeq,T}$ lasting not more than 4 weeks in any 12 month period
Negligible	Construction noise is generally less than or equal to 60 dB $L_{Aeq,T}$, with periods of up to 65 dB $L_{Aeq,T}$ lasting not more than 4 weeks in any 12 month period

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

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

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

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

3.4.8 In accordance with the guidance in BS 6472-2: 2008 / PAN50 Annex D, ground vibration caused by blasting operations will be considered acceptable if peak particle velocity (PPV) levels, at the nearest sensitive locations, do not exceed 6 mm/s for 95% of all blasts measured over any 6 month period, and no individual blast exceeds a PPV of 12 mm/s.

3.5 Operational Noise Criteria

3.5.1 The acceptable limits for wind turbine operational noise are clearly defined in the ETSU-R-97 document and these limits should not be breached. Consequently, the test applied to operational noise is whether or not the calculated wind turbine 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, wind turbine 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.

3.5.2 Noise from fixed plant other than the wind turbines are assessed in line with the BS 4142:2014[xvii] standard. Assessment according to this standard is based on the $L_{Aeq,t}$ level from the plant (with the potential addition of penalties to account for some characteristics of the sound) which is compared to baseline $L_{A90,t}$ noise levels at relevant noise-sensitive receptors. When these are similar, this corresponds to a low impact (depending on the context) according to the standard, which is considered to represent negligible effects for EIA purposes.

3.6 Consultation

3.6.1 Prior to undertaking the noise assessment a summary of the proposed approach to determining baseline background noise levels and how the proposed Development would be assessed was forwarded to Dumfries and Galloway Council and East Ayrshire Council. Through this consultation, it was proposed to utilise existing baseline data to complete the noise assessment and set out which baseline data would be utilised for relevant receptor locations near to the proposed Development, rather than undertake supplementary baseline noise surveys. These baseline data are discussed further below. No responses were received to the methodology proposed via this consultation process.

3.7 Matters Scoped-out of the Assessment

3.7.1 Ground-borne vibration resulting from the operation of wind turbines is imperceptible at typical receptor separation distances (as discussed in Annex A) and is therefore scoped out from the noise assessment and is not discussed further.

4. Baseline & Assessment Criteria

4.1 General Description

4.1.1 The area of the wind turbines on the proposed Development will cover an area extending approximately eight kilometres north to south and five kilometres west to east, located in Dumfries and Galloway and East Ayrshire in an area of relatively low population density. The noise environment in the surrounding area is generally characterised by ‘natural’ sources, such as wind disturbed vegetation, birds, farm animals, water flow sounds as well as existing wind energy developments. Other sources of noise are likely to include agricultural vehicle movements in the area, commercial forestry, occasional road traffic and distant aircraft.

4.1.2 There are a number of other wind energy developments in the area around the proposed Development, some of which are operational, some consented but not yet operational and others which are proposed; for which planning applications have been submitted but not yet determined. Each of these other wind energy developments were required to consider baseline information in order to derive noise limits in accordance with ETSU-R-97 and undertake an appropriate noise assessment. A review of these adjacent sites has confirmed that suitable baseline background noise levels for all relevant noise sensitive receptors around the proposed Development have already been sufficiently defined for the purposes of an assessment in accordance with ETSU-R-97, accordingly additional baseline surveys were not undertaken for the proposed Development. The resulting data remains representative of the noise environment. This approach also provides consistency when considering cumulative effects of the proposed Development and the appropriate noise limits which may apply to the proposed Development.

4.2 Details of the Baseline Background Noise Environment

4.3 A number of noise sensitive receptor locations were considered at the scoping stage of the application at which assessment of noise from the proposed Development may be required. For each of these locations, the scoping report[xviii] set out the source of baseline data which were proposed to be used. This list of locations has been revised to only include those locations which are closest to the proposed Development and are those which require noise effects of the proposed Development to be assessed. The ten assessment locations are shown on the plan in Annex B and listed in Table 2. This list is not intended to be exhaustive but sufficient to be representative of noise levels typical of those receptors closest to the proposed Development. Those locations which are further from the proposed Development would be less exposed to noise from the proposed Development, with consequently reduced effects, and are not considered further. This approach is consistent with the guidance provided by ETSU-R-97 and current good practice as set out in the IOA GPG.

Table 2 - Assessment locations in the vicinity of the development

Property	Easting	Northing	Approximate Distance to Closest Turbine (m)	Closest Turbine (ID)	Source of assessment criteria (see Annex C)
Cairnhead	270133	597200	2026	EUC20	Lorg Windfarm
Corlae	265835	597727	3841	EUC19	Lorg Windfarm
Craig	263442	606454	3776	EUC05	Afton Windfarm & Sanquhar II Windfarm
Dalgonar[(A)]	270038	603129	1874	EUC13	Sanquhar II Windfarm
Euchanbank Cottage	270530	606420	2082	EUC01	Whiteside Hill Windfarm & Sanquhar II Windfarm
Hillend	268201	608890	2378	EUC01	Harehill Windfarm & Harehill Extension Windfarm
Lorg[(B)]	266850	600875	1041	EUC11	Lorg Windfarm
Polgown[(A)])	271866	603844	3347	EUC13	Whiteside Hill Windfarm & Sanquhar II Windfarm
Shinnelhead	272926	599169	1953	EUC21	Sanquhar II Windfarm
Upper Holm of Dalquhairn	265565	599279	3076	EUC11	Lorg Windfarm

During construction and operation of the proposed Development, the receptor location of Polskeoch (268688, 602320) will be under the ownership and management of ScottishPower Renewables and will be removed from residential use for the life of the proposed Development based on current project programme and contracted grid connection dates, therefore this location has not been considered as a receptor for the purposes of this assessment.
(A) "These properties would not be inhabited for the lifetime of the Sanquhar II Wind Farm".
(B) This receptor location would be removed from residential use during the life of the Lorg Windfarm

4.4 ETSU-R-97 Assessment Criteria

4.4.1 Full details of the review of the existing baseline situation and noise criteria/limits which are relevant to assessment of noise from the proposed Development for each property in Table 2 are detailed in Annex C.

4.4.2 The ETSU-R-97 assessment method requires baseline data, and consequently noise limits/criteria, to be related to wind speed data at a height of 10 m, with wind speeds either directly measured at a height of 10 m 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 windfarm noise assessments.

4.4.3 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 generally been referenced in the noise assessment for the proposed Development to account for the potential effect of site-specific wind shear, by utilising wind speeds at hub height and converting these to 10 m height assuming reference wind shear conditions, consistent with the preferred method described in the IOA GPG. Wind speeds are therefore referred to as 'standardised' ten metre wind speeds to reflect the methodology used.

4.4.4 The wind speed references for baseline data and criteria/limits have been discussed for each of the sources of information which have been utilised for the assessment, as set out in detail in Annex C. In some cases, due to uncertainties as to potential wind shear effects due to the wind speed monitoring used in some of the assessments referenced, the potential increases in the noise limits associated with the background-related component of the noise limit was discounted to provide stringent criteria for the assessment of the proposed Development.

4.4.5 Noise limits / criteria required by ETSU-R-97 that apply during the day-time and night-time periods up to 12 m/s have been derived for this assessment. Table 3 (day-time) and Table 4 (night-time) define stringent criteria that have been derived for comparison only with levels of noise due to operation of the proposed Development in isolation. Operational noise from the proposed Development alone which are below these criteria would be 10 dB below the ETSU-R-97 noise limits, and would not add an acoustically relevant contribution to cumulative noise levels[1], accordingly a cumulative assessment against the full ETSU-R-97 noise limits is not necessary, in accordance with the IOA GPG. Assessment criteria are included for the receptor location Polgown: whilst this receptor location would not be inhabited during the lifetime of the Sanquhar II Windfarm, the effects of the proposed Development need to be assessed should the Sanquhar II Windfarm not be built.

4.4.6 For the assessment locations of Dalgonar, Lorg and Shinnelhead the criteria defined in Table 5 (day-time) and Table 6 (night-time) are to enable a full ETSU-R-97 assessment to be completed, with contributions to total cumulative noise levels from all acoustically relevant nearby windfarms. The Lorg receptor location would be removed from residential use during the life of the Lorg Windfarm; however, to account for the possibility that the Lorg Windfarm does not get constructed, a cumulative noise assessment is undertaken at this property without including a contribution from the Lorg Windfarm. Similarly, the Dalgonar receptor location would be removed from residential use during the life of the Sanquhar II Windfarm; however, to account for the possibility that the Sanquhar II Windfarm does not get constructed, a cumulative noise assessment is undertaken at this property without including a contribution from the Sanquhar II Windfarm.

Table 3 – Day-time $L_{A90,T}$ dB stringent noise limits / criteria derived from baseline noise data according to ETSU-R-97 and used to assess noise from the proposed Development in isolation and demonstrate the Development does not have an acoustically important contribution.

Property	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Cairnhead	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
Corlae	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
Craig	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
Euchanbank Cottage	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
Hillend	31.2	31.2	31.2	31.2	31.2	31.2	31.2	31.2	31.2	31.2	31.2	31.2
Polgown	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
Upper Holm of Dalquhairn	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0

1 The IOA GPG suggests that where noise from adjacent developments differ by more than 10 dB(A) then this represents effectively negligible effects and that cumulative effects need not be considered. Two noise sources which differ by 10 dB(A) gives rise to total 0.4 dB(A) higher than the greater source. Accordingly it is generally assumed that increases of 0.4 dB(A) or less are not acoustically important.

Table 4 – Night-time $L_{A90,T}$ dB stringent noise limits / criteria derived from baseline data according to ETSU-R-97 and used to assess noise from the proposed Development in isolation and demonstrate the Development does not have an acoustically important contribution.

Property	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Cairnhead	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0
Corlae	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0
Craig	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0
Euchanbank Cottage	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0
Hillend	31.2	31.2	31.2	31.2	31.2	31.2	31.2	31.2	31.2	31.2	31.2	31.2
Polgown(*)	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0
Upper Holm of Dalquhairn	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0
* Whilst this receptor location would not be inhabited during the lifetime of the Sanquhar II Windfarm, the effects of the Proposed Development need to be assessed should the Sanquhar II Windfarm not be built.												

Table 5 – Day-time $L_{A90,T}$ dB noise limits / criteria derived from baseline noise data according to ETSU-R-97 and used for assessment of cumulative noise levels.

Property	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Dalgonar(#)	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	41.0	42.0	44.0
Lorg(*)	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0
Shinnelhead	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	42.0	45.0	47.0
* Cumulative assessment without a contribution from the Lorg Windfarm. # Cumulative assessment without a contribution from the Sanquhar II Windfarm.												

Table 6 – Night-time $L_{A90,T}$ dB noise limits / criteria derived from baseline data according to ETSU-R-97 and used for assessment of cumulative noise levels.

Property	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Dalgonar(#)	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0
Lorg(*)	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0
Shinnelhead	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	46.0
* Cumulative assessment without a contribution from the Lorg Windfarm. # Cumulative assessment without a contribution from the Sanquhar II Windfarm.												

5. Predicted Noise Effects

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 construction 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 this type of development, 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 construction plant and machinery 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 7 lists the key construction activities, the associated types of plant normally involved, the expected worst-case sound power level over a working day for each activity, the property which would be closest to the activity for a portion of construction, and the predicted noise level. It must be emphasised that these predictions only relate the noise level occurring during the time when the activity is closest to the referenced property. In many cases such as access track construction and wind turbine erection, the separation 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. Predictions are shown for the two potential access track options: for the route to the north (Access Route A) and for the route to the east (Access Route B).

5.1.5 Comparing the predicted construction noise levels (Table 7) to typical background noise levels measured for other wind energy schemes 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 majority of construction activities will have effects of negligible to minor significance. For the activity which is closest to Euchanbank for Access Route B, predicted noise levels are likely to represent those for a very short term period of less than one week when activity is closest to this receptor. Noise levels will quickly diminish as construction progresses, moving the activity further from the property. The construction working hours for the proposed Development would allow working on Saturday afternoons and on Sundays: these short-term high noise level activities may potentially occur outside the working hours assumed in deriving the criteria of Table 1, therefore increasing their significance. However, specific restrictions are to be adopted (detailed in Section 6) which restrict these higher noise level activities during Saturday afternoons and Sundays. The short-term nature of these activities, in conjunction with activities being restricted to weekdays or Saturday mornings, consequently categorises the effects to be of minor significance.

Table 7 - Predicted construction noise levels (both access options considered)

Task Name	Plant/Equipment	Upper Collective Sound Emission Over Working Day $L_{WA,T}$ dB(A)	Nearest Receiver	Minimum Distance to Nearest Receiver (m)	Predicted Upper Day-Time L_{Aeq} dB
Upgrade Access Track (Access A)	excavator / dump trucks / tippers / dozers / vibrating rollers	120	Dalgonar	1350	46

Task Name	Plant/Equipment	Upper Collective Sound Emission Over Working Day $L_{WA,T}$ dB(A)	Nearest Receiver	Minimum Distance to Nearest Receiver (m)	Predicted Upper Day-Time L_{Aeq} dB
Upgrade Access Track (Access B)	excavator / dump trucks / tippers / dozers / vibrating rollers	120	Euchanbank	70	74
Construct temporary site compounds (Access A)	excavator / dump truck / tippers / rollers/ delivery trucks	120	Dalgonar	1100	48
Construct temporary site compounds (Access B)	excavator / dump truck / tippers / rollers/ delivery trucks	120	Euchanbank	130	68
Construct site tracks	excavators / dump trucks / tippers / dozers / vibrating rollers	120	Lorg	920	49
Construct Sub-Station	excavator / concrete truck / delivery truck	110	Dalgonar	2400	30
Construct crane hardstandings	excavators / dump trucks	120	Dalgonar	1600	44
Construct turbine / met mast foundations	Piling Rigs / excavators / tippers / concrete trucks / mobile cranes / water pumps / pneumatic hammers / compressors / vibratory pokers	120	Dalgonar	1600	44
Excavate and lay site cables	excavators / dump trucks / tractors & cable drum trailers / wacker plates	110	Dalgonar	1300	36
Erect turbines	cranes / turbine delivery vehicles / artics for crane movement / generators / torque guns	120	Dalgonar	1600	44
Reinstate crane bases	excavator / dump truck	115	Dalgonar	1600	39
Reinstate road verges	excavator / dump truck	115	Dalgonar	1600	39
Winning Stone from Borrow Pits (BP1)	Primary and secondary stone Crushers / excavators / screening systems / pneumatic breakers / conveyors	125	Euchanbank	1300	51
Concrete Batching	Batching Plant (in main compound)	110	Dalgonar	3500	26

Task Name	Plant/Equipment	Upper Collective Sound Emission Over Working Day $L_{WA,T}$ dB(A)	Nearest Receiver	Minimum Distance to Nearest Receiver (m)	Predicted Upper Day-Time L_{Aeq} dB
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	Dalgonar	1300	41

5.1.6 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 proposed Development presented in Chapter 12: Access, Traffic & Transport has assessed two scenarios: a worst-case scenario where all aggregate and concrete are sourced off site, and a likely scenario where these are sourced and batched on-site, with the worst-case assumed for the purposes of this noise assessment. In addition, two access option have been considered: Access Route A to the north and Access Route B to the east[2]. In the worst case scenario and for both access options, the highest volume of traffic generated by construction is expected to occur in months seven and eight of the construction program. This most intense period of activity is projected to be within a six month period of construction, with lower intensity in other months. Data for traffic flows presented in Chapter 12 have been used to ascertain the projected traffic flows for the worst case scenarios with and without the proposed Development..

Table 8 - Projected traffic flows and CRTN predicted increase in day-time average traffic noise levels ($L_{A10,18hour}$) for the worst-case scenario of all aggregate and concrete sourced off-site: Access Route A

Road	Without Development		With Development		Maximum Change in Traffic Noise Level, dB(A)
	Annual Average Daily Traffic Flow	% Heavy Goods Vehicles	Annual Average Daily Traffic Flow	% Heavy Goods Vehicles	
1. A76 (east of the A77 at Hurlford)	11779	0.7%	11866	1.1%	0.1
2. A76 (at Mauchline)	12908	0.8%	12995	1.2%	0.1
3. A76 (north of Cumnock)	11090	0.5%	11177	0.9%	0.1
4. A76 (west of New Cumnock)	6416	1.4%	6691	4.7%	0.9
5. A76 (east of New Cumnock)	2827	1.1%	3103	8.3%	1.9
6. A76(at the Hare Hill Windfarm access)	2404	23.0%	2679	29.1%	1.3
7. A76 (at Kirkconnel)	4135	10.4%	4374	14.1%	0.8
8. A70 (at Ochiltree)	7388	2.3%	7587	4.9%	0.6
9. A76 (south of Sanquhar)	3214	21.8%	3453	25.7%	0.8
10. A76 (at Thornhill)	4359	11.3%	4597	14.8%	0.7

2 An additional option of mixed use of both access options would result in lower traffic flows than exclusive use of Access Route A and has not therefore been specifically assessed.

Table 9 - Projected traffic flows and CRTN predicted increase in day-time average traffic noise levels ($L_{A10,18hour}$) for the worst-case scenario of all aggregate and concrete sourced off-site: Access Route B

Road	Without Development		With Development		Maximum Change in Traffic Noise Level, dB(A)
	Annual Average Daily Traffic Flow	% Heavy Goods Vehicles	Annual Average Daily Traffic Flow	% Heavy Goods Vehicles	
1. A76 (east of the A77 at Hurlford)	11779	0.7%	11856	0.9%	0.1
2. A76 (at Mauchline)	12908	0.8%	12984	1.0%	0.1
3. A76 (north of Cumnock)	11090	0.5%	11166	0.7%	0.1
4. A76 (west of New Cumnock)	6416	1.4%	6668	4.3%	0.8
5. A76 (east of New Cumnock)	2827	1.1%	3080	7.6%	1.8
6. A76 (at the Hare Hill Windfarm access)	2404	23.0%	2657	28.5%	1.2
7. A76 (at Kirkconnel)	4135	10.4%	4369	14.0%	0.8
8. A70 (at Ochiltree)	7388	2.3%	7614	4.6%	0.6
9. A76 (south of Sanquhar)	3214	21.8%	3430	25.2%	0.7
10. A76 (at Thornhill)	4359	11.3%	4574	14.4%	0.6

5.1.7 The above-referenced projected changes in traffic flows are summarised in Table 8 for Access Route A and in Table 9 for Access Route B. On this basis, the methodology set out in CRTN has been used to determine the associated maximum total changes in the average day-time traffic noise levels at any given location due to construction of the proposed Development (see Tables 8 & 9).

5.1.8 Tables 8 & 9 indicate a maximum potential increase of 1.9 dB(A) in the day-time average noise level during the most intense phases of the construction programme at locations adjoining the A76 (east of New Cumnock). Based on the criteria set out in the DMRB, the predicted short term change in traffic noise level would correspond to minor impact for either access option. Should the Access Route B be used, this traffic would pass along Blackaddie Road from Sanquhar to the site entrance. The predicted construction traffic flow value is well below the minimum flow volume of 1000 vehicles per day that is required by the CRTN methodology to enable reliable predictions. However, based on the predicted noise levels that CRTN suggests for the lowest flow value, it can be deduced that the associated $L_{Aeq,T}$ for the working day would be below 60 dB L_{Aeq} and would correspond to a temporary minor effect at most. As discussed above, construction hours allow for working on Saturday afternoons and on Sundays: these high flows and estimated higher noise levels may potentially occur outside the working hours assumed in deriving the criteria of Table 1. Specific restrictions are to be adopted (detailed in Section 6) which restrict these higher noise level activities during Saturday afternoons and Sundays. With the proposed restriction in traffic flows during Saturday afternoons and on Sundays consequently categorises the effects to be of negligible significance.

5.1.9 The most sensitive receiver locations in respect of vehicle movements are properties such as Euchanbank which lie relatively close to the midsection of the site access track, should Access Route B be used. For this access option, this receptor is at a distance of approximately 70 m or more, and is relatively isolated. Large vehicles can generate noise levels in the region of 108 dB (sound power level) when in motion. However, these types of plant usually pass a receiver location quite quickly. Based on the prediction methodology in BS 5288, once vehicles are travelling on this haul road this will give rise to a maximum predicted noise level of 56 dB(A) $L_{eq,1hr}$ based on 31 vehicles per hour[3] travelling at 35 km/hr[4]. At this location, in terms of significance criteria noise effects are considered to be of negligible significance. As discussed above, construction hours allow for working on Saturday afternoons and on Sundays: these haul route flows may potentially occur outside the working hours assumed in deriving the criteria of Table 1. Specific restrictions are to be adopted (detailed in Section 6) through a Construction Traffic Management Plan (CTMP) which would restrict higher noise level activities and restrict traffic movements for Access Route B during Saturday afternoons and Sundays. With the proposed restriction in traffic flows during Saturday afternoons and on Sundays, this consequently categorises the effects to be of negligible significance. Should Access Route A be used, distances to the nearest receptors would be greater, resulting in lower noise levels from vehicles using the access track and noise effects are considered to be of negligible significance, therefore no traffic restrictions are required.

5.1.10 In conclusion, noise from construction activities has been assessed and is predicted to result in a minor effect.

5.2 Construction Noise & Vibration Levels – Blasting

5.2.1 Because of the difficulties in predicting noise and air overpressure resulting from blasting operations, these activities are best controlled following the use of good practice during the setting and detonation of charges, as set out earlier in this report. Given the separation distances between the location of borrow pits and the nearest noise sensitive receptors (approximately 1.3 km as a minimum) it is very unlikely that these activities would cause unacceptable residual adverse effects.

