HOARE LEA

Hollandmey Renewable Energy Development.

Technical Appendix 13.1 - Environmental Noise Assessment.

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Contents.

Executive Summary

Hoare Lea (HL) have been commissioned by ScottishPower Renewables to undertake a noise assessment for the construction and operation of the proposed Hollandmey 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 Stroupster Windfarm (operational), Lochend Windfarm (operational) and Slickly Windfarm (proposed). 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, an energy storage facility and a solar installation, 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 Executive 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 Hollandmey 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: Lochend Windfarm (operational and adjacent to the west), Stroupster Windfarm (operational and approximately 3.5 km south east) and Slickly Windfarm (proposed and approximately 2.5 km to the south east). Other, more distant wind turbines or windfarms were not considered because their potential noise contribution was not considered acoustically important.

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, solar installation and an energy storage facility. 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 <u>or</u> a fixed level in the range 35 dB(A) to 40 dB(A). The precise choice of the fixed lower limit within the range 35 dB(A) to 40 dB(A) depends on a number of factors: the number of noise affected properties, the likely duration and level of exposure and the consequences of the choice on the potential power generating capability of the 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 not be at the lowest choice within 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 turbines of the proposed Development, are set out subsequently in this assessment. Assessment of the substation and ancillary services/energy storage is described in the next section.

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 (see Section 3.5 below). 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 submitted to The Highland Council (THC)[xviii]. THC has a stated policy[xix] of expecting the lowest value of 35 dB(A) to be selected for the fixed part of the day-time noise limit, within the range from 35 dB(A) to 40 dB(A) allowed by ETSU-R-97. In addition, THC has previously expressed a reluctance to accept noise limits during the night-time with the fixed part of the night-time limit set at 43 dB(A) as specified in ETSU-R-97, preferring instead to adopt a value of 38 dB(A). Through this consultation, it was proposed to utilise existing baseline data to complete the noise assessment, setting 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. THC responded[xx] to the consultation and confirmed that the proposed approach to baseline background noise levels would be acceptable. They also asked that additional aspects be considered:-

– A robust argument based on ETSU-R-97 criteria should be provided for the choice of the fixed part of the day-time noise limits where this is not based on 35 dB(A), within the range between 35 dB(A) and 40 dB(A) allowed by ETSU-R-97.

– Provide information / analysis to allow consideration of the duration and level of exposure of those nearby receptor locations which lay in between wind energy developments and where the duration of exposure to wind turbine noise may increase whilst remaining within the ETSU-R-97 noise limits.

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.

3.7.2 The application boundary of the Site includes a minor road to the north, along which site construction traffic will pass to enter/leave the site entrance. There is potential that this road may require some upgrading or repair works following and during use. Control and management of this activity would be included within the Construction Traffic Management Plan (CTMP) which will covers the main construction activities, including restrictions. These works will be minor, temporary and unlikely to cause significant noise effects, accordingly detailed assessment of these effects is scoped out of this assessment.

4. Baseline & Assessment Criteria

4.1 General Description

4.1.1 The area of the wind turbines on the proposed Development is located within the administration area of The Highland Council 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 and occasional road traffic.

4.1.2 There are a number of other wind energy developments in the area around the proposed Development, some of which are operational, one proposed and for which a planning application has been submitted but not yet determined and one which was proposed and refused on appeal. 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, and as agreed with THC, 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 appropriate noise limits which may apply to the proposed Development.

4.2 Details of the Baseline Background Noise Environment

4.2.1 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 which require noise effects of the proposed Development to be assessed. Eight assessment locations are shown on the plan in Figure B1 of 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.

4.2.2 In addition to the locations of Table 2, a consented commercial development (Mey Data Centre) was identified in proximity to the proposed Development (see Figure B1 of Annex B). However, due to its commercial nature, it is considered to have a low sensitivity to noise and will therefore be assessed separately.

Table 2 - Assessment locations in the vicinity of the development

Receptor Location	Easting	Northing	Approximate Distance to Closest Turbine (m)	Closest Turbine (ID)	Source of assessment criteria (see Annex C)
Brabstermire House	331549	969137	1424	HM10	Generic (Lyth WF)
Kevill	332398	969747	1864	HM10	Generic (Lyth WF)
Lochend 10(1)	327495	967732	1385	HM04	Syster (Lochend WF)
Lochend New Build	326879	968756	1826	HM03	Syster (Lochend WF)
Phillips Mains (Nearest)	329887	971953	1753	HM07	Generic (Lyth WF)
Slickly Croft	330192	966236	2452	HM04	Slickly Croft (Slickly WF)
Slickly (Nearest)	329471	966952	1463	HM04	Mooredge (Lyth WF)
Syster*	327028	969081	1653	HM01	Syster (Lochend WF FI) Syster (Lochend WF)
* The Syster receptor location is financially involved with the Lochend Windfarm and accordingly has higher noise limits for a financially involved location, however reference has also been made to non-financially involved noise limits.					