5.2.2 The transmission and magnitude of ground vibrations associated with blasting operations at borrow pits are subject to many complex influences including charge type and position, and importantly, the precise nature of the ground conditions (material composition, compaction, discontinuities) at the source, receiver, and at every point along all potential ground transmission paths. Clearly any estimation of such conditions is subject to considerable uncertainty, thus limiting the utility of predictive exercises. Mitigation of potential effects of these activities is best achieved through on-site testing processes carried out in consultation with the Local Authorities.

5.3 De-commissioning Noise

5.3.1 De-commissioning is likely to result in less noise than during construction of the proposed Development. The construction phase has been considered to have minor noise effects, therefore de-commissioning will, in the worst case, also have minor noise effects.

5.4 Operational Wind Turbine Emissions Data

5.4.1 The exact model of turbine to be used at the site will be the result of a future tendering process and therefore an indicative candidate turbine model has been assumed for this noise assessment. This operational noise assessment is based upon the noise specification of the Vestas EnVentus V150-5.6 MW wind turbine. 21 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 150 m and a hub height of 155 m. 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.

3 The traffic assessment reports a maximum of 369 HGV vehicle movements per day for the most intense period. This is a total of 31 vehicles per hour for the twelve hour construction day.

4 A speed of 35 km/hr is estimated based on our experience of this type of activity and considered reasonably representative.

5.4.2 In addition to this general low noise characteristic at lower wind speeds the candidate 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 the wind turbines on the proposed Development have been modelled assuming standard operation and that none of these control modes are used.

5.4.3 Vestas have supplied specification noise emission data for the Vestas EnVentus V150-5.6 MW turbine which are values the manufacturer considers to be typical of this model of turbine. This turbine is as standard supplied with blades which have serrated trailing edges, typically resulting in lower noise emission levels than turbines without this blade technology. In the absence of specific information about uncertainty allowances in the manufacturers' specification a further correction factor of +2 dB was added to these specification data, consistent with advice in the IOA GPG. Sound power data have been made available for a range of wind speeds at hub height, converted to standardised ten metre reference wind speeds for the range from 3 m/s to 12 m/s inclusive. In addition to the overall sound power data, reference has been made to additional documentation from the manufacturer to derive a representative sound spectrum for the turbine. The overall sound power and spectral data are presented in Annex B.

5.4.4 A detailed ETSU-R-97 assessment is required at only three of the assessment locations listed above, at Dalgonar, Lorg and Shinnelhead, due to predicted noise immission levels from the proposed Development being higher than at the other assessment locations. At Lorg and Shinnelhead , cumulative noise needs to be assessed which includes a contribution from operation of the proposed Sanquhar II Windfarm only. At Dalgonar, a cumulative noise assessment together with a contribution from operation of the proposed Sanquhar II Windfarm is not required: this receptor location would be unoccupied during the life of the Sanqhuar II windfarm. Accordingly the assessment at Dalgonar considers noise from the proposed Development alone. All other windfarms are sufficiently distant from these three assessment locations that their relative contributions is acoustically not important, as they are at least 10 dB(A) below the ETSU-R-97 noise limits of Table 5 and Table 6, which control cumulative noise. Accordingly, operational noise from these more distant wind energy schemes has not been included in the assessments. Individual predicted noise immission levels from these other schemes has however been calculated for these three receptor locations, as illustrated in Annex D, to demonstrate that the noise contribution from these more distant windfarms make an acoustically unimportant contribution to total cumulative noise levels, therefore not included in the cumulative total (discussed further below). The Lorg assessment location would not be in residential use should Lorg Windfarm be built[5], accordingly assessment at this location is required only for a cumulative scenario without a contribution from Lorg Windfarm.

5.4.5 For the other seven assessment locations, predicted noise immission levels from the proposed Development alone are compared to the stringent criteria of Table 3 and Table 4. By meeting these criteria, the noise from the proposed Development would be at least 10 dB(A) below the full

[5] Lorg Windfarm Environmental Statement, November 2015, Amec Foster Wheeler Environment & Infrastructure UK Limited. Chapter 13: Geology, Hydrology and Hydrogeology states for Lorg Farmhouse that *"The landowner has confirmed that the property, and therefore the water supply, is not in use and will not be used during the construction, operation or decommissioning phases of the Proposed Development".*

ETSU-R-97 noise limits and would have an acoustically unimportant contribution to total cumulative noise levels.

5.4.6 Assessment of cumulative effects from operating the proposed Development and the adjacent Sanquhar II Windfarm requires source information for the turbine types on Sanquhar II. Data have been assumed for Sanquhar II Windfarm for the Enercon E-138 EP3 (131 m hub height) for all turbines except for two turbines which are Enercon E-115 EP3, consistent with information for the candidate turbines specified in the noise assessment for Sanquhar II Windfarm[xix]. Turbine sound power levels used in this assessment are those specified in the noise assessment for Sanquhar II (see in Annex B for further details). The noise assessment for Sanquhar II states that a suitable allowance for measurement uncertainty has been included in the sound power levels used for noise modelling, in accordance with the IOA GPG.

5.4.7 Predicted noise immission levels for other more distant windfarms have been considered for the three cumulative assessment locations. These predicted noise immission levels require source information for the turbine types for each of these other windfarms. A detailed discussion of each of these windfarms and associated sound power levels is provided in Annex B.

5.5 Choice of Wind Turbine Operational Noise Propagation Model

5.5.1 The ISO 9613-2 model[xx] 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, barrier and ground effects. All attenuation calculations have been made on an octave band basis and therefore account for the sound frequency characteristics of the turbines.

5.5.2 For the purposes of the present assessment, all noise level predictions have been undertaken using a receiver height of 4 m above local ground level, mixed ground (G=0.5) and an air absorption based on a temperature of 10 °C and 70% relative humidity. A receiver height of 4 m will be typical of first floor windows and result in slightly higher predicted noise levels than if a 1.2 to 1.5 metre receiver height were chosen in the ISO 9613 algorithm. 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 +3 dB(A) was added. This method is consistent with the recommendations of the above-referenced Institute of Acoustics Good Practice Guide which provides recommendations on the appropriate approach when predicting wind turbine noise levels. The corrections applied are detailed in Annex B.

5.5.3 The IOA GPG also allows for directional effects to be taken into account within the noise modelling: under upwind propagation conditions between a given receiver and the windfarm the noise immission level at that receiver can be as much as 10 dB(A) to 15 dB(A) lower than the level predicted using the ISO 9613-2 model. However, predictions have been made assuming downwind propagation from every turbine to every receptor at the same time as a worst-case.

5.6 Predicted Wind Turbine Operational Noise Immission Levels

5.6.1 Table 10 shows predicted noise immission levels at each of the selected assessment locations for each wind speed from 3 m/s to 12 m/s inclusive for the proposed Development alone. All wind turbine noise immission levels in this report are presented in terms of the $L_{A90,T}$ noise indicator in accordance with the recommendations of the ETSU-R-97 report, obtained by subtracting 2 dB(A) from the calculated $L_{Aeq,T}$ noise levels, based on the turbine sound power levels presented in Annex B.

Table 10 - Predicted $L_{A90,T}$ dB 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
Cairnhead	-	-	17.5	21.5	26.0	28.4	29.3	29.3	29.3	29.3	29.3	29.3
Corlae	-	-	14.3	18.3	22.8	25.2	26.1	26.1	26.1	26.1	26.1	26.1
Craig	-	-	10.7	14.7	19.2	21.6	22.5	22.5	22.5	22.5	22.5	22.5
Dalgonar	-	-	21.6	25.6	30.1	32.5	33.4	33.4	33.4	33.4	33.4	33.4
Euchanbank Cottage	-	-	16.2	20.2	24.7	27.1	28.0	28.0	28.0	28.0	28.0	28.0
Hillend	-	-	12.9	16.9	21.4	23.8	24.7	24.7	24.7	24.7	24.7	24.7
Lorg	-	-	24.1	28.1	32.6	35.0	35.9	35.9	35.9	35.9	35.9	35.9
Polgown	-	-	15.0	19.0	23.5	25.9	26.8	26.8	26.8	26.8	26.8	26.8
Shinnelhead	-	-	18.4	22.4	26.9	29.3	30.2	30.2	30.2	30.2	30.2	30.2
Upper Holm of Dalquhairn	-	-	14.7	18.7	23.2	25.6	26.5	26.5	26.5	26.5	26.5	26.5

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 wind turbines to be used for this site will be chosen to ensure that the noise emitted will comply with the requirements of ETSU-R-97 including any relevant tonality corrections.

5.7 ETSU-R-97 Assessment – Proposed Development in Isolation

5.7.1 Table 11 and Table 12 show the differences between predicted noise immission levels due to the proposed Development alone at the seven assessment locations shown in Table 3 and Table 4 where it was appropriate to derive stringent criteria for assessment of noise levels from the proposed Development alone. These tables show that the predicted wind turbine noise immission levels from the proposed Development alone meet these stringent criteria / limits set 10 dB(A) below appropriate ETSU-R-97 noise criterion under all wind speeds and at all relevant locations, accordingly it is concluded that these precautionary minus 10 dB(A) criteria / limits are complied with at all of these locations and all wind speeds.

5.7.2 These precautionary minus 10 dB(A) criteria / limits have been used to demonstrate that predicted noise immission levels from the proposed Development would not add an acoustically important contribution to cumulative noise immission levels at these assessment locations, consequently a full cumulative assessment is not required for these assessment locations and it can be concluded that the requirements of ETSU-R-97 would be met at these locations. This is also illustrated in the relevant charts of Annex C.

Table 11 - Difference between the derived day-time stringent noise criteria (10 dB below the ETSU-R-97 noise limits) and the predicted $L_{A90,t}$ dB wind turbine noise immission levels at each noise assessment location for the proposed Development alone. Negative values indicate the noise immission level is below the criterion.

Property	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Cairnhead	-	-	-12.5	-8.5	-4.0	-1.6	-0.7	-0.7	-0.7	-0.7	-0.7	-0.7
Corlae	-	-	-15.7	-11.7	-7.2	-4.8	-3.9	-3.9	-3.9	-3.9	-3.9	-3.9
Craig	-	-	-19.3	-15.3	-10.8	-8.4	-7.5	-7.5	-7.5	-7.5	-7.5	-7.5
Euchanbank Cottage	-	-	-13.9	-9.9	-5.4	-3.0	-2.1	-2.1	-2.1	-2.1	-2.1	-2.1
Hillend	-	-	-18.3	-14.3	-9.8	-7.4	-6.5	-6.5	-6.5	-6.5	-6.5	-6.5
Polgown	-	-	-15.0	-11.0	-6.5	-4.1	-3.2	-3.2	-3.2	-3.2	-3.2	-3.2
Upper Holm of Dalquhairn	-	-	-15.3	-11.3	-6.8	-4.4	-3.5	-3.5	-3.5	-3.5	-3.5	-3.5

Table 12 - Difference between the derived night-time stringent noise criteria (10 dB below the ETSU-R-97 noise limits) and the predicted $L_{A90,t}$ dB wind turbine noise immission levels at each noise assessment location for the proposed Development alone. Negative values indicate the noise immission level is below the criterion.

Property	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Cairnhead	-	-	-15.5	-11.5	-7.0	-4.6	-3.7	-3.7	-3.7	-3.7	-3.7	-3.7
Corlae	-	-	-18.7	-14.7	-10.2	-7.8	-6.9	-6.9	-6.9	-6.9	-6.9	-6.9
Craig	-	-	-22.3	-18.3	-13.8	-11.4	-10.5	-10.5	-10.5	-10.5	-10.5	-10.5
Euchanbank Cottage	-	-	-16.9	-12.9	-8.4	-6.0	-5.1	-5.1	-5.1	-5.1	-5.1	-5.1
Hillend	-	-	-18.3	-14.3	-9.8	-7.4	-6.5	-6.5	-6.5	-6.5	-6.5	-6.5
Polgown	-	-	-18.0	-14.0	-9.5	-7.1	-6.2	-6.2	-6.2	-6.2	-6.2	-6.2
Upper Holm of Dalquhairn	-	-	-18.3	-14.3	-9.8	-7.4	-6.5	-6.5	-6.5	-6.5	-6.5	-6.5

5.8 ETSU-R-97 Assessment – Cumulative

5.8.1 Table 13 shows predicted noise immission levels at each these noise assessment locations for each standardised wind speed from 3 m/s to 12 m/s inclusive due to operation of the Sanquhar II Windfarm. Similarly, Table 14 shows cumulative predicted noise immission levels from the proposed Development when operating together with the proposed Sanquhar II Windfarm. These predictions are cumulative assuming that these receptors are downwind of all wind turbines on the proposed Development and Sanquhar II at the same time. These cumulative noise levels are therefore unlikely to occur in practice and represent a conservative estimate of likely actual cumulative noise levels.

Table 13 - Predicted $L_{A90,T}$ dB noise immission levels at each of the cumulative noise assessment locations as a function of standardised wind speed for the Sanquhar II Windfarm operating alone.

Property	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Shinnelhead			27.0	32.9	34.2	35.2	35.8	36.4	37.1	37.1	37.1	37.1
Lorg	-	-	18.4	24.3	25.6	26.6	27.3	27.9	28.6	28.6	28.6	28.6

Table 14 – Cumulative predicted $L_{A90,T}$ dB noise immission levels at each of the cumulative noise assessment locations as a function of standardised wind speed for Sanquhar II Windfarm and the proposed Development operating together.

Property	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Shinnelhead			27.6	33.3	34.9	36.2	36.9	37.3	37.9	37.9	37.9	37.9
Lorg	-	-	25.1	29.6	33.4	35.6	36.5	36.5	36.6	36.6	36.6	36.6

Table 15 – Difference between the ETSU-R-97 noise limits and the cumulative predicted $L_{A90,t}$ dB windfarm noise immission levels at each noise assessment location. Negative values indicate the noise immission level is below the limits.

Property	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Shinnelhead (day)			-12.4	-6.6	-5.0	-3.7	-3.1	-2.6	-2.0	-4.0	-7.0	-9.0
Lorg (day)	-	-	-14.8	-10.4	-6.6	-4.4	-3.6	-3.5	-3.4	-3.4	-3.4	-3.4
Shinnelhead (night)			-15.4	-9.6	-8.0	-6.7	-6.1	-5.6	-5.0	-5.0	-5.0	-8.0
Lorg (night)	-	-	-17.8	-13.3	-9.5	-7.4	-6.5	-6.4	-6.3	-6.3	-6.3	-6.3

5.8.2 The cumulative assessment (shown in tabular form in Table 15) shows the difference between cumulative predicted noise immission levels due to the cumulative total of the Sanquhar II Windfarm operating with the proposed Development at the two relevant assessment locations, for both day-time and night-time periods.

5.8.3 Predicted noise immission levels for Sanquhar II alone and cumulatively with the proposed Development are not shown for the Dalgonar receptor location, as this receptor would be unoccupied for the life of the Sanqhuar II windfarm. For the Dalgonar receptor location the relevant assessment is to compare predicted noise immission levels from the proposed Development operating alone with the ETSU-R-97 criteria. Table 16 shows this comparison at the Dalgonar assessment location, for both day-time and night-time periods.

Table 16 – Difference between the ETSU-R-97 noise limits and the predicted $L_{A90,t}$ dB wind turbine noise immission levels at the Dalgonar noise assessment location for the proposed Development alone. Negative values indicate the noise immission level is below the criterion.

Property	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Dalgonar (day)	-	-	-18.4	-14.4	-9.9	-7.5	-6.6	-6.6	-6.6	-7.6	-8.6	-10.6
Dalgonar (night)	-	-	-21.4	-17.4	-12.9	-10.5	-9.6	-9.6	-9.6	-9.6	-9.6	-9.6

5.8.4 Figures D1 to D20 (Annex D) show the calculated windfarm noise immission levels at the ten noise assessment locations and correspond to those already presented in the tables set out above, plotted as a function of standardised ten metre wind speed. The calculated noise immission levels are shown overlaid on the day-time and night-time noise criteria / limit curves. These limits curves have been derived from ETSU-R-97 noise limits appropriate to each location, which were derived from background noise data already surveyed for other nearby windfarms, as detailed in Annex C.

5.8.5 For the three assessment locations where a full ETSU-R-97 assessment has been completed, additional criteria have been shown on the associated charts for both day-time and night-time, which are set 10 dB(A) below the relevant ETSU-R-97 noise limits (see Figures D7 & D8 for Dalgonar, Figures D13 & D14 for Lorg and Figures D17 & D18 for Shinnelhead). These lower criteria are provided to demonstrate that predicted noise immission levels for more distant windfarms are acoustically unimportant at these three assessment locations, with predicted noise immission levels laying below these additional criteria.

5.8.6 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: the area of the proposed Development and its surroundings is generally of very low population density, with a limited number of surrounding properties near to wind energy developments in the area.
- Duration and level of exposure: For the majority of properties in the area, their exposure to noise from the proposed Development would be very low, with only three locations exposed to higher noise levels such that a full ETSU-R-97 assessment is required. All predictions are based on downwind conditions (wind blowing from all sources to all receivers at the same time), and the actual levels which occur in practice will be lower than those set in the above tables, particularly for those assessment locations which may be affected cumulatively.
- Generation capacity: The generating capability of the proposed Development is significant and when added to the generating potential of other schemes already present or proposed in the area near to the proposed Development suggests noise limits at the upper end of those given in ETSU-R-97. 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 windfarm site comprising around 196 turbines[6] would have been required to achieve a similar generating capacity to that of the proposed Development, thus highlighting the significance of the scheme.

5.8.7 A review of adjacent windfarm consents and noise assessments (see Annex C) confirms that the choice of the day-time limit has already been set at 40 dB(A) for many of these schemes and so remains appropriate for the proposed Development and the cumulative assessment undertaken, on the premise of the significant energy generating capacity, combined with the relatively low number of dwellings in the surrounding area. The presence of the proposed Development would increase the duration of exposure of the assessment locations to wind turbine noise. For seven of the assessment location the level of exposure would remain very low and meet these precautionary minus 10 dB(A) criteria / limits. For the three assessment locations for which a cumulative assessment has been completed, the level of exposure would remain low compared with the overall ETSU-R-97 cumulative criteria. Accordingly the 40 dB(A) ETSU-R-97 criteria would be appropriate.

5.8.8 It is finally concluded that predicted cumulative noise immission levels from the proposed Development when operating together with Afton Windfarm, Harehill and Harehill Extension Windfarms, Lorg

[6] Based on typically 0.6 MW turbines being at the upper end of turbine capacities at the time of ETSU-R-97 was formulated and the candidate 5.6 MW turbine used for the noise assessment. The Development would have turbines of the type and size typical of the candidate used for the noise assessment, with a generating capacity of around 6 MW.

Windfarm, Sanquhar Windfarm, Sanquhar Six Windfarm, Sanquhar II Windfarm, Whiteside Hill Windfarm and Windy Rig Windfarm would be compliant with the ETSU-R-97 criteria at all assessment locations and all wind speeds.

5.8.9 Satisfactory control of cumulative noise immission levels would therefore be achieved through enforcement of the individual consent limits for each of the individual windfarms. These criteria of Table 3 and Table 4 would represent suitable partial noise limits which apply to the proposed Development in isolation for the relevant seven assessment locations.

5.8.10 For the assessment locations of Lorg and Shinnelhead, a cumulative assessment has been completed for the proposed Development operating together with the proposed Sanquhar II Windfarm. Should the Sanquhar II Windfarm be consented, it would be appropriate to apportion the full ETSU-R-97 noise limits between Sanquhar II Windfarm and the proposed Development. Suitable apportioned noise limits have been derived in Annex E and tabular limit values are shown in Tables E1 & E2, which could be applied to control operational noise from both schemes at these two assessment locations. These apportioned noise limits have been derived following the process described in the IOA GPG (See IOA GPG Para 5.4.2 & Figure 7). The resulting partial noise limits are such that compliance of the proposed Development with these noise limits would maintain the conclusion of the cumulative assessment and result in cumulative levels which do not exceed the derived ETSU-R-97 noise criteria.

5.8.11 Should the Sanquhar II Windfarm not be granted consent then apportionment of the noise limits would not be necessary and the full ETSU-R-97 noise limits (see Table 5 and Table 6) could be applied to control noise from the proposed Development at these two assessment locations.

5.8.12 For the assessment location of Dalgonar, this location would not be occupied during the life of the Sanqhuar II windfarm, accordingly the full assessment at this receptor compared predicted noise immission levels from the proposed Development alone with the full ETSU-R-97 noise limits. Noise from other more distant windfarms was not included within the assessment as they are at least 10 dB(A) below the ETSU-R-97 noise limits and their contribution is acoustically unimportant. Consequently, the full ETSU-R-97 noise limits (see Table 5 and Table 6) could be applied to control noise from the proposed Development at this assessment location.

5.9 Substation and Energy Storage Operational Noise

5.9.1 The main noise sources associated with the substation are likely to be the power transformers and the cooling fans. Operational noise associated with any ancillary services such as energy storage facility would arise from ventilation/air conditioning systems, modular inverters and lower-voltage transformers and higher-voltage transformers associated with grid connection (were this not to be shared with the main substation).

5.9.2 Given the large separation distances of approximately 2.4 km or more between the substation (and energy storage facility which is also located with the substation) and the nearest residential properties, experience of similar installations and professional judgement, the associated levels of operational noise would be negligible and not significant.

5.10 Low Frequency Noise, Vibration and Amplitude Modulation

5.10.1 Low frequency noise and vibration resulting from the operation of windfarms 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 windfarms.

5.10.2 Annex A also discusses the most recently 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.

5.11 Evaluation of Effects

Table 17 – Summary of effects

Potential Effect	Evaluation of Effect
Construction Noise	Noise levels have been predicted using the methodology set out in BS 5228. Based on assessment criteria derived and supported by a range of noise policy and guidance, overall construction noise levels are considered to represent a minor effect, and therefore considered not significant in EIA terms.
Operational Noise	Noise criteria have been established in accordance with ETSU-R-97. It has also been shown that these criteria are achievable with a commercially available turbine suitable for the proposed Development. The basis of the ETSU-R-97 method is to define acceptable noise limits thought to offer reasonable protection to residents in areas around windfarm developments. At some locations under some wind conditions and for a certain proportion of the time, wind turbine noise may be audible; however, operational noise immission levels are acceptable in terms of the guidance commended by planning policy for the assessment of windfarm noise, and therefore considered not significant in EIA terms. Operational noise from the substation and energy storage facility would be negligible and not significant in EIA terms.

6. Mitigation, Offsetting and Enhancement Measures

6.1 Proposed Construction Noise Mitigation Measures

6.1.1 To reduce the potential effects of construction noise, the following types of mitigation measures are proposed:

- Those activities that may give rise to audible noise at the surrounding properties and heavy goods vehicle deliveries to the site would be limited to the hours 07:00 to 19:00 Monday to Friday and 07:00 to 16:00 at weekends. Turbine deliveries would only take place outside these times with the prior consent of the Council and Police Scotland. Some quieter activity (e.g. turbine installation) may occur outside the specified hours. Should Access Route B be used, some construction activities will be further restricted. Specifically, no construction HGV traffic will use Access Route B during Saturday afternoons and Sundays and light vehicles will be phased to spread the intensity of use so there are no more than approximately 35 vehicle movements per hour. In addition, activities related to upgrading of the access track or construction of the temporary site compound within 500 m of the Euchanbank receptor would be restricted to weekdays (07:00 to 19:00) and Saturday mornings (07:00 to 13:00).
- All construction activities shall adhere to good practice as set out in BS 5228.
- All equipment will be maintained in good working order and any associated noise attenuation such as engine casing and exhaust silencers shall remain fitted at all times.
- Where flexibility exists, activities will be separated from residential neighbours by the maximum possible distances.

- A CTMP will be developed to control the movement of vehicles to and from the proposed Development site, including the above-described restrictions for Access Route B.
- Construction plant capable of generating significant noise and vibration levels will be operated in a manner to restrict the duration of the higher magnitude levels.

6.1.2 The potential noise and vibration effects of blasting operations will be reduced according to the guidance set out in the relevant British Standards and PAN50 annex D and discussed below:-

- Blasting should take place under strictly controlled conditions with the agreement of the relevant authorities, at regular times within the working week, that is, Mondays to Fridays, between the hours of 10:00 and 16:00pm. Blasting out with these times should be a matter for negotiation between the contractor and the local authorities;
- Vibration levels at the nearest sensitive properties are best controlled through on-site testing processes carried out in consultation with the Local Authorities. This site testing based process would include the use of progressively increased minor charges to gauge ground conditions both in terms of propagation characteristics and the level of charge needed to release the requisite material. The use of onsite monitoring at neighbouring sensitive locations during the course of this preliminary testing can then be used to define upper final charge values that will ensure vibration levels remain within the criteria set out previously, as described in BS 5228-2 and BS 6472-2 2008;
- Blasting operations shall adhere to good practice as set out in BS 5228-2, and in PAN50, Annex D in order to control air overpressure.
- A scheme will be submitted to the mineral planning authority, for approval of blasting details, which will outline the mitigation measures to be adopted.

6.2 Proposed Operational Noise Mitigation Measures

6.2.1 The selection of the final turbine to be installed at the site would be made on the basis of enabling the relevant ETSU-R-97 noise limits to be achieved at the surrounding properties.

7. Monitoring

7.1.1 It is proposed that if planning consent is granted for the proposed Development, conditions attached to the planning consent should include the requirement that, in the event of a noise complaint, noise levels resulting from the operation of the proposed Development are measured in order to demonstrate compliance with the conditioned noise limits. Such monitoring should be done in full accordance with ETSU-R-97 and include penalties for characteristics of the noise (if present).

8. Summary of Key Findings and Conclusions

8.1.1 This report has presented an assessment of the effects of construction and operational noise from the proposed Development on the residents of nearby dwellings.

8.1.2 A number of residential properties lying around the proposed Development have been selected as being representative of the closest located properties to the proposed Development. The minimum separation distance between the nearest wind turbine and the closest located residential property is approximately 1040 m. Noise assessments have been undertaken at these properties by comparing predicted construction and operational noise levels with relevant assessment criteria. In the case of construction noise, relevant assessment criteria are in the form of absolute limit values derived from a range of environmental noise guidance. In relation to operational noise, the limits have been derived from the existing background noise levels at surrounding properties, as derived from measurements made for adjacent wind energy schemes.

8.1.3 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 effects are considered minor.

8.1.4 Operational wind turbine noise from the proposed Development has been assessed in accordance with the methodology set out in the 1996 DTI Report ETSU-R-97, 'The Assessment and Rating of Noise from Windfarms'. This document provides a robust basis for assessing the operational noise of a windfarm as recommended by Scottish Planning Policy.

8.1.5 Applying the ETSU-R-97 derived noise limits at the assessment locations it has been demonstrated that both the day-time and night-time noise criterion limits can be satisfied at all properties across all wind speeds. This assessment has been based on the use of the manufacturer's warranted sound power data for the Vestas EnVentus V150-5.6 MW candidate wind turbine, which is typical of the type and size of turbine which may be considered for this site, and assuming worst case downwind propagation.

8.1.6 In summary, the overall levels of construction noise are considered to represent a minor effect, and therefore considered not significant in EIA terms. At some locations under some wind conditions and for a certain proportion of the time, wind turbine noise may be audible; however, operational noise immission levels are acceptable in terms of the guidance commended by planning policy for the assessment of wind turbine noise, and therefore considered not significant in EIA terms.

9. References

i Scottish Planning Policy (SPP), Scottish Government, 2014.

ii Planning Advice Note 1/2011: Planning & Noise, Scottish Government, March 2011.

iii Scottish Government, Online Renewables Planning Advice, Onshore Wind Turbines (http://www.gov.scot/Resource/0045/00451413.pdf). Updated May 28, 2014.

iv 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.

v 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.

vi Letter from John Swinney MSP, Scottish Government, 29/05/2013

vii PAN1/2011 Technical Advice Note – Assessment of Noise, Scottish Government, March 2011.

viii Control of Pollution Act, Part III, HMSO, 1974.

ix BS 5228 Noise and Vibration Control on Construction and Open Sites, Parts 1 to 4.

x BS 5228-1:2009-A:2014 'Code of practice for noise and vibration control on construction and open sites – Part 1: Noise'.

xi BS 5228-2:2009-A:2014 'Code of practice for noise and vibration control on construction and open sites – Part 2: Vibration'.

xii Planning Advice Note 50: Controlling The Environmental Effects of Surface Mineral Workings, 1996.

xiii BS 6472-2:2008:Guide to evaluation of human exposure to vibration in buildings - Part 2: Blast-induced vibration.

xiv Calculation of Road Traffic Noise, HMSO Department of Transport, 1988.

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

xvi Design Manual for Roads and Bridges, Volume 11, section 3, Part 7, Traffic Noise and Vibration, The Highways Agency, Transport Scotland, Transport Wales, The Department for Regional Development (Northern Ireland)

xvii BS 4142:2014+A1:2019 'Methods for rating and assessing industrial and commercial sound'.

xviii Euchanhead Renewable Energy Development, EIA Scoping Topic Factsheet, Noise. February, 2020

xix Sanquhar II Community Wind Farm – EIA Report: Section 11: Noise, January 2019 and Sanquhar II Community Wind Farm – Additional Information Report: Section 11: Noise, August 2020.

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

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.

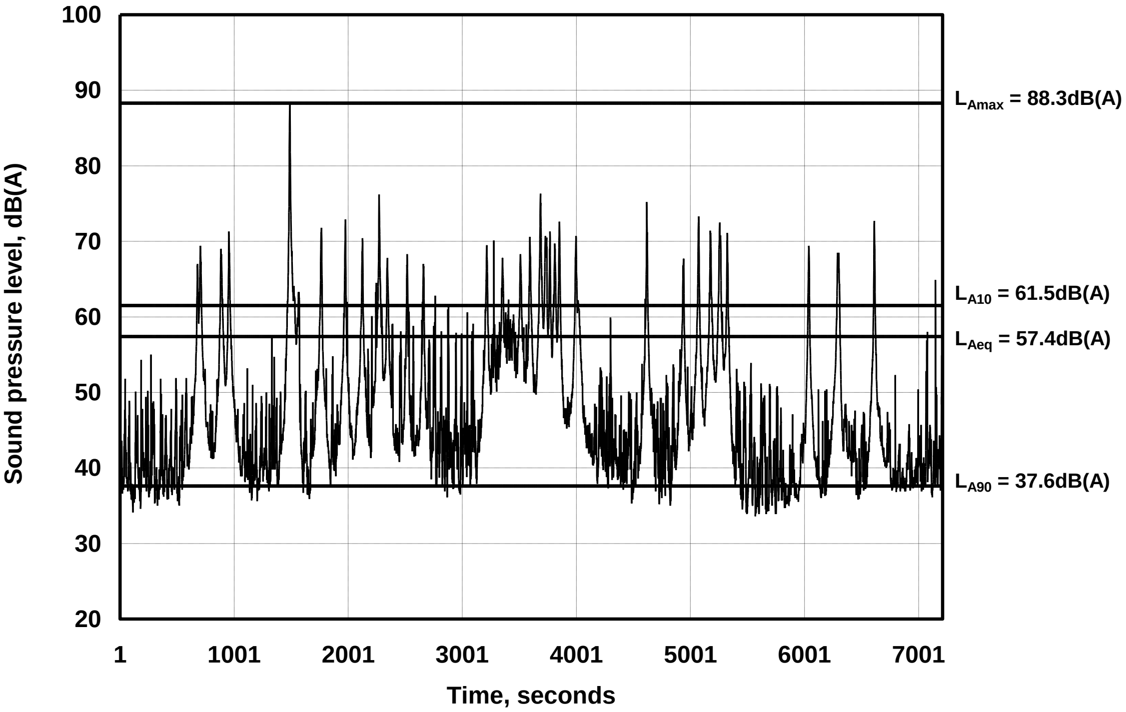
A.5 Before reviewing the potential effects of environmental sound on people, it is useful first to consider the means by which physical sound can be quantified.

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 m 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 windfarms 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 windfarm 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 windfarm 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'.*

A.33 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.34 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 windfarms 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.35 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.36 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.37 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.38 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.39 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.40 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.41 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.42 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.43 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.44 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.45 Table 4.1 of the WHO Guidelines 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.46 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.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.

Effects of Noise on Wildlife

A.51 There are large numbers of papers in the literature which describe the effects of noise on birds and animals, both wild and livestock.

A.52 Just as the assessment of noise effects on humans is made difficult by the variability of responses between different people and between different situations, assessment of noise effects on wildlife is even more problematical, not least due to the problem of monitoring the response of wildlife to noise.

A.53 For larger species, it may be possible to install telemetry on the body of the animal to relay information about its body systems (e.g. heart rate, temperature etc.). However, the minimum physical sizes of telemetry systems means this is not an option for smaller species. Also, even where it is possible, the fact that the animals must first be captured to have a system installed disturbs them, and the results of the subsequent study may be biased. In the absence of such telemetric data, researchers must rely on observations such as flight from nests, short term departure from usually populated areas and deviations from expected line of travel. However, flock and pack instincts often mean that just one animal changing course or taking flight can result in all the others doing the same.

A.54 The only truly robust determinant to the effects of noise on wildlife is the long-term desertion of traditionally inhabited areas, or a reduction in breeding numbers. However, even these factors can be brought into question when the noise is a result of some other local activity, such as the passage of vehicles. In these cases, it is often difficult to establish whether the observed effect is a consequence of the visual disturbance or the noise.

A.55 Direct comparisons of results between species, or even between different research findings into the same species, are therefore often unclear, and it is difficult to draw firm conclusions as to the effects of noise on wildlife, other than in a highly generalised manner.

A.56 General features apparent from the literature are that the most sensitive time for animals is during nesting or breeding seasons. Those that take flight whilst sitting on their eggs or tending their young can leave them open to predators, even if they return fairly quickly. However, many species have been shown to habituate to noise of all types, including road traffic noise, aircraft noise or even the decreasing effectiveness with time of impulsive type bird scarers, such as those used around airports.

Low Frequency Noise and Vibration – Windfarms

A.57 One issue that has increasingly been raised concerning potential noise effects of operational windfarms 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.58 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.59 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.60 The fact that low frequency sound and infrasound from windfarms has only relatively recently 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.61 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.62 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.63 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.

C-Weighting

A.64 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.65 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.

G-Weighting

A.66 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.

A.67 Over the past few years there has been considerable attention paid to the possibility that operational windfarms may radiate sufficiently high levels of infrasound to cause health problems. It has, however, been the case that dedicated research investigations have shown this not to be the case.

A.68 As early as 1997 a report by Snow [2] 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 windfarm. Measurements were made both on the windfarm 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 m 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 m from the turbines.

A.69 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 windfarm 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.70 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 [1]. Dr Leventhall notes that despite the numerous published studies there is little or no agreement about the biological effects of infrasound or low frequency sound on human health. Leventhall notes that direct evidence of adverse effects of exposure to low-intensity levels of infrasound (less than 90 dB) is lacking. He goes on to describe the low frequency hearing threshold i.e. the lowest levels which are audible to an average person with normal hearing. He notes the threshold at 4 Hz is about 107 dB, at 10 Hz it is about 97 dB and at 20 Hz it is 79 dB. As such, high levels of infrasound are required to exceed the hearing thresholds at such low frequencies. Leventhall therefore concluded that most people can be reassured that there will be no serious consequences to peoples' health from infrasound exposure.

A.71 Indeed, specifically in relation to windfarms 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 windfarms, 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. 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.72 In 2004/2005 researchers from Keele University investigated the effects of the extremely low levels of vibration resulting from windfarms 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 have frequently been misinterpreted, as just discussed for the DEFRA/Leventhall report, in that if infrasonic vibrations from windfarms can be measured, then they must consequentially have some potential effect on humans. In order to clarify their position, the authors have subsequently explained that [3]:

'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.73 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.74 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.75 Even more recently, 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 windfarms have been published in what is commonly referred to as the DTI LFN Report [4].

A.76 The DTI LFN Report is a comprehensive study containing many pages of detailed results of measurements of both infrasound and low frequency sound around the three windfarms included in the study. These measurements were undertaken using measurement systems capable of detecting noise down to frequencies of 1 Hz, with results being reported up to a frequency of 500 Hz, thus extending beyond the full spectrum of what is normally considered to cover both infrasound (<20 Hz) and low frequency sound (20 Hz to 200 Hz).

A.77 The measurement locations at the three windfarms were selected to be at residential properties where occupants had raised concerns relating to low frequency sound disturbance. Noise immission measurements are reported both externally to and internally to the properties in question. In addition to these noise immission measurements, the results of noise emission measurements undertaken on a number of wind turbines are also reported with the aim of quantifying the level of infrasound actually emitted from individual wind turbines and windfarms.

A.78 Before summarising the findings of the DTI LFN Report, it is noted that the prevalence of the perceived problem of infrasound and/or low frequency sound is not a widespread one. Quoting from the Executive Summary to the DTI LFN Report:

> *'of the 126 wind farms operating in the UK, 5 have reports of low frequency sound problems which attract adverse comment concerning the noise. Therefore, such complaints are the exception rather than a general problem which exists for all wind farms'.*

A.79 The DTI LFN Report was actually commissioned primarily to investigate the effects of infrasound. This investigation was commissioned as a direct result of the claims made in the press concerning health problems arising from noise of such a low frequency 'that it is beyond the audible range, such that you can't hear it but you can feel it as a resonance'. For this reason the results pertaining to infrasound are reported separately from those pertaining to audible low frequency sound above 20 Hz.

A.80 In respect of infrasound, the DTI LFN Report is quite categorical in its findings: infrasound is not the perceived health threat suggested by some observers, nor should it even be considered a potential source of disturbance. Quoting from the Executive Summary to the DTI LFN Report:

> *'Infrasound noise emissions from wind turbines are significantly below the recognised threshold of perception for acoustic energy within this frequency range. Even assuming that the most sensitive members of the population have a hearing threshold which is 12 dB lower than the median hearing threshold, measured infrasound levels are well below this criterion.*
>
> *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.81 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.

A.82 Indeed, in the face of the apparent misunderstanding of the conclusions reached in the various reports on infrasound, and how these conclusions should be applied to consideration of the radiation of such noise from windfarms, the British Wind Energy Association have issued a fact sheet relating to the subject [5]. This fact sheet concludes:

> *'With regard to effects of noise from wind turbines, the main effect depends on the listener's reaction to what they may hear. There are no direct health effects from noise at the level of noise generated by wind turbines. It has been repeatedly shown by measurements of wind turbine noise undertaken in the UK, Denmark, Germany and the USA over the past decade, and accepted by experienced noise professionals, that the levels of infrasonic noise and vibration radiated from modern, upwind configuration wind turbines are at a very low level; so low that they lie below the threshold of perception, even for those people who are particularly sensitive to such noise, and even on an actual wind turbine site'.*

Low Frequency Sound

A.83 A report prepared for DEFRA by Casella Stanger [6] lists windfarms 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 windfarms.

A.84 In respect of low frequency sound as opposed to infrasound, the DTI LFN Report identified that windfarm 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 windfarms 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.

A.85 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.86 In November 2006, the UK Government released a statement [7] 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.87 The Government statement concluded the position regarding low frequency sound from windfarms 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 windfarms.

Blade Swish (Amplitude Modulation)

A.88 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 windfarm 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 windfarms reported to be operational at the time in 2006);

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

A.89 The Government then commissioned an independent research project to further investigate the prevalence of the impact of enhanced levels of amplitude modulation across UK windfarms. This research work was awarded to the University of Salford who reported on their findings in July 2007 [8]. 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.90 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 [9] 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.91 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.92 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. This research, commissioned by RenewableUK (ReUK) was specifically aimed at identifying and explaining some of the key features of wind turbine AM noise.

A.93 Claims have emerged from different researchers that wind turbines were capable of generating noise with characteristics outwith 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.94 The research identified the most likely cause of OAM noise is transient stall on the wind turbine blade (i.e. stall which occurs over a small area of each turbine blade in one part of the blade’s rotation only). The occurrence of transient stall will be dependent on a combination of factors, including the air inflow conditions onto the individual blades, how these inflow conditions may vary across the rotor disc, the design of the wind turbine blades and the manner in which the wind turbine is operated. Variable inflow conditions may arise, for example, from any combination of wind shear, wind veer, yaw errors, turbine wake effects, topographic effects, large scale turbulence, etc. However, the occurrence of OAM on any particular site cannot be predicted at this stage.

A.95 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 [11] for implementation as a planning condition, although this was subject to discussion.

A.96 The Institute of Acoustics (IOA) published in 2016 a standardised methodology [12] 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.97 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 [13] 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 windfarm. 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. The Scottish Government is currently reviewing this report in the context of the Scottish planning system.

References for LFN and AM Section

[1] ‘A review of published research on low frequency noise and its effects’, G. Leventhall, report for DEFRA, 2003

[2] ‘Low frequency noise and vibration measurements at a modern wind farm’, D. Snow, ETSU Report ETSU W/13/00392/REP, 1997

[3] ‘Wind farm noise’, P. Styles, letter by Prof P Styles and S Toon printed in The Scotsman, August 2005.

[4] ‘The measurement of low frequency noise at three UK wind farms’, M. Hayes, DTI Report W/45/00656/00, 2006

[5] ‘Low frequency noise and wind turbines’, BWEA Briefing Sheet, 2005

[6] ‘Low frequency noise’, Report by Casella Stanger for DEFRA, 2001

[7] ‘Advice on Findings of the Hayes McKenzie Report on Noise Arising from Wind Farms’, URN 06/2162 (November 2006)

[8] ‘Research into Aerodynamic Modulation of Wind Turbine Noise’, Report by University of Salford, URN 07/1235 (July 2007)

[9] ‘Government statement regarding the findings of the Salford University report into Aerodynamic Modulation of Wind Turbine Noise’, BERR, Ref: 2007/033 (1st August 2007)

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

[11] Template Planning Condition on Amplitude Modulation (guidance notes), RenewableUK, December 2013.

[12] Institute of Acoustics (IOA) Amplitude Modulation Working Group, Final Report, A Method for Rating Amplitude Modulation in Wind Turbine Noise, June 2016.