4.3 ETSU-R-97 Assessment Criteria

4.3.1 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.

4.3.2 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.

4.3.3 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 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.

4.3.4 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. Baseline data gathered for other schemes and which form the basis of this assessment have been compared (see Figures C1 and C2 of Annex C). This comparison demonstrates that appropriate account has been included for the effects of site specific wind shear and that baseline data and derived criteria are appropriate for assessment of the proposed Development.

4.3.5 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 and are shown in Table 3 and 4 for the day-time and Table 4 for the night-time. The three nearby windfarms (Lochend and Stroupster – both operating / Slickly - proposed) have all completed their noise assessments on the basis of a choice of 35 dB(A), the lowest within the range from 35 dB(A) to 40 dB(A) allowed by ETSU-R-97 during day-time periods, and with the fixed part of the limit being 38 dB(A) night-time, rather than 43 dB(A) specified in ETSU-R-97. This is consistent with THC's general preferences, which were expressed during consultation along with the recommendation this remained the same, when even including the proposed Development as part of a cumulative analysis.

4.3.6 But these noise limits /criteria represent the cumulative limits applicable to the proposed Development operated with other windfarms considered, which would leave in many cases no margin in which to operate the proposed Development and would therefore be un-necessarily restrictive. It was therefore proposed through consultation to consider two sets of cumulative criteria for day-time periods for all locations, with the fixed part chosen as both 35 dB(A) (see Table 3) and 38 dB(A) (see Table 4), within the range between 35 dB(A) to 40 dB(A) allowed by ETSU-R-97. During the night-time, the limits / criteria remain those the THC would prefer, as these are already based upon the fixed threshold being higher than the day-time at 38 dB(A) (see Table 5). It should be noted however that a choice of 38 dB(A) for the night-time is not consistent with ETSU-R-97 guidance, which suggests a value of 43 dB(A). The cumulative noise limits / criteria (based on a choice of 38 dB(A) day-time and 38 dB(A) night-time) are a compromise, between accommodating the aspirations of THC (expressed through consultation), which impose significantly lower noise limits, and the requirements of ETSU-R-97, which is should to be used according to Scottish Government guidance.

4.3.7 For financially involved locations the lower absolute fixed threshold element of the limit becomes 45 dB(A) day-time and night-time, as is the case for the receptor location Syster (see note in Table 2). However, this receptor location (and other involved receptors noted in the consent for Lochend Windfarm – see Table C10 of Annex C) is financially involved only with Lochend Windfarm. Financially involved noise limits would only apply at Syster when considering the cumulative total of the proposed Development operating with Lochend Windfarm. Should Lochend Windfarm to come to the end of its life and be removed, this financial involvement would end. In this scenario the non-financially involved criteria / limits would then be applicable at such receptors, however there would no longer be a contribution from Lochend Windfarm when comparing predicted cumulative noise immission levels with these criteria / limits. Accordingly, both financially involved and non-financially involved criteria are provided for the Syster receptor location in all three tables of noise limits.

Table 3 – Day-time $L_{A90,T}$ dB noise limits / criteria derived from baseline noise data according to ETSU-R-97, based upon a choice of 35 dB(A) for the fixed threshold and used to assess cumulative levels of noise, which include operation of the proposed Development.

Property	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Brabstermire House	35.0	35.0	35.0	35.0	35.0	35.0	35.0	36.8	39.5	42.5	45.7	48.9
Kevill	35.0	35.0	35.0	35.0	35.0	35.0	35.0	36.8	39.5	42.5	45.7	48.9
Lochend 10(1)	35.0	35.0	35.0	35.0	35.0	35.0	36.0	38.5	41.2	44.2	47.3	50.4
Lochend New Build	35.0	35.0	35.0	35.0	35.0	35.0	36.0	38.5	41.2	44.2	47.3	50.4
Phillips Mains (Nearest)	35.0	35.0	35.0	35.0	35.0	35.0	35.0	36.8	39.5	42.5	45.7	48.9
Slickly Croft	35.0	35.0	35.0	35.0	35.0	35.0	35.0	38.4	43.5	48.3	51.6	52.5
Slickly (Nearest)	35.0	35.0	35.0	35.0	35.0	35.0	35.0	36.5	39.5	42.7	46.0	49.2
Syster (FI)	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0
Syster (non-FI)	*35.0*	*35.0*	*35.0*	*35.0*	*35.0*	*35.0*	*36.0*	*38.5*	*41.2*	*44.2*	*47.3*	*50.4*

Table 4 – Day-time $L_{A90,T}$ dB noise limits / criteria derived from baseline noise data according to ETSU-R-97, based upon a choice of 38 dB(A) for the fixed threshold and used to assess cumulative levels of noise, which include operation of the proposed Development.

Property	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Brabstermire House	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	39.5	42.5	45.7	48.9
Kevill	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	39.5	42.5	45.7	48.9
Lochend 10(1)	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.5	41.2	44.2	47.3	50.4
Lochend New Build	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.5	41.2	44.2	47.3	50.4
Phillips Mains (Nearest)	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	39.5	42.5	45.7	48.9
Slickly Croft	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.4	43.5	48.3	51.6	52.5
Slickly (Nearest)	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	39.5	42.7	46.0	49.2
Syster (FI)	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0
Syster (non-FI)	*38.0*	*38.0*	*38.0*	*38.0*	*38.0*	*38.0*	*38.0*	*38.5*	*41.2*	*44.2*	*47.3*	*50.4*

Table 5 – Night-time $L_{A90,T}$ dB noise limits / criteria derived from baseline noise data according to ETSU-R-97, based upon a choice of 38 dB(A) for the fixed threshold (rather than 43 dB(A) specified by ETSU-R-97) and used to assess cumulative levels of noise, which include operation of the proposed Development.

Property	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Brabstermire House	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	41.4	45.1	49.0
Kevill	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	41.4	45.1	49.0
Lochend 10(1)	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.5	41.2	44.2	47.3	50.4
Lochend New Build	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.5	41.2	44.2	47.3	50.4
Phillips Mains (Nearest)	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	41.4	45.1	49.0
Slickly Croft	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	40.8	45.7	50.5	54.7
Slickly (Nearest)	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.9	42.3	45.4	48.0
Syster (FI)	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0
Syster (non-FI)	*38.0*	*38.0*	*38.0*	*38.0*	*38.0*	*38.0*	*38.0*	*38.5*	*41.2*	*44.2*	*47.3*	*50.4*

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.

5.1.5 Comparing the predicted construction noise levels (Table 6) 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 significance. For the activity which is closest to West Lodge (328899, 972263) near the site entrance, the upgrading of the access and related forestry work are predicted to have noise levels that could be categorised as being of moderate significance. However these activities 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, quickly moving the activity further from the property and reducing noise levels. The short-term nature (shorter than the 4 weeks normally allowed for periods of noisier activity) of these activities consequently categorises the effects to be of minor significance.

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 and Transport, has assessed a worst-case scenario where all aggregate and concrete are sourced off site with the worst-case assumed for the purposes of this noise assessment. The highest volume of traffic generated by construction is expected to occur in months 3 to 12 of the 22 month construction program with similar levels of vehicle movements over this 10 month period. The most intense period of activity is projected to be within month three of construction. Data for traffic flows have been used to ascertain the projected traffic flows for the worst case scenarios with and without the proposed Development.

Table 6 - Predicted construction noise levels

Task Name	Plant/Equipment	Upper Collective Sound Emission Over Working Day $L_{WA,T}$ dB(A)	Nearest Receiver	Minimum Distance to Nearest Receiver (m)	Predicted Upper Day-Time L_{Aeq} dB
Upgrade Access Track	excavator / dump trucks / tippers / dozers / vibrating rollers	120	West Lodge (328899, 972263)	26	84
Construct temporary site compounds	excavator / dump truck / tippers / rollers/ delivery trucks	120	West Lodge (328899, 972263)	930	49
Construct site tracks	excavators / dump trucks / tippers / dozers / vibrating rollers	120	Philips Mains (nearest)	700	52
Construct Sub-Station	excavator / concrete truck / delivery truck	110	West Lodge (328899, 972263)	600	43
Construct crane hardstandings	excavators / dump trucks	120	Lochend 10(1)	1360	46
Construct turbine / met mast foundations	Piling Rigs / excavators / tippers / concrete trucks / mobile cranes / water pumps / pneumatic hammers / compressors / vibratory pokers	120	Lochend 10(1)	1360	46
Excavate and lay site cables	excavators / dump trucks / tractors & cable drum trailers / wacker plates	110	Philips Mains (nearest)	700	42
Erect turbines	cranes / turbine delivery vehicles / artics for crane movement / generators / torque guns	120	Lochend 10(1)	1360	46
Reinstate crane bases	excavator / dump truck	115	Lochend 10(1)	1360	41
Reinstate road verges	excavator / dump truck	115	Philips Mains (nearest)	700	47
Lay cable to sub-stations	JCB / saws / hydraulic breaker / dump truck/ tipper / wacker plate / tandem roller / tractor & cable drum trailer / delivery truck	115	Philips Mains (nearest)	700	47
Borrow Pit Quarrying	Primary and secondary stone Crushers / excavators /	125	Philips Mains (Nearest)	970	54