[13] 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

Glossary of Acoustics Terminology

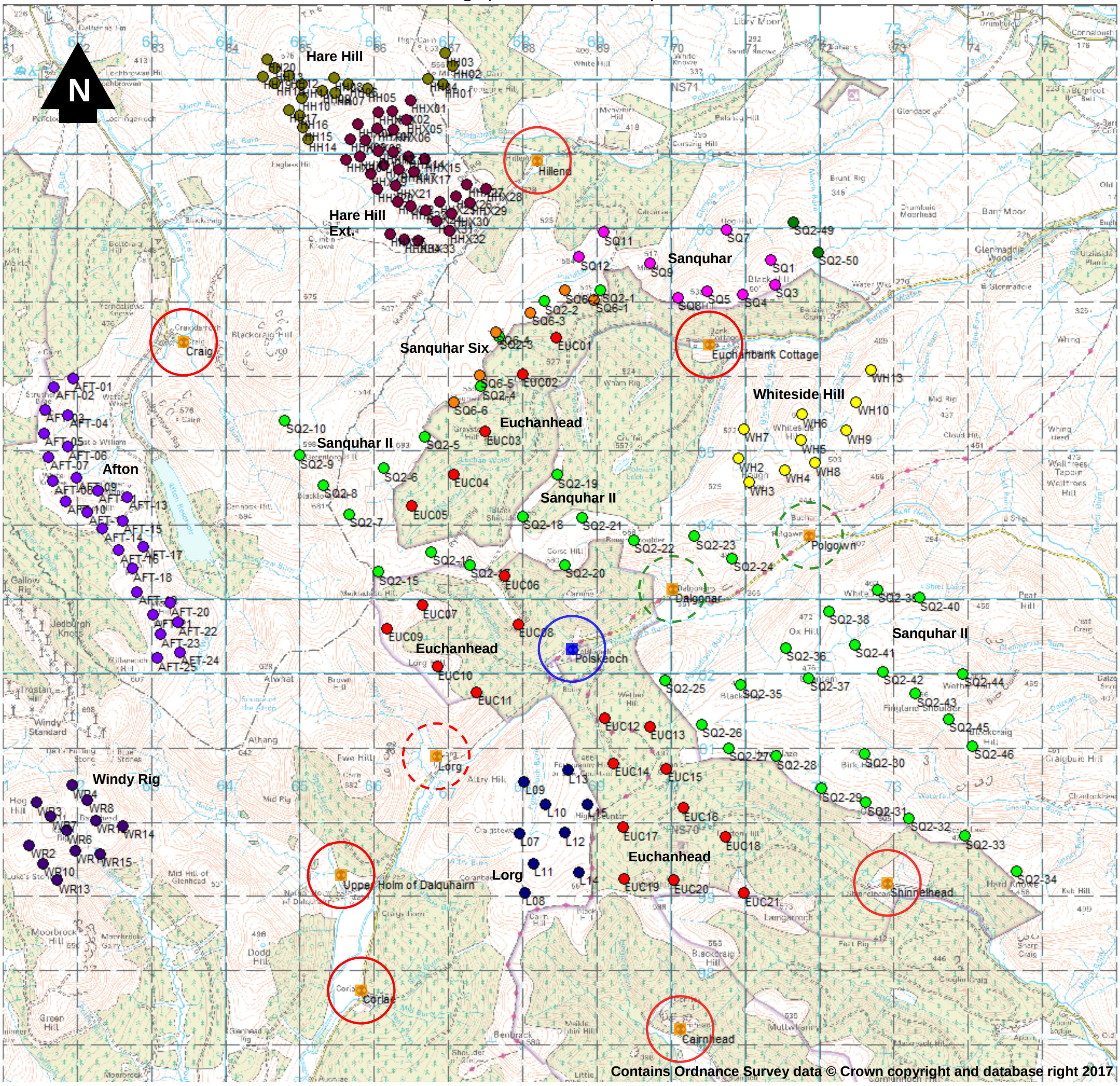
Terminology	Description
A-weighting	a filter that down-weights low frequency and high frequency sound to better represent the frequency response of the human ear when assessing the likely effects of noise on humans
acoustic character	one or more distinctive features of a sound (e.g. tones, whines, whistles, 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

Terminology	Description
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. 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

Terminology	Description
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 10 m using the same procedure as used in wind turbine emission testing
threshold of hearing	the lowest amplitude sound capable of evoking the sensation of hearing in the average healthy human ear (0.00002 Pa)
tone	the concentration of acoustic energy into a very narrow frequency range

Annex B – Location Maps and Turbine Coordinates

Figure B1 - Map showing the layout of the turbines on the proposed Development (red circles, prefixed 'EUC') and the nearby noise assessment locations (orange square within red circles). Also shown are the other sites which have been considered in this assessment: Afton Windfarm (purple circles, prefixed 'AFT'), Whiteside Hill Windfarm (yellow circles, prefixed 'WH'), Lorg Windfarm (dark blue circles, prefixed 'L'), Sanquhar Windfarm (bright purple circles, prefixed 'SQ'), Sanquhar Six Windfarm (orange circles, prefixed 'SQ6'), Sanquhar II Windfarm (green circles, prefixed 'SQ2'), Hare Hill Windfarm (dark green, prefixed 'HH') and Hare Hill Windfarm Extension (dark red, prefixed 'HHX'), Windy Rig Windfarm (dark purple, prefixed 'WR'. Please note: during construction and operation of the proposed Development, Polskeoch (blue square within a blue circle) will be under the ownership and management of ScottishPower Renewables and will be removed from residential use during the life of the proposed Development based on current project programme and contracted grid connection date, therefore this location has not been considered as a receptor for the purposes of this assessment. The Lorg receptor location (orange square within a dashed red circle) has been included in this assessment but would not be in residential use during operation of the Lorg Windfarm. The Dalgonar and Polgown receptor locations (orange square within dashed green circles) have been included in this assessment but would not be in residential use during operation of the Sanquhar II Windfarm.



Turbine & Propagation Details: the Proposed Development

Table B1 – Turbine coordinates – the proposed Development

Turbine	Easting	Northing	Turbine	Easting	Northing
EUC01	268456	606531	EUC12	269104	601408
EUC02	268000	606036	EUC13	269707	601291
EUC03	267494	605259	EUC14	269225	600793
EUC04	267071	604688	EUC15	269933	600718
EUC05	266509	604256	EUC16	270156	600193
EUC06	267749	603314	EUC17	269348	599928
EUC07	266646	602924	EUC18	270724	599799
EUC08	267942	602664	EUC19	269363	599239
EUC09	266175	602607	EUC20	270032	599218
EUC10	266848	602093	EUC21	270983	599044
EUC11	267381	601757			
All turbines modelled using the hub height of 155 m and operating in Mode 0 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.

Turbine	Property									
	Cairnhead	Corlae	Craig	Dalgonar	Euchanbank Cottage	Hillend	Lorg	Polgown	Shinnelhead	Upper Holm of Dalquhairn
EUC01	2	2	2	2	0	2	2	2	2	2
EUC02	2	2	2	2	0	2	2	2	2	2
EUC03	2	2	2	2	2	2	2	2	2	2
EUC04	2	2	2	2	2	2	2	2	2	2
EUC05	2	2	2	2	2	2	2	2	2	2
EUC06	2	0	2	0	2	2	2	2	2	2
EUC07	2	-3	2	2	2	2	2	2	0	2
EUC08	2	-3	2	0	2	2	2	2	0	2
EUC09	2	-3	2	2	2	2	0	2	-3	2
EUC10	2	-3	2	0	2	2	0	2	0	2
EUC11	2	-3	2	-3	2	2	0	2	0	2
EUC12	2	2	2	0	2	2	0	0	0	2
EUC13	2	2	2	0	2	2	2	0	0	2
EUC14	2	2	2	0	2	2	2	0	0	0
EUC15	2	2	2	0	2	2	2	0	-3	2
EUC16	2	2	2	2	2	2	2	0	0	2
EUC17	2	2	2	0	2	2	2	0	2	0

Turbine	Property									
	Cairnhead	Corlae	Craig	Dalgonar	Euchanbank Cottage	Hillend	Lorg	Polgown	Shinnelhead	Upper Holm of Dalquhairn
EUC18	2	2	2	2	2	2	2	2	0	2
EUC19	2	0	2	2	2	2	2	0	2	2
EUC20	2	0	2	0	2	2	2	0	0	2
EUC21	2	2	2	0	2	2	2	2	0	2

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 V150-5.6 MW Mode 0	-	-	95.1	99.1	103.6	106.0	106.9	106.9	106.9	106.9	106.9	106.9
Derived from: Performance Specification, Vestas EnVentus V150-5.6 MW. Document no.: 0081-5059 V02, 2019-01-24. Serrated trailing edges (standard). Converted from hub height data to standardised 10 m data for a hub height of 155 m for Mode 0, with +2 dB(A) added to the values provided by the manufacturer for those shown above.												

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 V150-5.6 MW	87.6	95.4	100.2	102.1	100.9	96.8	89.7	79.6	106.9
Derived from: Vestas V150-5.6MW Third octave noise emission. DMS 0079-5099_01, 2019-01-23. Mode 0, at 11 m/s hub height wind speed, converted to octave bands from one-third octave band values and scaled to match overall sound power levels.									

Turbine & Propagation Details: Sanquhar II

Table B5 – Turbine coordinates – Sanquhar II (supplied by SLR)

Turbine	Easting	Northing	Turbine	Easting	Northing	Turbine	Easting	Northing
SQ2-1	269049	607171	SQ2-20	268566	603463	SQ2-35	270939	601845
SQ2-2	268288	607015	SQ2-21	268793	604105	SQ2-36	271536	602350
SQ2-3	267673	606542	SQ2-22	269493	603801	SQ2-37	271853	601945
SQ2-4	267437	605867	SQ2-23	270312	603852	SQ2-38	272117	602837
SQ2-5	266682	605196	SQ2-24	270823	603554	SQ2-39	272772	603135
SQ2-6	266119	604768	SQ2-25	269912	601914	SQ2-40	273344	603022
SQ2-7	265660	604150	SQ2-26	270352	601350	SQ2-41	272466	602391
SQ2-8	265306	604543	SQ2-27	270767	600999	SQ2-42	272850	602033
SQ2-9	264993	604941	SQ2-28	271405	600887	SQ2-43	273291	601732
SQ2-10	264794	605413	SQ2-29	272015	600451	SQ2-44	273929	601996
SQ2-15	266055	603373	SQ2-30	272602	600916	SQ2-45	273733	601390
SQ2-16	266769	603637	SQ2-31	272622	600262	SQ2-46	274058	601025
SQ2-17	267282	603469	SQ2-32	273200	600051	SQ2-49	271644	608084
SQ2-18	267993	604117	SQ2-33	273949	599815	SQ2-50	271979	607680
SQ2-19	268463	604679	SQ2-34	274648	599339			
All turbines are Enercon E-138 EP3 with a 131 metre hub height except 49 & 50 which are Enercon E-115 EP3 with 92 metre hub height (turbine details derived from Sanquhar II Community Windfarm - Additional Information Report – Section 11 – Noise, August 2020).								

Table B6-Propagation attenuation effects due to terrain (dB) – Sanquhar II. 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.

Turbine	Property		Turbine	Property		Turbine	Property	
	Lorg	Shinnelhead		Lorg	Shinnelhead		Lorg	Shinnelhead
SQ2-1	2	2	SQ2-20	2	2	SQ2-35	2	2
SQ2-2	2	2	SQ2-21	2	2	SQ2-36	2	2
SQ2-3	2	2	SQ2-22	2	2	SQ2-37	2	2
SQ2-4	2	2	SQ2-23	2	2	SQ2-38	2	2
SQ2-5	2	2	SQ2-24	2	2	SQ2-39	2	2
SQ2-6	2	2	SQ2-25	2	0	SQ2-40	2	2
SQ2-7	2	2	SQ2-26	2	0	SQ2-41	2	2
SQ2-8	2	2	SQ2-27	2	0	SQ2-42	2	2
SQ2-9	2	2	SQ2-28	2	0	SQ2-43	2	2
SQ2-10	2	2	SQ2-29	2	0	SQ2-44	2	2
SQ2-15	2	0	SQ2-30	2	2	SQ2-45	2	2
SQ2-16	2	0	SQ2-31	2	0	SQ2-46	2	2
SQ2-17	2	0	SQ2-32	2	0	SQ2-49	2	2
SQ2-18	2	2	SQ2-33	2	0	SQ2-50	2	2

Turbine	Property		Turbine	Property		Turbine	Property	
	Lorg	Shinnelhead		Lorg	Shinnelhead		Lorg	Shinnelhead
SQ2-19	2	2	SQ2-34	2	0			

Table B7 - Wind turbine sound power levels (dB L_{Aeq}) used in the noise assessment - Sanquhar II.

Turbine make / model	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Enercon E138 EP3 4MW	-	-	95.9	101.8	103.1	104.1	104.7	105.3	106.0	106.0	106.0	106.00
Enercon E138 EP3 4MW reduced noise mode	-	-	95.9	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Enercon E-115 EP3 4MW	-	-	90.3	95.7	100.6	104.6	106.7	107.3	108.0	108.0	108.0	108.0
Data from Table 11.5 of Sanquhar II Community Windfarm - Additional Information Report – Section 11 – Noise, August 2020. During the day-time, turbines T7 to T14 and T22 to T24 are operating in the reduced noise mode, and T14 is shut down for wind speeds of 4-5 m/s. During the night-time. two turbines (T13 and T14) are operating in the reduced noise mode (from paragraph 11.8.7 of the Sanquhar II EIA Report).												

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

Turbine make / model	Octave Band Centre Frequency (Hz)								
	63	125	250	500	1000	2000	4000	8000	A
Enercon E138 EP3 4MW	89.8	95.7	98.4	100.4	100.2	97.8	89.3	68.5	-
Enercon E-115 EP3 4MW	91.3	97.2	100.2	102.4	102.3	100.1	92.6	95.7	-
Data from Table 11.6 of Sanquhar II Community Windfarm - Additional Information Report – Section 11 – Noise, August 2020.									

Turbine & Details: Other Windfarms

B.1 This assessment (detailed in the main text) is based upon considering only those nearby windfarms which potentially make an acoustically relevant contribution to cumulative predicted noise immission levels at noise sensitive receptors where a full cumulative assessment is required (Dalgonar, Lorg and Shinnelhead). The threshold for considering whether adjacent windfarms make an acoustically relevant contribution is to determine whether predicted noise immission levels from those windfarms in isolation are within 10 dB of noise limits which apply at these noise sensitive receptors. Assessment of these other windfarms requires turbine source information similar to that detailed in the Tables above for the proposed Development and for Sanquhar II Windfarm.

B.2 For operational windfarms, noise predictions were based on the actual installed turbine model. Those sites which are proposed but not consented (such as Sanquhar II detailed above), the candidate turbine considered in the planning application was assumed. Where windfarms are consented but not built, the candidate turbine considered in the planning application was assumed, with further consideration of what further uplift in noise emission levels may be appropriate, when considering the noise limits which apply to these more distant windfarms. For each windfarm considered, details are provided below of the source of data used in the noise modelling. Tabular values of these data (overall sound power levels and frequency spectra) are provided in Table B9 and Table B10.

- Lorg Windfarm (consented, proposed variation): Data on sound power levels for the turbines are taken from the document *'Lorg Wind Farm Section 42 Application: Environmental Impact Assessment Report: Volume 1: Main Report, June 2019. Wood Environment & Infrastructure Solutions UK Limited'*. This document provides representative sound power levels as an 'envelope' which would permit a range of turbines to be chosen to build the windfarm. Whilst the windfarm has been given planning permission, it is currently subject to an application to vary the requirements of that planning permission, with the latest noise assessment *('Lorg Wind Farm Further Environmental Information RWE, March 2020'*) being based upon the same envelope sound power levels. Predictions provided in the latest Lorg Windfarm noise assessment (FEI 2020) show predicted noise levels for Log Windfarm in isolation within 0.8 dB of the noise limits at the Polskeoch receptor location. Accordingly, assumption of these envelope sound power levels is sufficiently robust.

- Whiteside Hill Windfarm (operational): Data on sound power levels for the turbines are taken from the document *'Capital Dynamics Whiteside Wind Farm, Noise Impact Assessment, Sgurr Energy 18 November 2015'*. This document provides sound power levels for the turbines chosen to build the site. That document suggests predicted noise immission levels at the nearest noise sensitive receptor (Polgown 271866, 603844) could be at or above the noise limits with unconstrained turbine operation. Assumption of these sound power levels is therefore sufficiently robust.

- Sanquhar Windfarm (operational): This windfarm is operated by Community Windpower who in 2019 proposed the Sanquhar II Windfarm. The make and model installed as well as data on sound power levels for the Sanquhar Windfarm turbines have therefore been derived from those provided in the noise assessment for Sanquhar II: *'Sanquhar II Community Windfarm - Additional Information Report – Section 11 – Noise, Hayes McKenzie Partnership, August 2020'*. Assumption of these sound power levels is appropriate for comparing predicted noise immission levels with the 10 dB assessment threshold at those noise sensitive receptors where a cumulative assessment is required.

- Sanquhar Six Windfarm (consented but not built): This windfarm is under the control of Community Windpower who in 2019 proposed the Sanquhar II Windfarm. Should Sanquhar II be consented and built it is unlikely the Sanquhar Six windfarm would be built and operated. A candidate Senvion MM92-2050 kW wind turbine was detailed in the document: *'Sanquhar 'Six' Community Wind Farm – Environmental Statement, Section 11 – Noise, ACIA, 27 March 2015'*. The maximum sound power levels for this turbine were stated as 104.8 dB(A) and used to predict noise immission levels at nearby receptor locations. Comparison of the values in that document with known emission data for this turbine suggests marginally greater values (~0.4 dB) could be adopted to fully account for uncertainties. A further uplift in sound power levels was not considered necessary given full cumulative assessment of Sanquhar II windfarm has been included. Accordingly, these sound power levels are appropriate for comparing predicted noise immission levels with the 10 dB assessment threshold at those noise sensitive receptors where a cumulative assessment is required.

- Hare Hill Windfarm (operational) and Hare Hill Extension Windfarm (operational): Data on sound power levels for the turbines are taken from the document: *'ScottishPower Renewables, Hare Hill Extension Wind Farm, Condition 30(g) - Turbine Details, Arcus Consultancy Services, January 2016'*. This document shows that the combination of these windfarms could potentially operate up to the noise limits, therefore adoption of the sound power levels provided in this document for comparing predicted noise immission levels with the 10 dB assessment threshold at those noise sensitive receptors where a cumulative assessment is required.

- Afton Windfarm (operational): Data on sound power levels for the installed turbines are taken from the document: *'Sanquhar II Community Wind Farm – EIA Report, Section II – Noise, Hayes McKenzie Partnership, Jan 2019'*. These sound power levels include a suitable margin of uncertainty. A further uplift was not considered necessary given predicted noise levels were at least 5 dB(A) below the 10 dB(A) assessment cut-off threshold, therefore adoption of these sound power levels is appropriate for comparing predicted noise immission levels with the 10 dB assessment threshold at those noise sensitive receptors where a cumulative assessment is required.

- Windy Rig Windfarm (consented and under construction): Predicted noise immission levels were based on using sound power levels for the same wind turbine model assumed for Sanquhar Windfarm as discussed above. These were almost identical (within 0.1 dB) to sound power levels shown in the environmental assessment for Windy Rig (*'Windy Rig Wind Farm, Environmental Statement Volume 2 Report May 2015, Atmos Consulting')*, which were based upon a Nordex N90 2.5 MW candidate. Whilst there was a margin (≥ 3.4 dB) between predicted noise levels and noise limits presented in the Windy Rig ES, a further uplift was not considered necessary given predicted noise levels were at least 5 dB(A) below the 10 dB(A) assessment cut-off threshold. Accordingly, the assumed emission data was considered sufficiently robust.

Table B9 - Wind turbine sound power levels (dB L_{Aeq}) used in the noise assessment –more distant windfarms.

Site & Turbine make / model	Standardised 10 m Wind Speed (m/s)									
	3	4	5	6	7	8	9	10	11	12
Lorg Windfarm Envelope R133	99.9	104.3	108.3	109.5	109.5	109.5	109.5	109.5	109.5	109.5
Whiteside Hill GE 2.85-103		95.3	99.1	102.7	106.4	107.0	107.0	107.0	107.0	107.0
Sanquhar Vestas V112-3.6 STE	95.3	97.3	101.5	105.4	107.6	107.6	107.6	107.6	107.6	107.6
Sanquhar 'Six' Senvion MM92	-	97.0	102.4	104.3	105.2	105.2	105.2	105.2	105.2	105.2
Harehill Windfarm Vestas V47-660 kW	-	101.0	101.5	101.9	102.4	102.8	103.3	103.7	104.2	104.6
Harehill Extension Gamesa G52-850	-	95.6	100.0	101.7	102.5	103.1	103.4	103.9	105.8	105.8
Afton Windfarm Gamesa G80-2000		97.9	102.7	105.0	105.1	105.1	105.1	105.1	105.1	105.1

Table B10 - Octave band sound power spectrum (dB L_{Aeq}) for reference wind speed conditions (v_{10} = 8 m/s) –more distant windfarms.

Site & Turbine make / model	Octave Band Centre Frequency (Hz)							
	63	125	250	500	1000	2000	4000	8000
Lorg Windfarm Envelope R133	90.8	96.6	99.8	103.1	104.1	103.2	97.8	84.0
Whiteside Hill GE 2.85-103	88.1	95.7	98.2	99.6	101.2	101.3	95.0	75.6
Sanquhar Vestas V112-3.6 STE	86.3	97.1	100.0	102.6	101.5	98.8	93.5	77.5
Sanquhar ‘Six’ Senvion MM92	85.4	92.5	97.4	99.0	98.6	92.9	84.4	74.0
Hare Hill Windfarm Vestas V47-660 kW	78.2	86.1	89.8	95.2	97.0	92.9	87.9	69.2
Hare Hill Extension Gamesa G52-850	81.0	87.9	92.9	94.5	94.1	91.6	86.1	75.3
Afton Windfarm Gamesa G80-2000	81.5	89.4	94.1	95.7	96.5	94.9	88.4	74.1

Annex C – Baseline Information & Derived Noise Limits/Criteria

Receptor: Hillend (268201, 608890)

C.1 Noise at nearby residential receptors due to operation of the Harehill Windfarm and Harehill Windfarm Extension are controlled by noise limits, which apply to the cumulative total of both schemes operating together. These windfarms are built and operating. These noise limits are defined in documentation related to Harehill Windfarm Extension[7], separately for both day-time (0700-2300) and night-time (2300-0700) periods as shown in Table C1. This table only shows noise limits which apply at the receptor location Hillend (268201, 608890), which is the relevant receptor location for assessment of the proposed Development.

Table C1 – Noise limits which apply to control cumulative noise from the Harehill Windfarm and Harehill Windfarm Extension at two locations during day-time and night-time periods.

Property	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Hillend (day)	41.2	41.2	41.2	41.2	41.2	41.2	41.2	41.2	41.2	44.8	47.0	48.7
Hillend (night)	41.2	41.2	41.2	41.2	41.2	41.2	41.2	41.2	41.2	42.6	45.2	47.4

C.2 The submission to the council[7] suggests that mitigation would be required to operate the combination of both windfarms within the noise limits at the Hillend receptor location. There is therefore a clear likelihood that these windfarms would use the totality of the consented noise limit at this property. The IOA GPG suggests that where noise from adjacent developments differ by more than 10 dB(A) then this effectively represents a negligible acoustical contribution and that cumulative effects need not be considered further[8]. Accordingly, it would be appropriate to assess noise from the proposed Development by considering a criterion which is 10 dB below the current noise limits, in order to not add an acoustically relevant contribution to cumulative noise levels.

C.3 The hub height of the turbines on Harehill and Harehill Extension are between 40 m and 65 m, significantly lower than those on the proposed Development. Noise limits which apply to control noise from the cumulative total of both sites would therefore be relevant to standardised ten metre height wind speeds for hub heights of at most 65 m. In order to take account of the potential for differences that may arise due to the taller hub height of the turbines on the proposed Development, these noise criteria will be fixed at higher wind speeds to be the same as values for lower wind speeds, thereby removing any element of the noise criteria based on wind speed.

C.4 Inspecting the resulting noise criteria it is evident that the values would be the same during both day-time and night-time and so a single criteria can be applied at all times, as shown in Table C2.

Table C2 – Noise criteria which are used to determine whether noise levels from the proposed Development are sufficiently low to be acoustically unimportant - Hillend.

Property	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Hillend (all times)	31.2	31.2	31.2	31.2	31.2	31.2	31.2	31.2	31.2	31.2	31.2	31.2

7 The Construction and Operation of Hare Hill Extension Windfarm – Noise - Planning Consent Response by ScottishPower Renewables (UK) Limited to East Ayrshire Council, Planning application number: 07/0809/FL Condition 30(g), Version 01, March 2016. Based upon a report by Arcus Consultancy Services 'ScottishPower Renewables - Hare Hill Extension Windfarm - Condition 30(g) - Turbine Details, January 2016'.

8 The IOA GPG suggests that where noise from adjacent developments differ by more than 10 dB(A) then this represents effectively negligible effects and that cumulative effects need not be considered. Two noise sources which differ by 10 dB(A) gives rise to total 0.4 dB(A) higher than the greater source. Accordingly it is generally assumed that increases of 0.4 dB(A) or less are not acoustically important.

Receptors: Euchanbank Cottage (270530, 606420) & Polgown (271866, 603844)

C.5 Operational noise at nearby residential receptors for the Whiteside Hill Windfarm (built and operating from March 2018) is controlled by noise limits, based on background noise levels at two locations: Glenglass Cottage (270871, 606349) and Polgown (271862, 603837) surveyed for the original noise assessment[9] supporting the application. A 2015 revised noise assessment for Whiteside Hill[10] by Sgurr provides these baseline data at whole value wind speeds, noting that they were related to directly measured ten metre wind speeds, not standardised ten metre wind speeds now required by the IOA GPG. The 2015 noise assessment used a simplified method for correcting these limits for wind shear for the 70 m hub height of the turbines by shifting values to the right by 3 m/s. This is likely to be a pessimistic correction. These noise limits are shown in Table C3.

Table C3 – Shear-corrected noise limits (Sgurr 2015) which apply to control noise from the Whiteside Hill Windfarm during day-time and night-time periods, based on survey data at two named locations.

Property	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Glenglass (day)	-	-	-	38.9	39.3	39.9	40.5	41.2	41.9	42.7	43.6	44.6
Polgown (day)	-	-	-	37.7	37.7	37.7	37.8	38.0	38.3	38.8	39.4	40.1
Glenglass (night)	-	-	-	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.6
Polgown (night)	-	-	-	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0

C.6 Baseline noise measurements were undertaken in September 2009 by ACIA for the noise assessment for the Sanquhar Windfarm (operational March 2018) at Euchanbank Cottage, referred to as Bank Cottage (270529, 606422) in the Sanquhar EIA Report[11]. These baseline data and the resulting noise limits (see Table C4) were related to wind speeds directly measured at 10 m and not corrected for wind shear within that assessment.

Table C4 –Noise limits derived in the Sanquhar noise assessment (ACIA 2010) related to directly measured ten wind speeds.

Property	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Euchanbank Cottage (day)	-	-	35	35	36	37	39	42	44	46	49	51
Euchanbank Cottage (night)	-	-	43	43	43	43	43	43	45	48	49	50

C.7 New baseline noise measurements were undertaken in 2018 by the Hayes McKenzie Partnership for the proposed Sanquhar II Windfarm at Polgown[12], related to wind speeds at the hub height of the proposed turbines for Sanquhar II of 131 m. In deriving relevant ETSU-R-97 noise limits for assessing Sanquhar II windfarm, the noise assessment for the scheme determine it was appropriate to base the fixed part of noise limits which apply during the day-time on a choice of 40 dB(A), within the range from 35 dB(A) to 40 dB(A) allowed by ETSU-R-97 (for assessing cumulative noise levels) on the basis of the significant energy generating potential of both Sanquhar II and Whiteside Hill operating together. The revised noise assessment for Sanquhar II[13] shows this location would no longer be considered as a noise sensitive receptor should that windfarm be constructed. Were Sanquhar II not to be constructed, the choice of

9 Planning permission was granted in February 2013 (Grant of Planning Permission, Dumfries & Galloway Council 26th February 2013) and refers to an application 6th June 2006. It is assumed therefore that baseline background measurements were undertaken prior to June 2006 but we do not have the original noise assessment.

10 Capita Dynamics Whiteside Hill Windfarm – Noise Impact Assessment – 18 November 2015, Sgurr Energy, 5/15/639/001/GLA/O/R/001 B1.

11 Sanquhar Community Windfarm – Environmental Statement. Assessment of Environmental Noise – ACIA, 235.01/ifb, 15th January 2010.

12 Sanquhar II Community Windfarm - EIA Report – Section 11 – Noise, January 2019, Hayes McKenzie Partnership Ltd.

13 Sanquhar II Community Windfarm - Additional Information Report – Section 11 – Noise, August 2020.

40 dB(A) for the fixed part of the day-time limit remains justified as a cumulative assessment criteria, given the significant energy generating capacity of the proposed Development, particularly in combination with all wind energy schemes in the area. Noise limits for Polgown as derived in the original Sanquhar II assessment are shown in Table C5.

Table C5 – Noise limits derived in the Sanquhar II noise assessment (Hayes McKenzie 2018) related to standardised ten metre wind speeds for a 131 m hub height.

Property	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Polgown (day)	-	-	40	40	40	40	40	40	41	43	46	48
Polgown (night)	-	-	43	43	43	43	43	43	43	43	45	48

C.8 The nearest receptor to the proposed Development (adjacent to Glenglass, discussed above) is the receptor location Euchanbank Cottage (270530, 606420). Noise limits which would apply at Euchanbank Cottage are those stated at Glenglass as shown above for the Whiteside Hill Windfarm. Neither Glenglass nor Euchanbank Cottage (referred to as Bank Cottage in the Sanquhar II EIA Report) were specifically assessed in the original or revised Sanquhar II noise assessments, on the basis that these locations *'are abandoned or derelict, and therefore not considered further'*. It is not known whether both these locations can no longer be considered residential, therefore for assessment of the proposed Development, relevant noise criteria have been developed on a precautionary basis for Euchanbank Cottage. Euchanbank Cottage is nearest to the proposed Development and assessment there would provide sufficient protection at Glenglass.

C.9 Consistent with the approach of the Sanquhar II noise assessment, and the above discussion of the choice of 40 dB(A) in relation to the proposed Development, the noise criteria which applies during the day-time in Table C5 has been based on a minimum noise limit of 40 dB(A). This represents a marginal increase (~1 dB for Euchanbank and ~2 dB for Polgown) from some of the lower values shown in Table C3 for existing windfarm noise limits.

C.10 As discussed above, appropriate criteria have been derived to assess noise from the proposed Development by considering criteria which are 10 dB below the relevant cumulative noise limits, in order to not add an acoustically relevant contribution to cumulative noise levels. The resulting precautionary criteria which are to apply to noise from the proposed Development alone are shown in Table C6. These discount the increase in the noise limits from 9 m/s and above shown in Table C5, due to any potential uncertainties related to wind shear considerations and to provide a conservative assessment.

Table C6 – Noise criteria which are used to determine whether noise levels from the proposed Development are sufficiently low to be acoustically unimportant - Euchanbank Cottage & Polgown.

Property	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Euchanbank Cottage (day)	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
Polgown (day)	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
Euchanbank Cottage (night)	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0
Polgown (night)	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0

Receptors: Dalgonar (270038, 603129) & Shinnelhead (272926, 599169)

C.11 New baseline noise measurements were undertaken in 2018 for the proposed Sanquhar II Windfarm at both locations[12], related to standardised ten metre wind speeds for the hub height of 131 m of the proposed turbines for Sanquhar II. As discussed above, during the day-time, the limit was based on a lower limit of 40 dB(A), within the range from 35 dB(A) to 40 dB(A). Derived limits for these locations are shown in Table C7. The choice of 40 dB(A) for the fixed part of the day-time noise limits is justified, given the significant energy generating capacity of the proposed Development in combination with all wind energy schemes in the area and is consistent with the noise limits in the planning permission[14] for the adjacent Lorg Windfarm.

Table C7 – Noise limits derived in the Sanquhar II noise assessment (Hayes McKenzie 2018) related to standardised ten metre wind speeds for a 131 m hub height.

Property	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Dalgonar (day)	-	-	40	40	40	40	40	40	40	41	42	44
Shinnelhead (day)	-	-	40	40	40	40	40	40	40	42	45	47
Dalgonar (night)	-	-	43	43	43	43	43	43	43	43	43	43
Shinnelhead (night)	-	-	43	43	43	43	43	43	43	43	43	46

C.12 The ETSU-R-97 noise limits shown in Table C7 would apply to the cumulative total of noise from all wind energy developments. For the locations of Dalgonar and Shinnelhead, a cumulative assessment has been completed based upon the noise limits derived above for the proposed Sanquhar II Windfarm. The difference in the hub height for the proposed Development (155 m) and Sanquhar II (131 m) would not cause a significant difference in wind speeds due to likely wind shear effects and has therefore been neglected[15]. The resulting criteria are shown in Table C8.

Table C8 – Noise criteria which are used to assess cumulative noise - Dalgonar and Shinnelhead.

Property	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Dalgonar (day)	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	41.0	42.0	44.0
Shinnelhead (day)	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	42.0	45.0	47.0
Dalgonar (night)	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0
Shinnelhead (night)	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	46.0

14 Conditions 35 to 38 of the Grant of Planning Permission, Dumfries & Galloway Council, December 2015 reference 15/P/2/0337.

15 Differences in the wind speeds between the Development (155 m) and Sanquhar II (131 m) have already been accounted for in the sound power levels used for the candidate turbines for these developments. These wind speed differences are accounted for assuming standardised conditions (roughness length of 0.05 m) for sound power level data related to their proposed hub heights. In practice, site specific wind shear conditions may differ from these standardised conditions. However, the difference in hub height is small compared to the relatively tall heights of both schemes, therefore any differences in wind shear conditions from standardised conditions are not likely to result in acoustically important changes in the applicable limits and assessment outcomes.

Receptors: Cairnhead (270133, 597200), Corlae (265835, 597727), Upper Holm of Dalquhairn (265565, 599279) & Lorg (266850, 600875)

C.13 Baseline noise measurements were undertaken in 2013[16] for the consented but not yet built Lorg Windfarm at the following receptors: Upper Holm of Dalquhairn, Nether Holm of Dalquhairn (265537,599018) and at Polskeoch (268660, 602308). These background noise survey results were related to standardised ten metre wind speeds from those measured at a height of 80 m, in accordance with the IOA GPG. The planning permission[17] for Lorg Windfarm contains noise limits which reference the background noise surveys in the original ES and also a 2017 FEI[18] by Amec. The planning permission does not however contain tabular limits defined for each location, rather it references the FEI, where limits are defined in tables (Table 7.A1 and Table 7.A2 of Appendix 7.A), with limits at the non-surveyed locations of Corlae and Cairnhead utilising limits derived from baseline surveyed at Nether Holm of Dalquhairn.

C.14 However, the wording of the noise conditions in the planning permission for Lorg Windfarm[17] during the day-time defines the noise limits for non-involved locations having the lower ETSU-R-97 fixed threshold as 40 dB(A). This would increase the values shown in the Lorg FEI to be a minimum of 40 dB(A) for noise limits applying to this windfarm during day-time periods. The resulting noise limits would also apply to control total cumulative noise from all wind energy development, in accordance with ETSU-R-97. These uplifted noise limits consistent with the planning permission for Lorg Windfarm are shown in Table C9.

Table C9 – Noise limits derived from the Lorg Windfarm noise assessment (Amec 2017) related to standardised ten metre wind speeds for a 80 metre hub height. Day-time noise limits have been uplifted to be based on 40 dB(A) minimum, consistent with the planning permission for Lorg Windfarm.

Property	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Upper Holm of Dalquhairn (day)	-	-	37.3	38.1	39.3	40.8	42.6	44.7	47.1	49.9	53.0	56.4
Polskeoch (day)	-	-	35.0	35.0	35.0	35.1	36.9	38.9	41.1	43.4	45.8	48.3
Corlae (day)	-	-	35.3	36.2	37.3	38.5	39.9	41.5	43.2	44.7	46.2	47.7
Cairnhead (day)	-	-	35.3	36.2	37.3	38.5	39.9	41.5	43.2	44.7	46.2	47.7
Upper Holm of Dalquhairn (night)	-	-	43.0	43.0	43.0	43.0	43.0	43.0	44.4	47.3	50.5	54.2
Polskeoch (night)	-	-	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	44.7	48.3
Corlae (night)	-	-	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.8	47.0	50.6
Cairnhead (night)	-	-	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.8	47.0	50.6

C.15 As discussed above, the noise limits for Lorg Windfarm relate to a hub height of 80 m. In absence of detailed site-specific wind shear data, a simplistic and precautionary approach has been adopted by deriving assessment criteria for the proposed Development which are the same at all wind speeds, based on the lowest values specified. Similar to other locations discussed above, appropriate criteria can be derived to assess noise from the proposed Development alone by considering criteria which are 10 dB below these total ETSU-R-97 noise limits, in order to not add an acoustically relevant contribution to cumulative noise levels. This approach has been adopted for assessment of noise at Upper Holm of Dalquhairn, Corlae and Cairnhead. Noise criteria to be used at these locations are shown in Table C10.

16 Chapter 7: Noise of the Lorg Windfarm Environmental Statement, November 2015, Amec Foster Wheeler Environment & Infrastructure UK Limited.

17 Conditions 35 to 38 of the Grant of Planning Permission, Dumfries & Galloway Council, December 2019 reference 15/P/2/0337. Land encompassing Lorg, Altry Hill, Craigstewart and Alwhat, approximately 12.5 km south-west of Sanquhar.

18 Chapter 7 (Noise) and Appendix 7.A (Noise: Proposed Noise Condition Limits) of the Lorg Windfarm Further Environmental Information, September 2017, Amec Foster Wheeler Environment & Infrastructure UK Limited.

Table C10 – Noise criteria which are used to determine whether noise levels from the proposed Development are sufficiently low to be acoustically unimportant- Upper Holm of Dalquhairn, Corlae and Cairnhead.

Property	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Upper Holm of Dalquhairn, Corlae and Cairnhead (day)	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
Upper Holm of Dalquhairn, Corlae and Cairnhead (night)	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0

C.16 The Lorg receptor location would not be in residential use should Lorg Windfarm be built[19]. Accordingly, assessment of noise at this location is required only for cumulative noise without a contribution from Lorg Windfarm. Suitable noise assessment criteria have been derived for the Lorg receptor from the noise limits which apply at Polskeoch. These criteria have however been set at their minimum value at all wind speeds, as discussed above, to account for any potential wind speeds differences on a precautionary basis. The resulting criteria are shown in Table C11.

Table C11 – Noise criteria which are used to for assessment of cumulative noise - Lorg.

Property	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Lorg (day)	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0
Lorg (night)	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0

19 Lorg Windfarm Environmental Statement, November 2015, Amec Foster Wheeler Environment & Infrastructure UK Limited. Chapter 13: Geology, Hydrology and Hydrogeology states for Lorg Farmhouse that *"The landowner has confirmed that the property, and therefore the water supply, is not in use and will not be used during the construction, operation or decommissioning phases of the Proposed Development".*

Receptor: Craig (263442, 606454)

C.17 Consent and deemed planning permission for the Afton Windfarm[20] includes ETSU-R-97 noise limits. These noise limits are based upon either a lower limit of 40 dB(A) during the day-time and 43 dB(A) during the night-time or 5 dB(A) above background noise levels, whichever is the greater. The windfarm is built and operating, consisting of 25 wind turbines with 22 of these having tip heights up to 120 m. The noise assessment for the proposed Sanquhar II Windfarm[12] references background noise levels in the Pencloe Windfarm Decision Letter and provides tabular values of these noise limits. The Sanquhar II noise assessment shows that noise from that development in combination with the operational Afton Windfarm may fully utilise the ETSU-R-97 noise limits at Craig.

C.18 Similar to other locations discussed above, an appropriate criteria can be derived to assess noise from the proposed Development alone at Craig by considering criteria which are 10 dB below total ETSU-R-97 noise limits, in order to not add an acoustically relevant contribution to cumulative noise levels. Also consistent with other receptors, these criteria are fixed at their lowest value for all wind speeds. This approach has been adopted for assessment of noise at Craig and are these assessment criteria shown in Table C12.

Table C12 – Noise criteria which are used to determine whether noise levels from the proposed Development are sufficiently low to be acoustically unimportant - Craig.

Property	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Craig (day)	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
Craig (night)	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0

20 Application for consent under S36 of the Electricity Act 1989 and deemed planning permission under S57(2) of the Town and Country Planning (Scotland) Act 1997 for the Afton Wind Powered Electricity Generating Station in the council area of East Ayrshire. Electricity Division of the Energy and Climate Change Division, The Scottish Government 17th October 2014, Condition 22.

Annex D – Predicted Noise and Noise Limits/Criteria

Figure D1 - Chart of the noise criteria / limit curve appropriate for the assessment location of Cairnhead, derived to be 10 dB(A) below the applicable ETSU-R-97 noise limit during day-time periods. Predicted immission noise levels are also shown for the proposed Development alone.

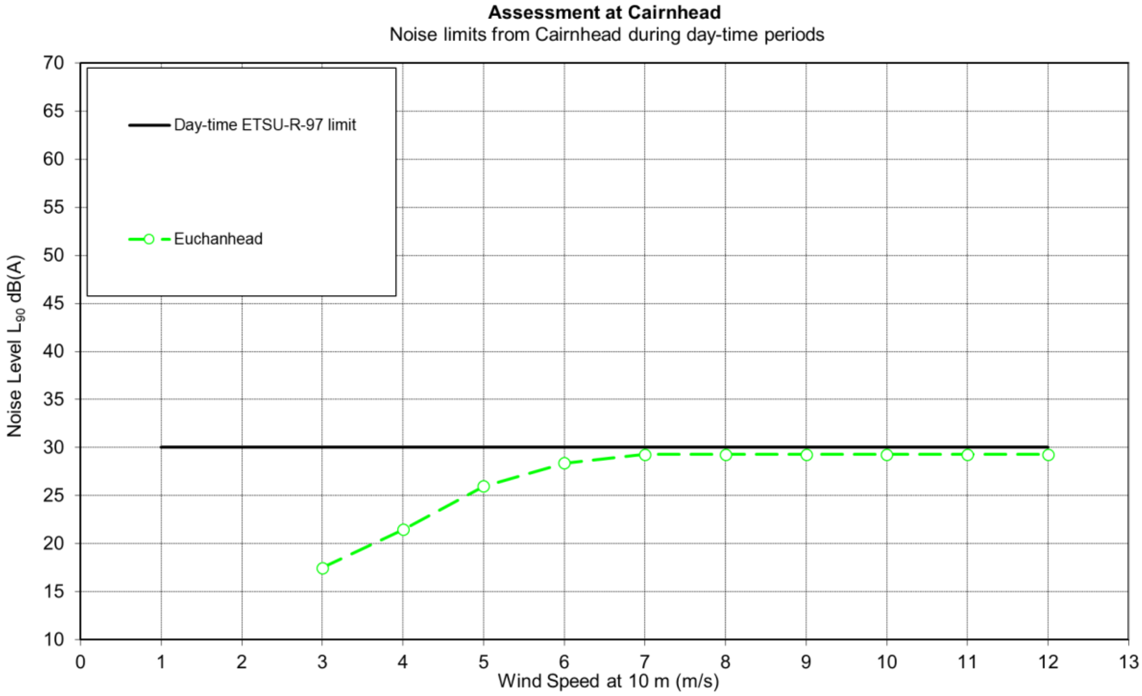


Figure D2 - Chart of the noise criteria / limit curve appropriate for the assessment location of Cairnhead, derived to be 10 dB(A) below the applicable ETSU-R-97 noise limit during night-time periods. Predicted immission noise levels are also shown for the proposed Development alone.