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
	screening systems / pneumatic breakers / conveyors				
Concrete Batching	Batching Plant (in main compound, should concrete not be sourced off-site)	110	Brabstermire House	1900	32
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	West Lodge (328899, 972263)	26	79

Table 7 - Projected two way traffic flows and CRTN predicted increase in day-time average traffic noise levels ($L_{A10,18hour}$)

Road	Without Development (2022)		With Development (2022)		Maximum Change in Traffic Noise Level, dB(A)
	Annual Average Daily Traffic Flow	% Heavy Goods Vehicles	Annual Average Daily Traffic Flow	% Heavy Goods Vehicles	
A9 Sordale	3781	8.7%	3897	11.4%	0.6
A9 Thurso Centre	15505	1.9%	15515	1.9%	0.0
A882 Oldhall	2062	5.1%	2178	10.1%	1.3
A836 Murkle (west of site)	3918	5.1%	4044	7.8%	0.6
A836	574	23.4%	700	35.8%	Low flow*
C1033	89	38.0%	225	66.6%	Low flow*
C1085	76	2.8%	212	55.7%	Low flow*
* Values indicated as ‘Low flow’ are below the minimum flow defined in CRTN for use of the CRTN prediction methodology (see further discussion in paragraph 5.1.8).					

5.1.7 The above-referenced projected changes in traffic flows are summarised in Table 8. 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 Table 7).

5.1.8 Table 7 indicates a maximum potential increase of 1.3 dB(A) in the day-time average noise level during the most intense phases of the construction programme at locations adjoining the A882 Oldhall. Based on the criteria set out in the DMRB, the predicted short term change in traffic noise level would correspond to minor impact. The predicted construction traffic flow value for some of the roads used by construction traffic fall 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.

5.1.9 The most sensitive receiver locations in respect of vehicle movements are properties such as West Lodge (328899, 972263) which lie relatively close to the site entrance and access track. This receptor is at a distance of approximately 26 m at the closest point to the access track/entrance. 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 10 heavy vehicles per hour[1] travelling at 35 km/hr[2]. The construction program indicates this intensity of heavy vehicle movements could be similar for months 3 to 12. At this location, in terms of significance criteria noise effects are considered to be of negligible significance.

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 Siemens SG5.0-132 wind turbine. Ten wind turbines have been modelled using the layout as indicated on the map at Annex B (coordinates also provided). The candidate turbine is a variable speed, pitch regulated machine with a rotor diameter of 132 m and a hub height of 84 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.

1 The traffic assessment reports a maximum of 116 HGV vehicle movements per day for the most intense period (month 3 of the construction programme). This is a total of approximately 10 vehicles per hour for the twelve hour construction day.

2 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. Use of control modes is discussed further below.

5.4.3 Siemens have supplied specification noise emission data for the Siemens SG5.0-132 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 modifications ('DinoTails'), typically resulting in lower noise emission levels than turbines without this blade technology. In accordance with the advice provided by Siemens in the manufacturers' specification a further correction factor of +2 dB was added to these specification data to allow for uncertainty in these data, which is consistent with advice in the IOA GPG and typically the largest allowance for uncertainty added to sound power levels suggested by 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 4 m/s to 12 m/s inclusive. In addition to the overall sound power data, reference has been made to the documentation from the manufacturer to derive a representative sound spectrum for the turbine. The overall sound power and spectral data are presented in Table B3 and B4 in Annex B.