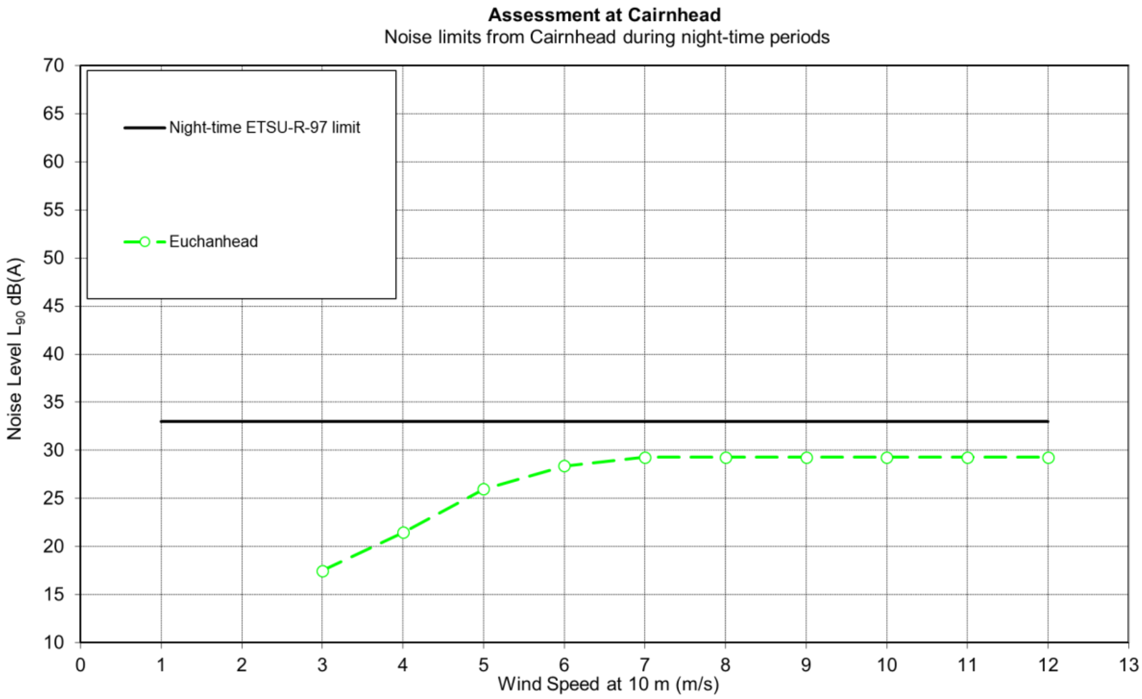


Figure D3 - Chart of the noise criteria / limit curve appropriate for the assessment location of Corlae, derived to be 10 dB(A) below the applicable ETSU-R-97 noise limit during day-time periods. Predicted immission noise levels are also shown for the proposed Development alone.

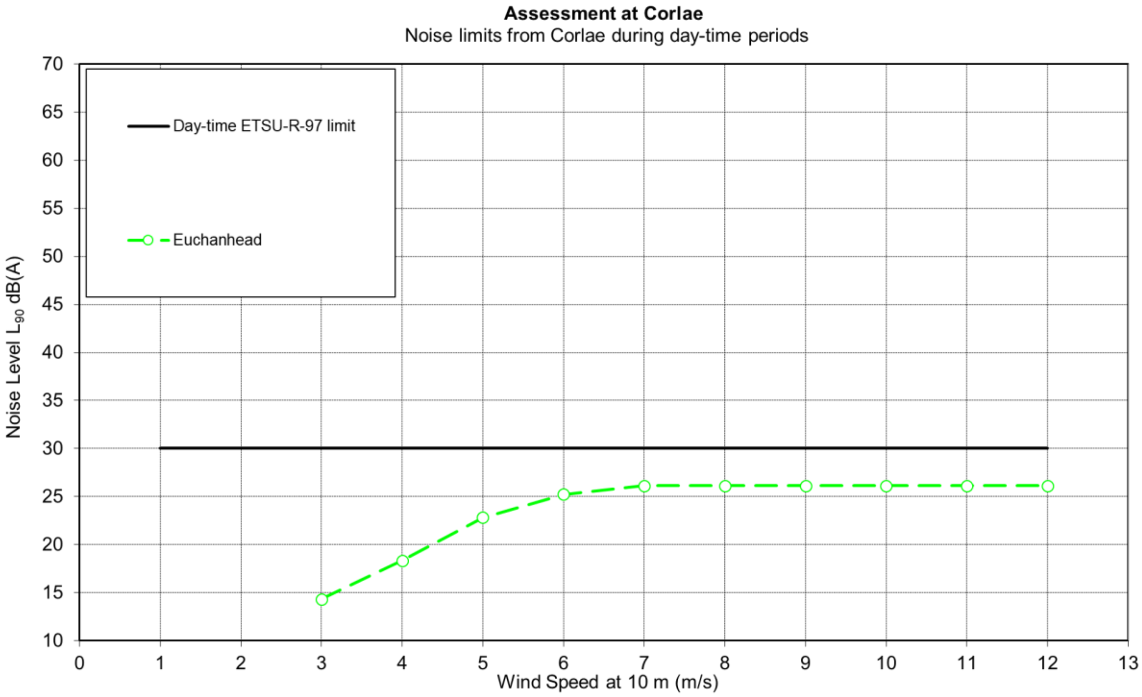


Figure D4 - Chart of the noise criteria / limit curve appropriate for the assessment location of Corlae, derived to be 10 dB(A) below the applicable ETSU-R-97 noise limit during night-time periods. Predicted immission noise levels are also shown for the proposed Development alone.

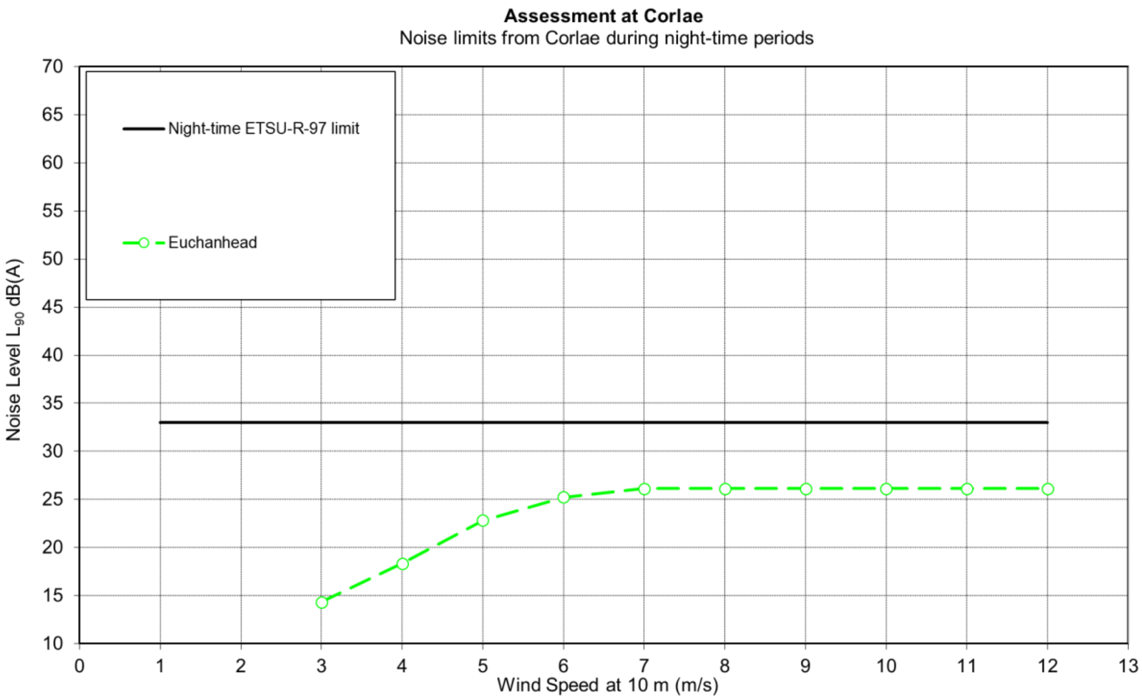


Figure D5 - Chart of the noise criteria / limit curve appropriate for the assessment location of Craig, derived to be 10 dB(A) below the applicable ETSU-R-97 noise limit during day-time periods. Predicted immission noise levels are also shown for the proposed Development alone.

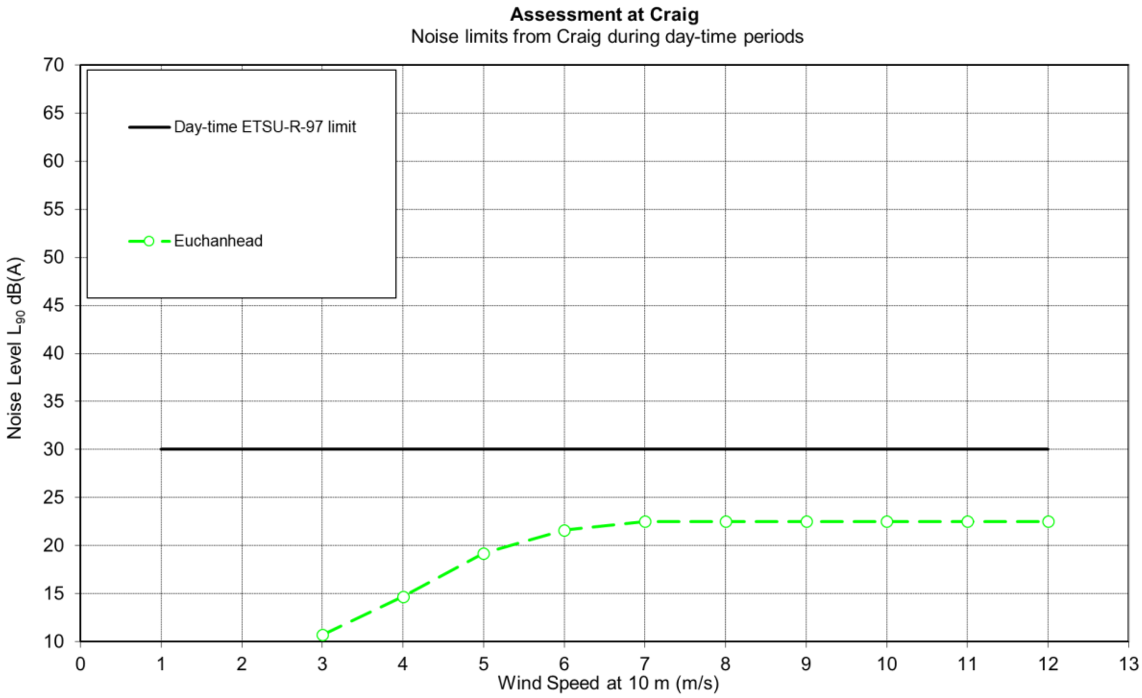


Figure D6 - Chart of the noise criteria / limit curve appropriate for the assessment location of Craig, derived to be 10 dB(A) below the applicable ETSU-R-97 noise limit during night-time periods. Predicted immission noise levels are also shown for the proposed Development alone.

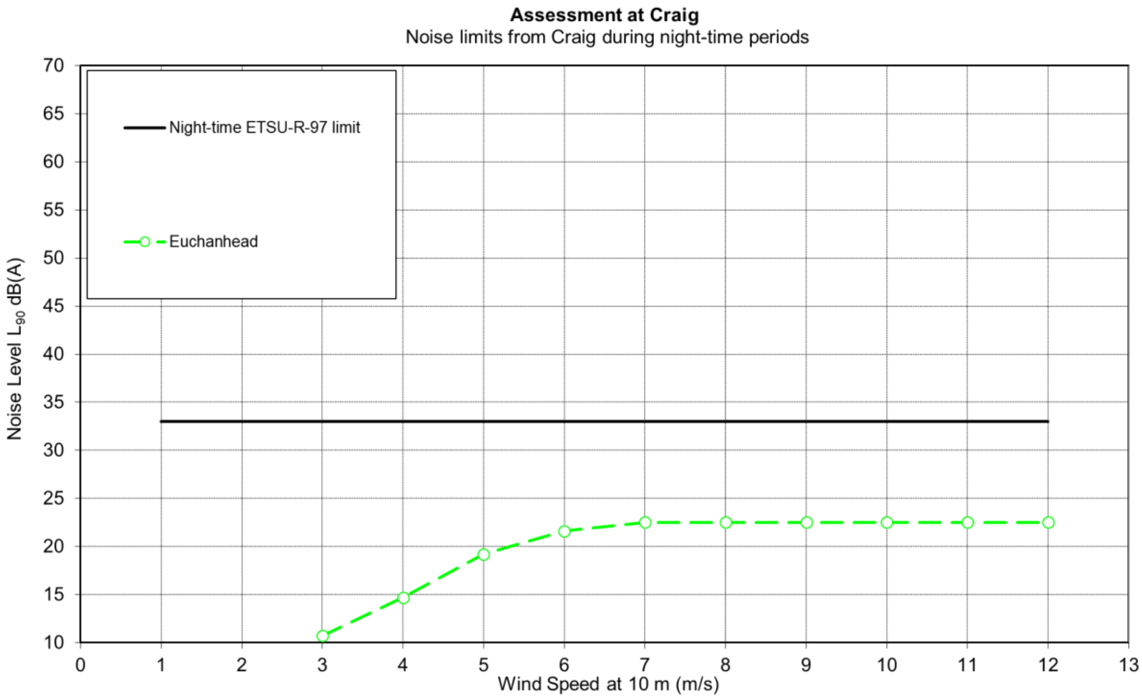


Figure D7 - Chart of the ETSU-R-97 noise criteria / limit curve appropriate for the assessment location of Dalgonar, during day-time periods. Predicted immission noise levels are shown for the proposed Development alone as no cumulative assessment is required. This receptor would be removed should the Sanquhar II Windfarm be built, therefore no predicted noise levels are shown for that windfarm. Also shown are more distant windfarms and confirmation predicted noise immission levels are ≥10 dB(A) below the ETSU-R-97 noise criteria.

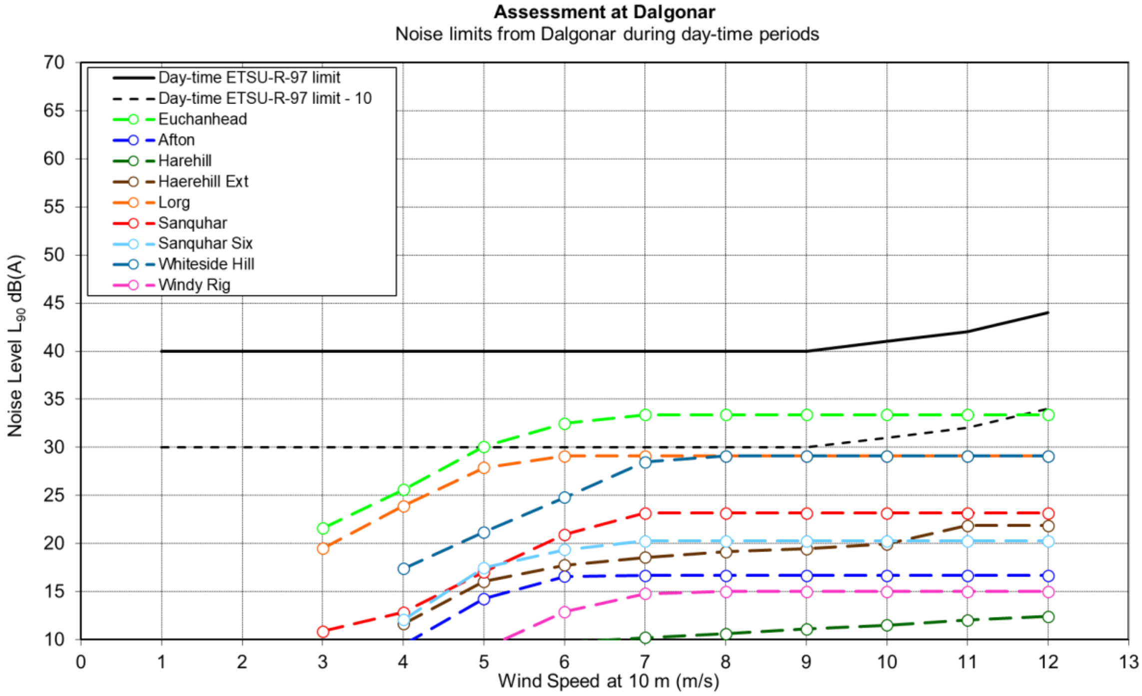


Figure D8 - Chart of the ETSU-R-97 noise criteria / limit curve appropriate for the assessment location of Dalgonar, during night-time periods. Predicted immission noise levels are shown for the proposed Development alone as no cumulative assessment is required. This receptor would be removed should the Sanquhar II Windfarm be built, therefore no predicted noise levels are shown for that windfarm. Also shown are more distant windfarms and confirmation predicted noise immission levels are ≥10 dB(A) below the ETSU-R-97 noise criteria.

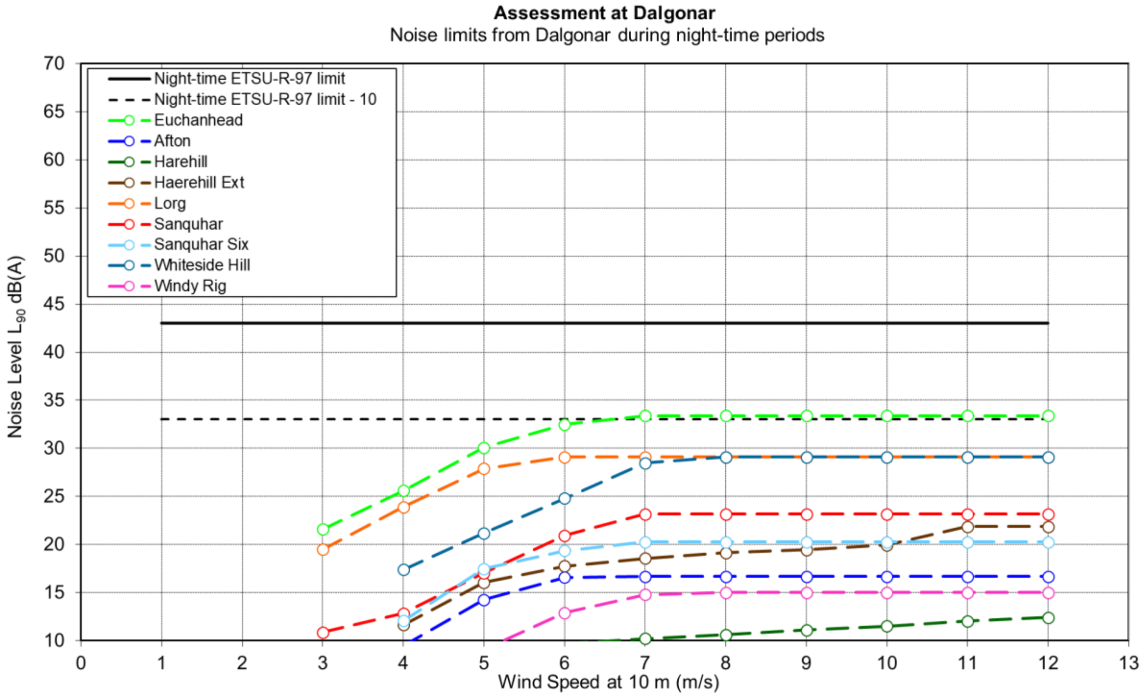


Figure D9 - Chart of the noise criteria / limit curve appropriate for the assessment location of Euchanbank Cottage, derived to be 10 dB(A) below the applicable ETSU-R-97 noise limit during day-time periods. Predicted immission noise levels are also shown for the proposed Development alone.

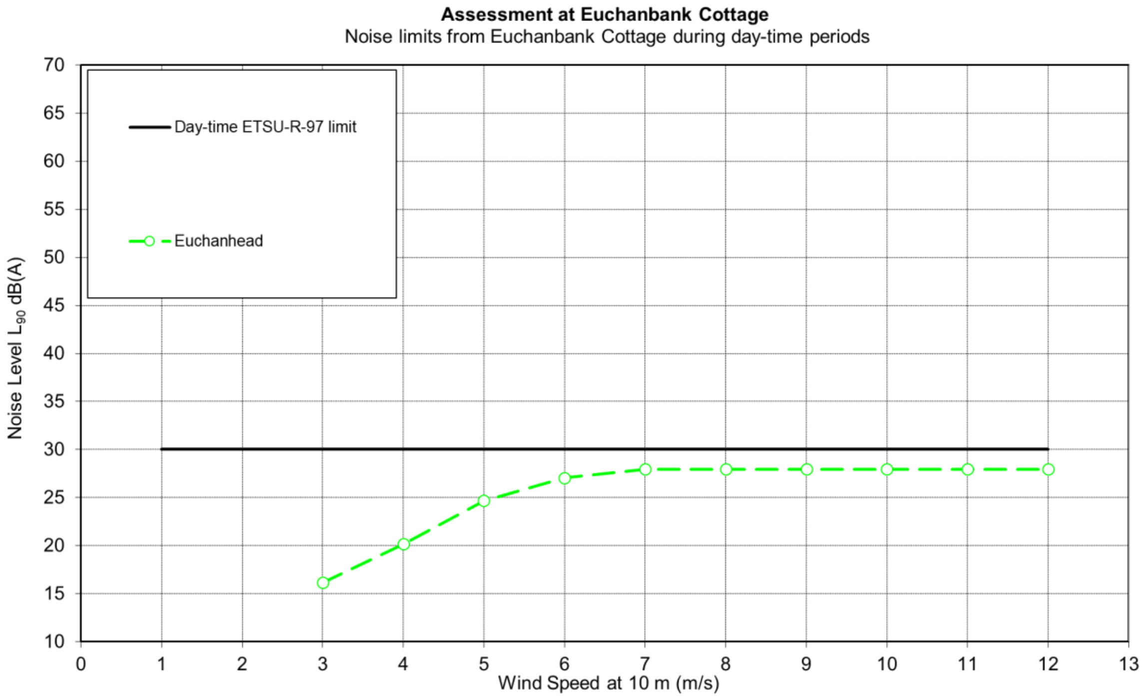


Figure D10 - Chart of the noise criteria / limit curve appropriate for the assessment location of Euchanbank Cottage, derived to be 10 dB(A) below the applicable ETSU-R-97 noise limit during day-time periods. Predicted immission noise levels are also shown for the proposed Development alone.

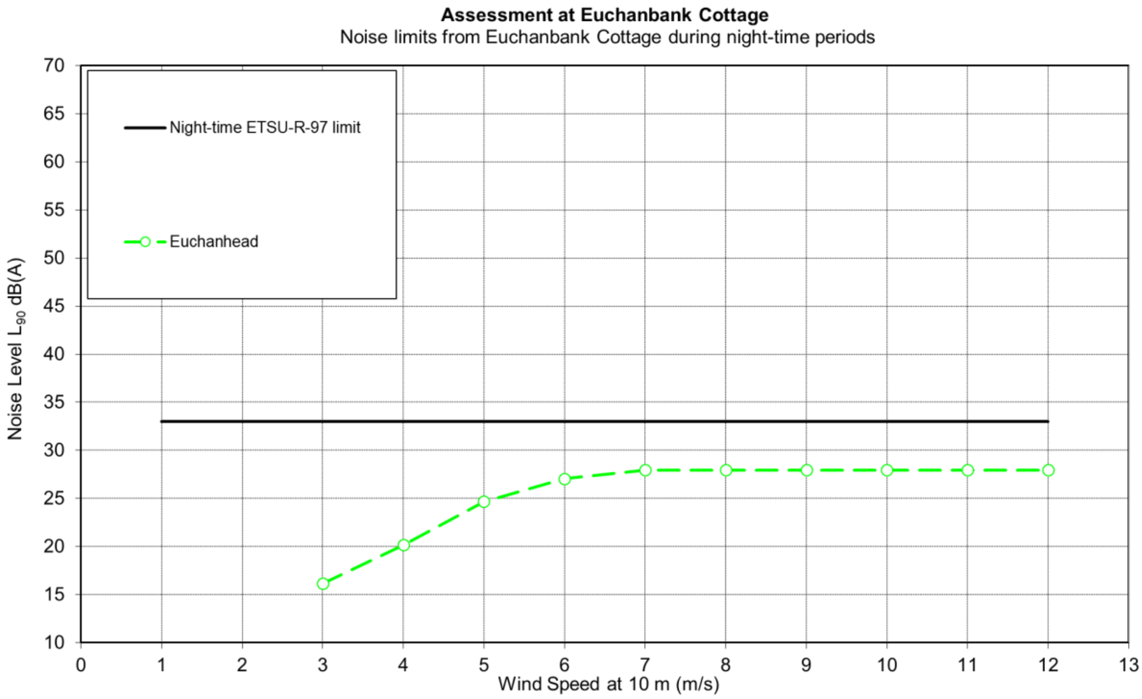


Figure D11 - Chart of the noise criteria / limit curve appropriate for the assessment location of Hillend, derived to be 10 dB(A) below the applicable ETSU-R-97 noise limit during day-time periods. Predicted immission noise levels are also shown for the proposed Development alone.

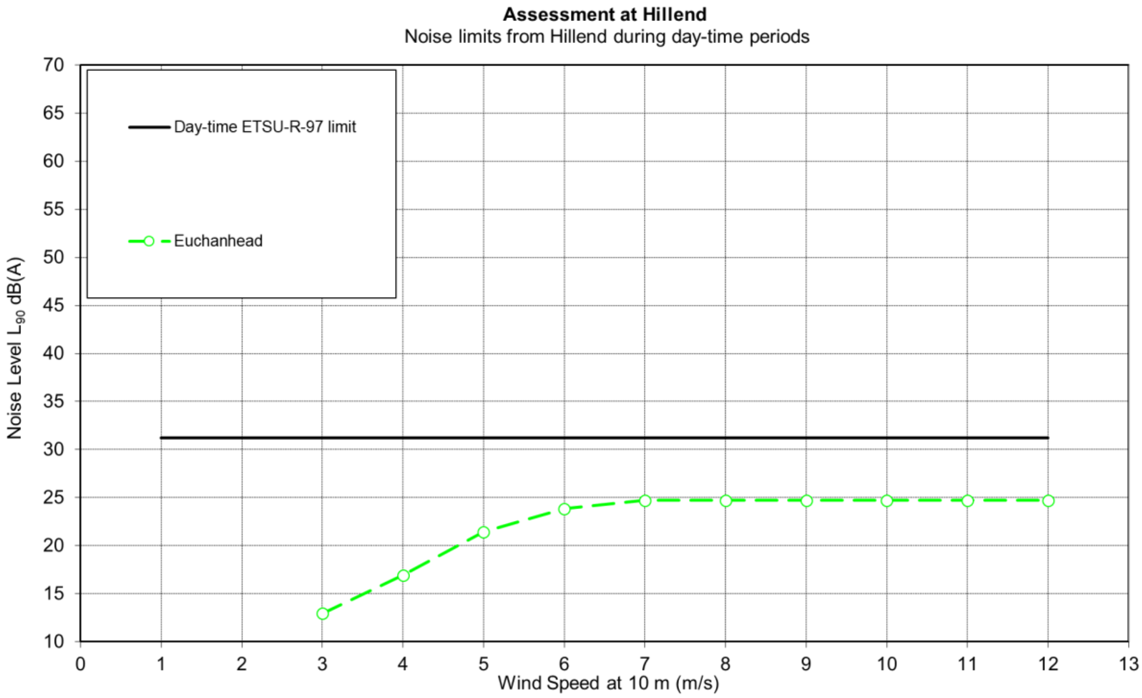


Figure D12 - Chart of the noise criteria / limit curve appropriate for the assessment location of Hillend, derived to be 10 dB(A) below the applicable ETSU-R-97 noise limit during day-time periods. Predicted immission noise levels are also shown for the proposed Development alone.

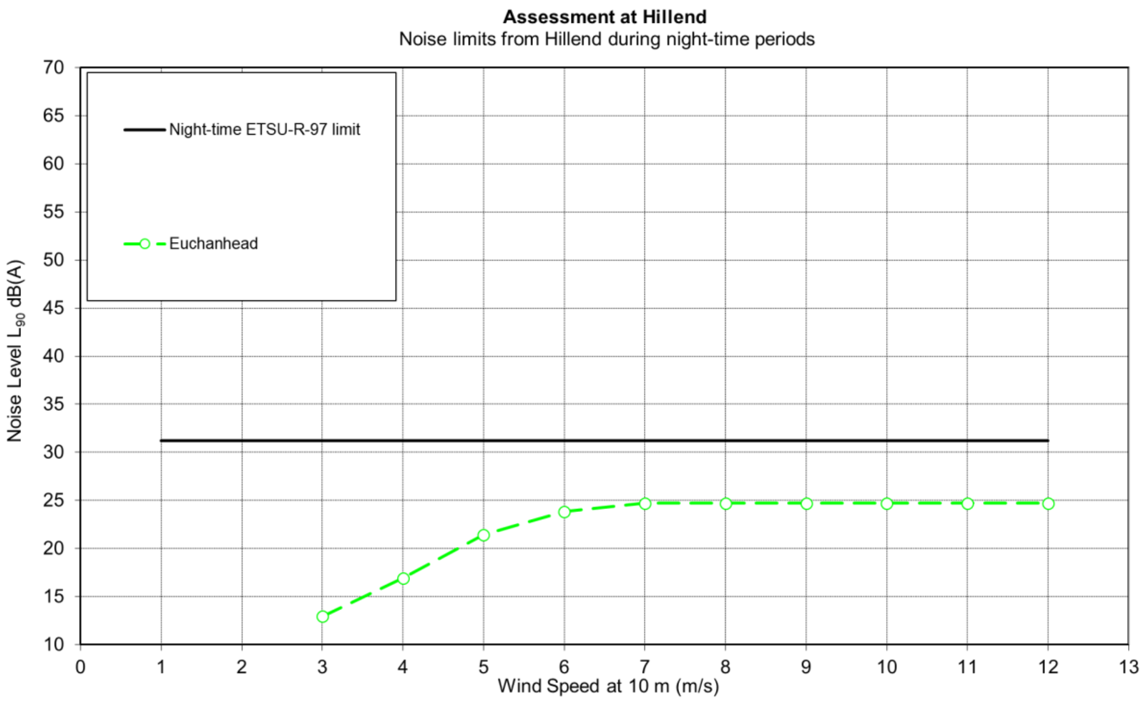


Figure D13 - Chart of the ETSU-R-97 noise criteria / limit curve appropriate for the assessment location of Lorg, during day-time periods. Predicted immission noise levels are also shown for the proposed Development, Sanquhar II and the total of these developments for the cumulative assessment, during day-time periods. Also shown are more distant windfarms and confirmation predicted noise immission levels are ≥10 dB(A) below the ETSU-R-97 noise criteria. Lorg Windfarm is not included in the cumulative assessment as this receptor would be removed for that development.

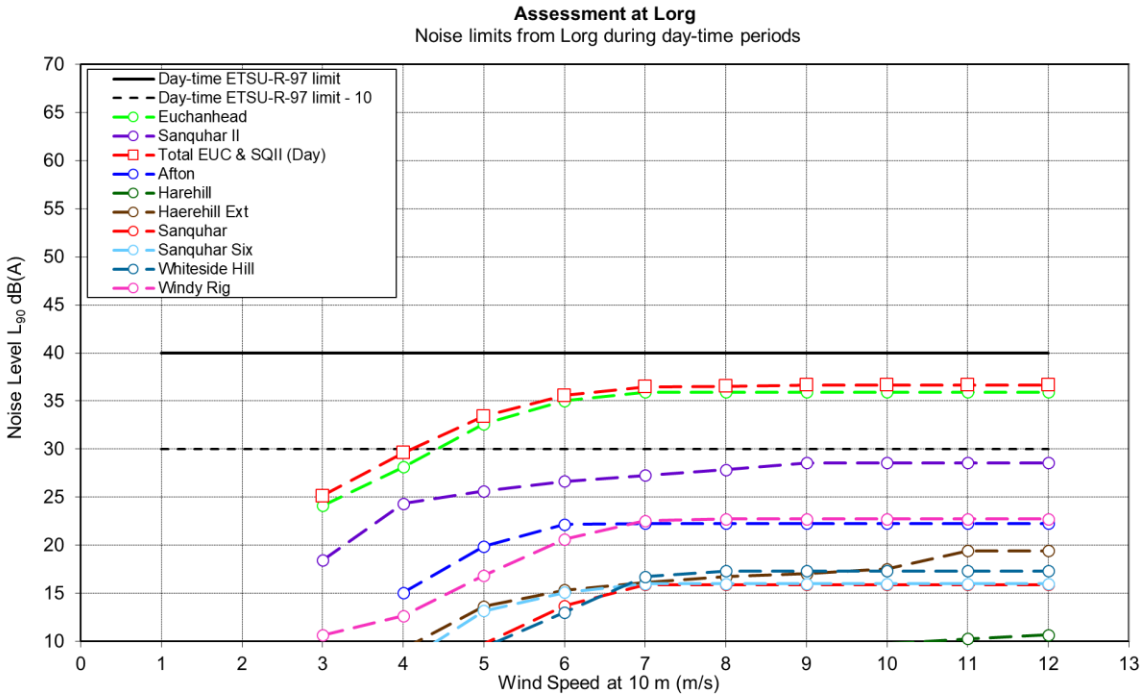


Figure D14 - Chart of the ETSU-R-97 noise criteria / limit curve appropriate for the assessment location of Lorg, during night-time periods. Predicted immission noise levels are also shown for the proposed Development, Sanquhar II and the total of these developments for the cumulative assessment, during night-time periods. Also shown are more distant windfarms and confirmation predicted noise immission levels are ≥10 dB(A) below the ETSU-R-97 noise criteria. Lorg Windfarm is not included in the cumulative assessment as this receptor would be removed for that development.

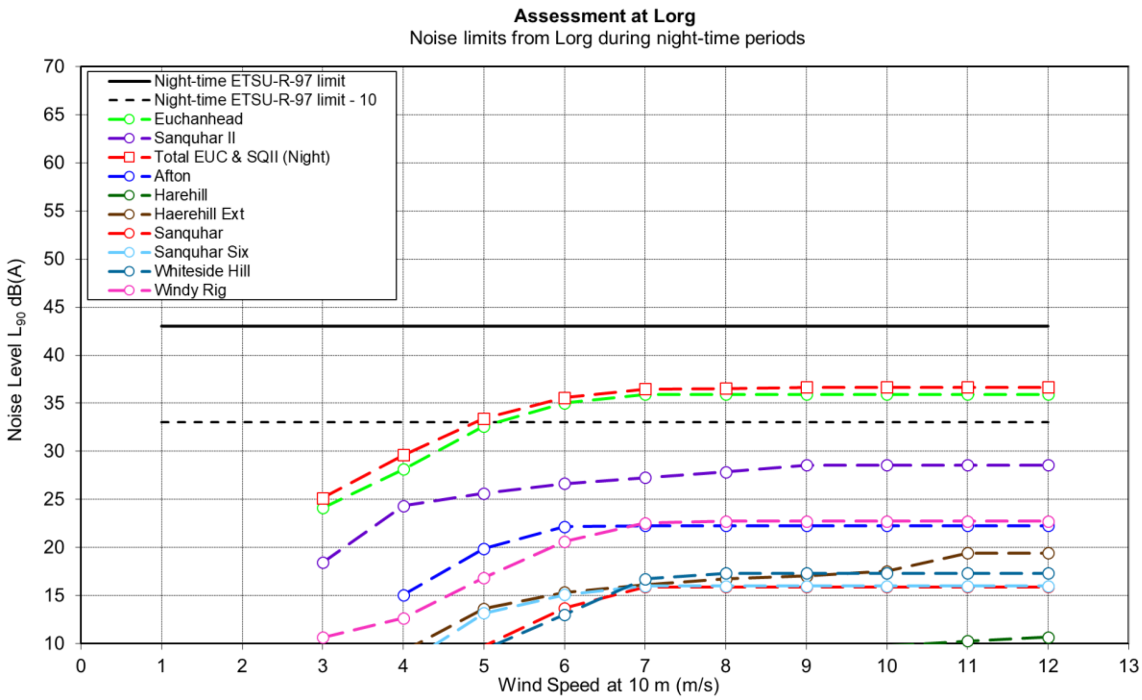


Figure D15 - Chart of the noise criteria / limit curve appropriate for the assessment location of Polgown, derived to be 10 dB(A) below the applicable ETSU-R-97 noise limit during day-time periods. Predicted immission noise levels are also shown for the proposed Development alone.

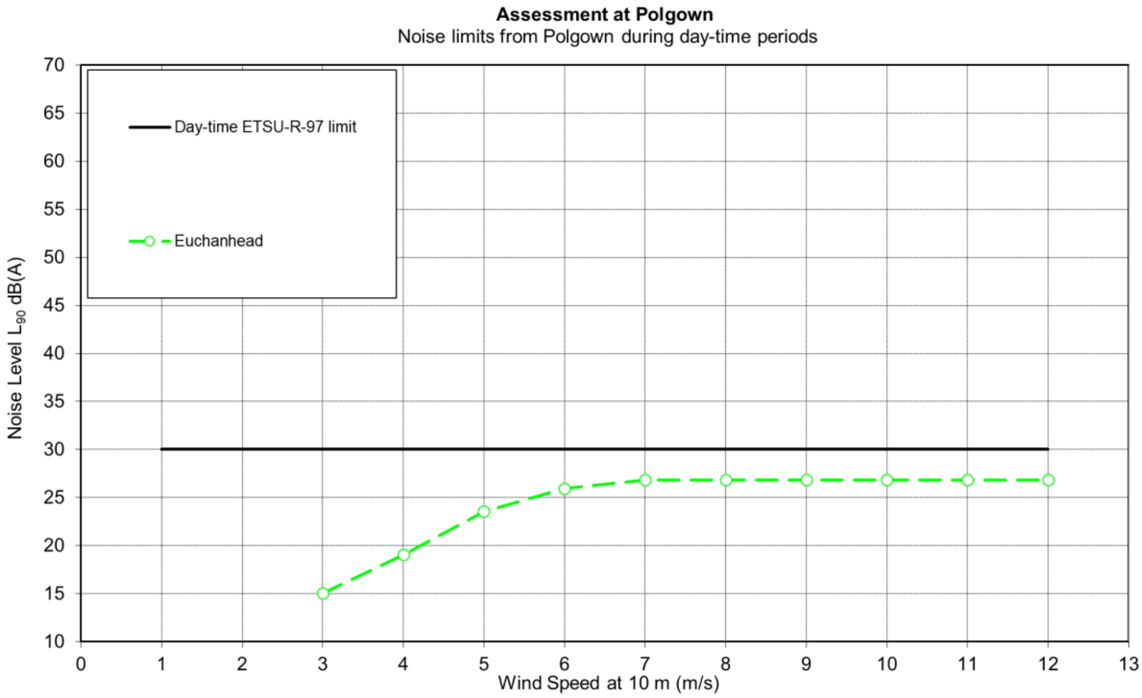


Figure D16 - Chart of the noise criteria / limit curve appropriate for the assessment location of Polgown, derived to be 10 dB(A) below the applicable ETSU-R-97 noise limit during night-time periods. Predicted immission noise levels are also shown for the proposed Development alone.

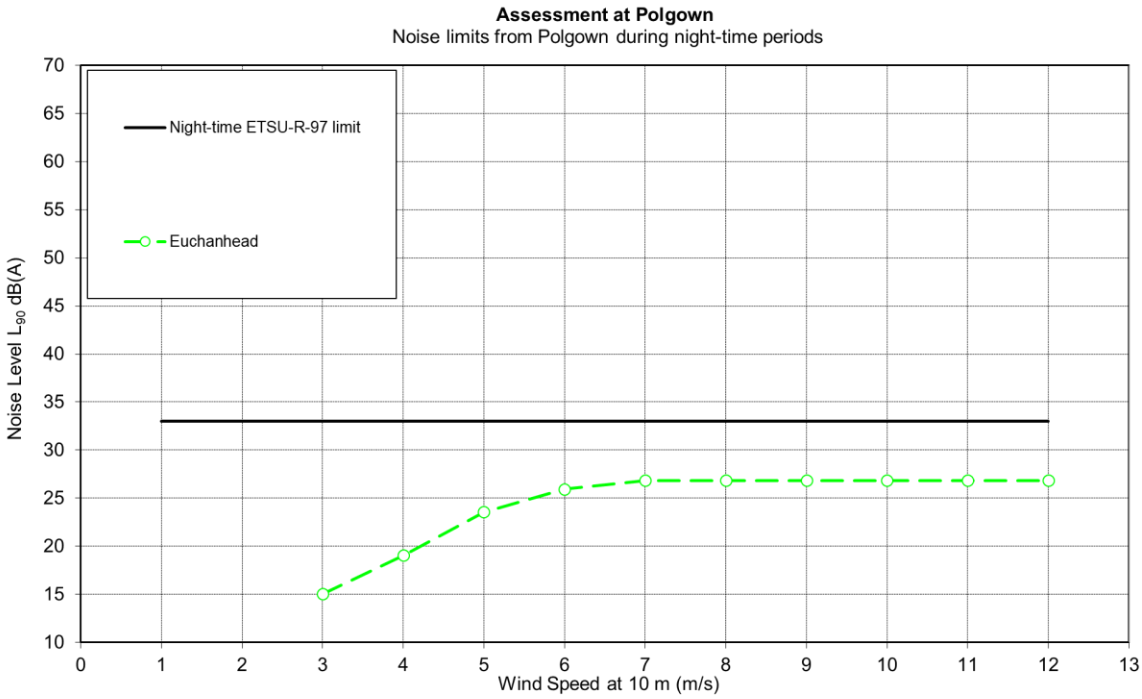


Figure D17 - Chart of the ETSU-R-97 noise criteria / limit curve appropriate for the assessment location of Shinnelhead, during day-time periods. Predicted immission noise levels are also shown for the proposed Development, Sanquhar II and the total of these developments for the cumulative assessment, during day-time periods. Also shown are more distant windfarms and confirmation predicted noise immission levels are ≥10 dB(A) below the ETSU-R-97 noise criteria.

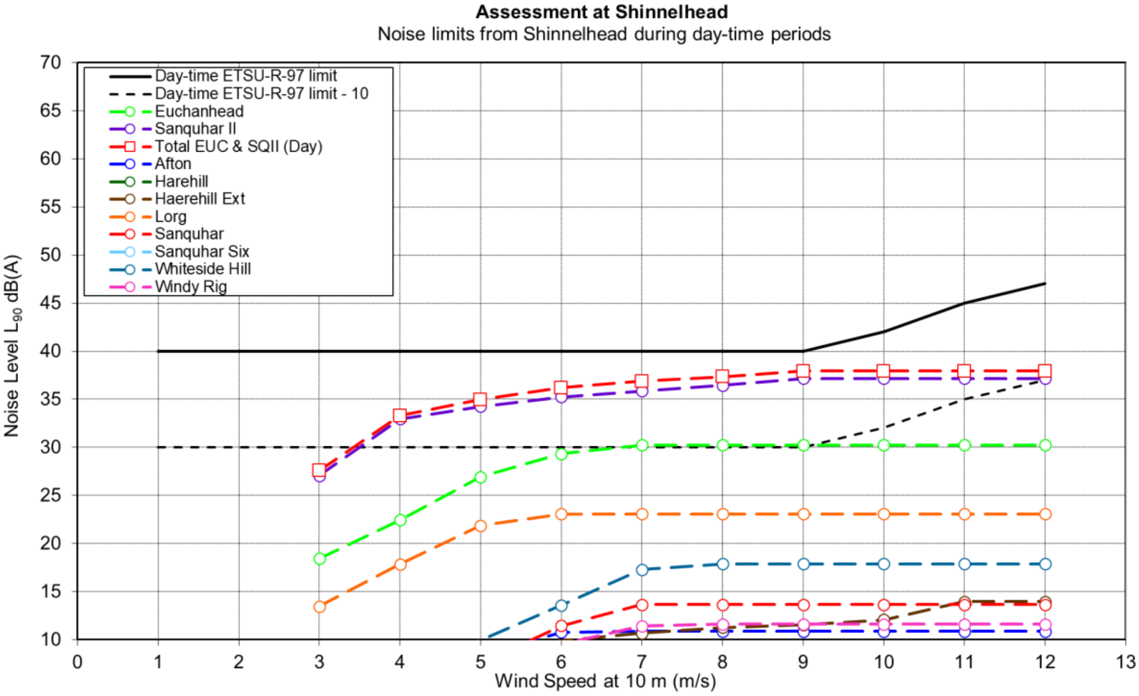


Figure D18 - Chart of the ETSU-R-97 noise criteria / limit curve appropriate for the assessment location of Shinnelhead, during night-time periods. Predicted immission noise levels are also shown for the proposed Development, Sanquhar II and the total of these developments for the cumulative assessment, during night-time periods. Also shown are more distant windfarms and confirmation predicted noise immission levels are ≥10 dB(A) below the ETSU-R-97 noise criteria.

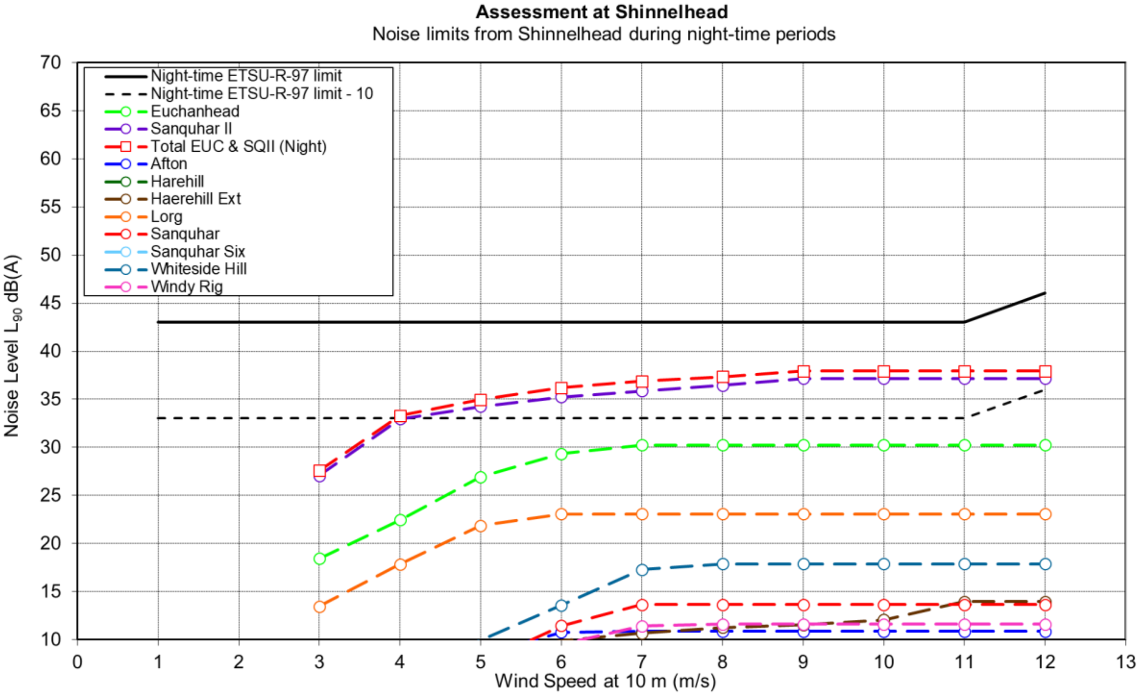


Figure D19 - Chart of the noise criteria / limit curve appropriate for the assessment location of Upper Holm of Dalquhairn, derived to be 10 dB(A) below the applicable ETSU-R-97 noise limit during day-time periods. Predicted immission noise levels are also shown for the proposed Development alone.

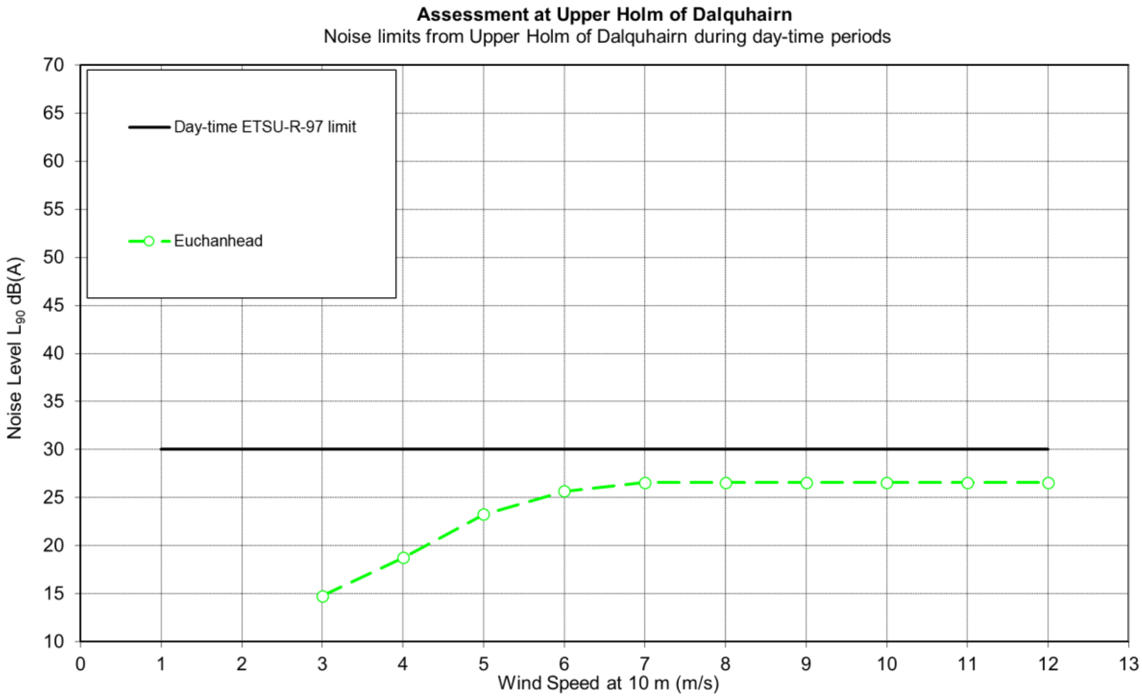
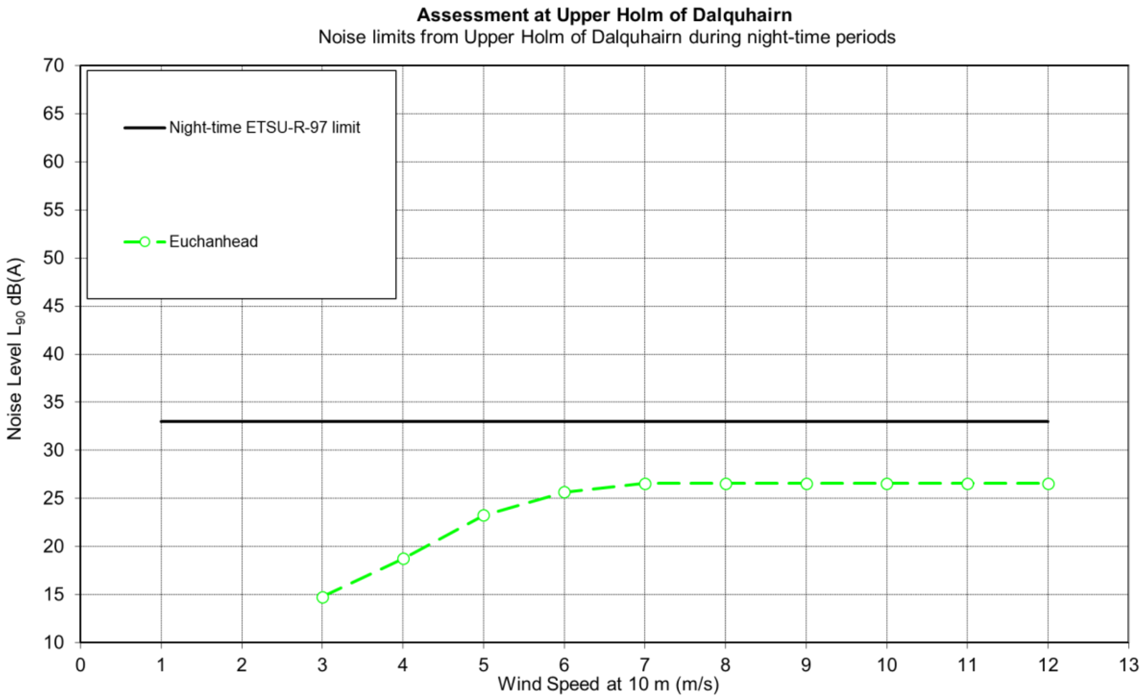


Figure D20 - Chart of the noise criteria / limit curve appropriate for the assessment location of Upper Holm of Dalquhairn, derived to be 10 dB(A) below the applicable ETSU-R-97 noise limit during night-time periods. Predicted immission noise levels are also shown for the proposed Development alone.



Annex E – Apportioned Limits

Figure E1 - Chart of the apportioned noise limits which could be applied during day-time periods to Sanquhar II Windfarm and the proposed Development so that the total cumulative noise levels meet the ETSU-R-97 day-time criteria at the assessment location Lorg. Predicted immission noise levels are also shown for the proposed Development, Sanquhar II and the cumulative total during day-time periods.

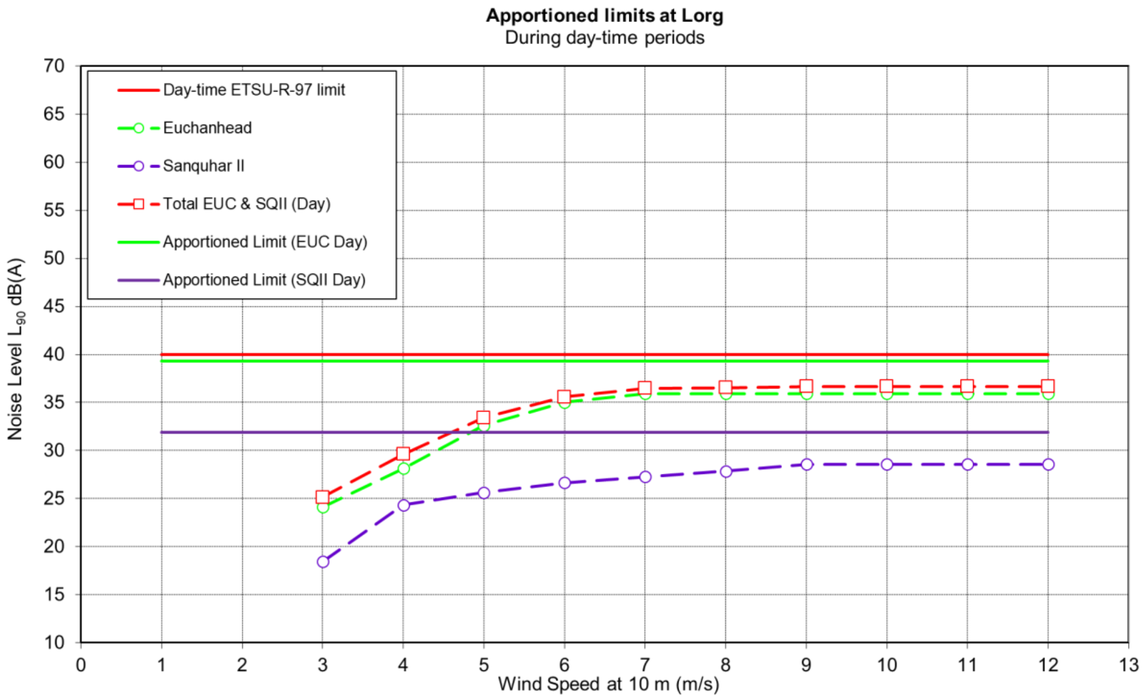


Figure E2 - Chart of the apportioned noise limits which could be applied during night-time periods to Sanquhar II Windfarm and the proposed Development so that the total cumulative noise levels meet the ETSU-R-97 night-time criteria at the assessment location Lorg.

Predicted immission noise levels are also shown for the proposed Development, Sanquhar II and the cumulative total during night-time periods.

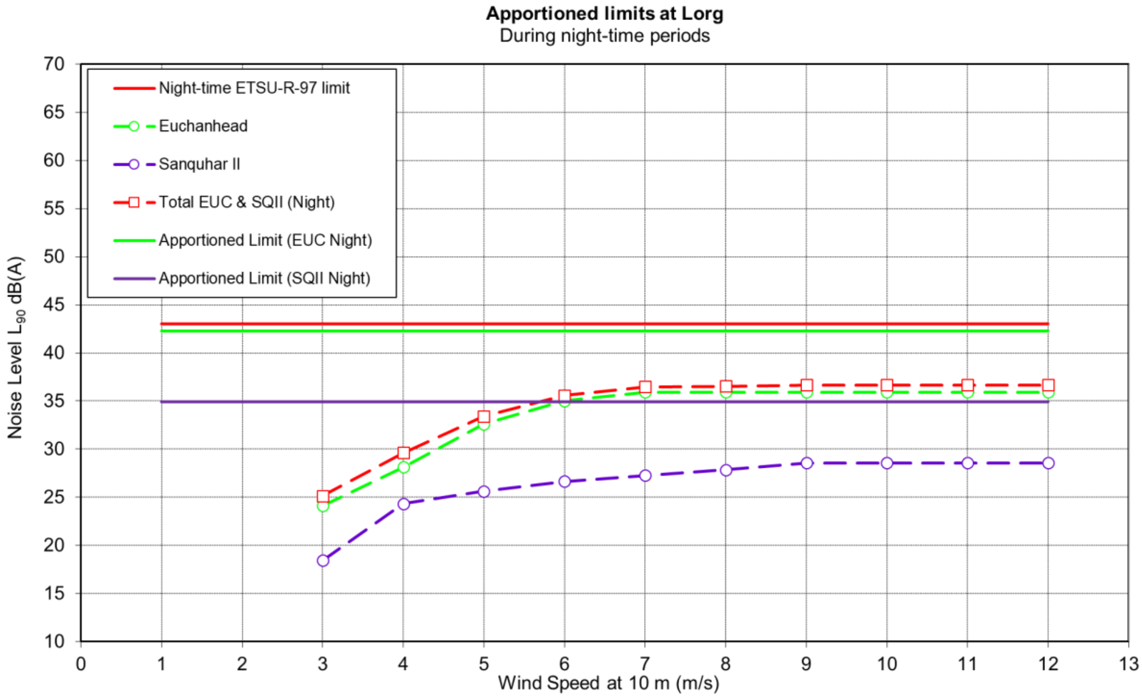


Figure E3 - Chart of the apportioned noise limits which could be applied during day-time periods to Sanquhar II Windfarm and the proposed Development so that the total cumulative noise levels meet the ETSU-R-97 day-time criteria at the assessment location Shinnelhead. Predicted immission noise levels are also shown for the proposed Development, Sanquhar II and the cumulative total during day-time periods.

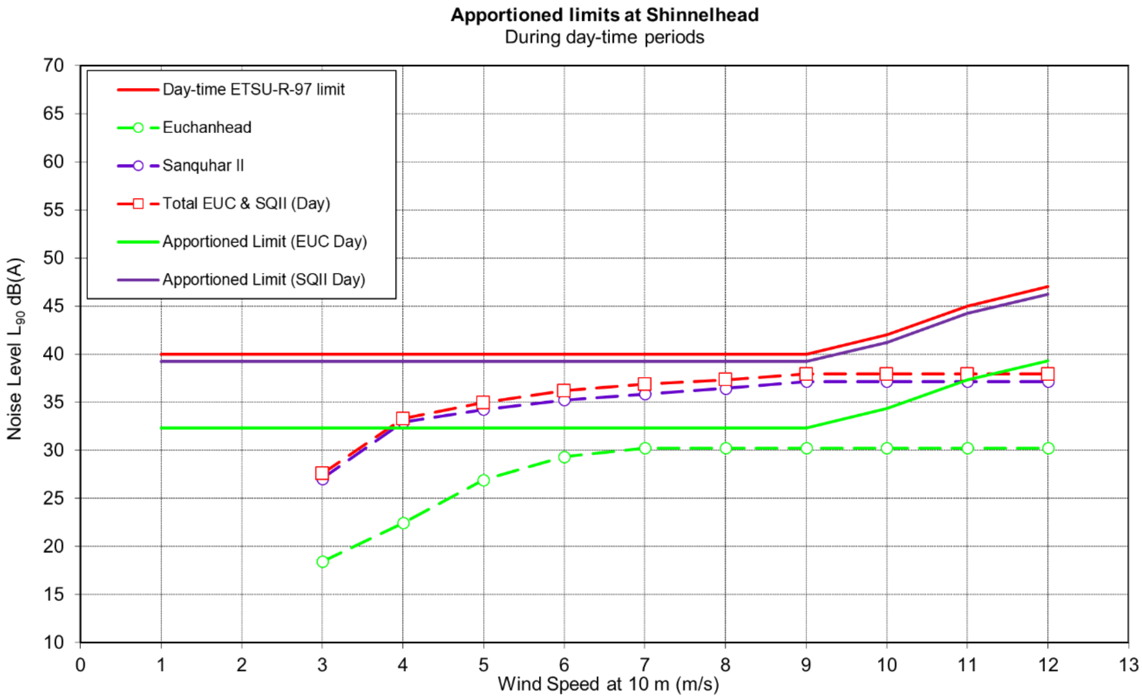


Figure E4 - Chart of the apportioned noise limits which could be applied during night-time periods to Sanquhar II Windfarm and the proposed Development so that the total cumulative noise levels meet the ETSU-R-97 night-time criteria at the assessment location

Shinnelhead. Predicted immission noise levels are also shown for the proposed Development, Sanquhar II and the cumulative total during night-time periods.

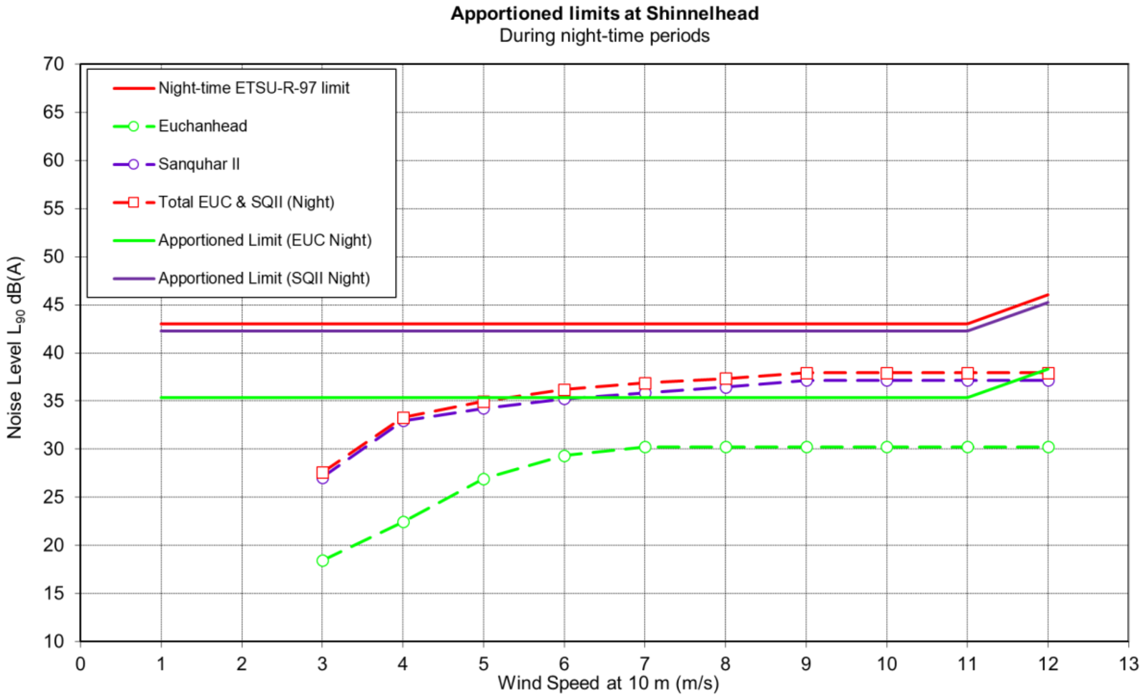


Table E1 – Apportioned noise limits which could be applied to Sanquhar II Windfarm and the proposed Development so that the total cumulative noise levels meet the ETSU-R-97 day-time and night-time criteria at the assessment location Lorg.

Property	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Sanquhar II (day)	31.9	31.9	31.9	31.9	31.9	31.9	31.9	31.9	31.9	31.9	31.9	31.9
Euchanhead (day)	39.3	39.3	39.3	39.3	39.3	39.3	39.3	39.3	39.3	39.3	39.3	39.3
Sanquhar II (night)	34.9	34.9	34.9	34.9	34.9	34.9	34.9	34.9	34.9	34.9	34.9	34.9
Euchanhead (night)	42.3	42.3	42.3	42.3	42.3	42.3	42.3	42.3	42.3	42.3	42.3	42.3

Table E2 – Apportioned noise limits which could be applied to Sanquhar II Windfarm and the proposed Development so that the total cumulative noise levels meet the ETSU-R-97 day-time and night-time criteria at the assessment location Shinnelhead.

Property	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Sanquhar II (day)	39.2	39.2	39.2	39.2	39.2	39.2	39.2	39.2	39.2	41.2	44.2	46.2
Euchanhead (day)	32.3	32.3	32.3	32.3	32.3	32.3	32.3	32.3	32.3	34.3	37.3	39.3
Sanquhar II (night)	42.2	42.2	42.2	42.2	42.2	42.2	42.2	42.2	42.2	42.2	42.2	45.2
Euchanhead (night)	35.3	35.3	35.3	35.3	35.3	35.3	35.3	35.3	35.3	35.3	35.3	38.3

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