5.4.4 Assessment of cumulative effects from operating the proposed Development with other windfarms requires source information for the turbine types similar to that presented in Table B3 and B4 in Annex B for each windfarm. For each of these adjacent windfarms, Annex C provides a detailed description of how appropriate sound power levels for the wind turbines were derived. In summary of the information presented therein, potential noise emission levels were considered in a robust way by considering the potential level of noise emission which would be allowed under the respective consent for each of the sites, allowing 'appropriate margins' in addition to uncertainty margins in the emission data for representative turbine models. This accords with good practice guidance as set out in the IOA GPG for assessing cumulative operational noise levels.

5.4.5 The contribution to cumulative noise immission levels from Slickly Windfarm has accounted for that development being limited to noise limits recommended by the EHO at THC and which are based on those proposed by the applicant, or 2 dB(A) above predicted noise levels, whichever are lowest. These site-specific noise limits for Slickly Windfarm would differ between day and night and would apply only over specific wind directions and wind speeds. These constraints have been accounted for when presenting predicted noise immission levels in this assessment (see Annex C for further details).

5.5 Choice of Wind Turbine Operational Noise Propagation Model

5.5.1 The ISO 9613-2 model[xxi] 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 IOA GPG which provides recommendations on the appropriate approach when predicting wind turbine noise levels. The propagation 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 for assessing cumulative noise levels against the ETSU-R-97 criteria in the assessment. Directional based predictions have been provided (discussed further below) in order to inform this assessment of the likely duration of exposure of those receptors located between different windfarm developments and also when considering the wind conditions in which constraints may be required for the proposed Development.

5.6 Predicted Wind Turbine Operational Noise Immission Levels

5.6.1 Predicted noise immission levels are provided at each of the assessment locations for each wind speed from 4 m/s to 12 m/s inclusive. Predicted noise immission levels are also provided for the other windfarms considered, each operating alone, and which include robust allowances for their potential noise emissions in line with IOA GPG guidance, as detailed above. 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. The predicted noise levels presented in the tables below are for:-

- Table 8 The proposed Development alone.
- Table 9 Lochend Windfarm alone.
- Table 10 Stroupster Windfarm alone.
- Table 11 Slickly Windfarm alone.
- Table 12 Cumulative total.

5.6.2 For Slickly Windfarm (Table 11), it is assumed this windfarm would operate with the constraints required to meet the limits recommended by THC. For those receptors which lay in the general direction of Slickly Croft (relative to Slickly Windfarm) both day-time and night-time predictions are shown, due to potential constraints being applied to Slickly Windfarm which would differ for these periods. For other locations not in this general direction, predictions for Slickly Windfarm assume no constraints.

5.6.3 Table 12 shows cumulative predicted noise immission levels from the proposed Development when operating together with the other adjacent windfarms, both those built and operating and those which are proposed (assuming Slickly Windfarm operates with constraints, as discussed above). These predictions are cumulative assuming that all receptors are downwind of all wind turbines on the proposed Development and these other windfarms 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: both through the conservative nature of directional effects not being applied and the additional margins added to source sound power levels for each windfarm. Due to the differing constraints potentially applied to Slickly Windfarm during daytime and night-time periods, predicted cumulative noise immission levels shown in Table 12 are provided for both periods where applicable.

Table 8 - 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
Brabstermire House	-	-	-	26.7	30.3	34.3	35.7	35.7	35.7	35.7	35.7	35.7
Kevill	-	-	-	22.6	26.2	30.2	31.6	31.6	31.6	31.6	31.6	31.6
Lochend 10(1)	-	-	-	25.2	28.8	32.8	34.2	34.2	34.2	34.2	34.2	34.2
Lochend New Build	-	-	-	24.0	27.6	31.6	33.0	33.0	33.0	33.0	33.0	33.0
Phillips Mains (Nearest)	-	-	-	23.8	27.4	31.4	32.8	32.8	32.8	32.8	32.8	32.8
Slickly Croft	-	-	-	21.0	24.6	28.6	30.0	30.0	30.0	30.0	30.0	30.0
Slickly (Nearest)	-	-	-	25.2	28.8	32.8	34.2	34.2	34.2	34.2	34.2	34.2
Syster	-	-	-	25.1	28.7	32.7	34.1	34.1	34.1	34.1	34.1	34.1

Table 9 - Predicted $L_{A90,T}$ dB noise immission levels at each of the noise assessment locations as a function of standardised wind speed for the built and operating Lochend Windfarm alone.

Property	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Brabstermire House	-	-	-	-	15.0	20.2	22.8	24.5	25.9	25.9	25.9	25.9
Kevill	-	-	-	-	12.4	17.6	20.2	21.9	23.3	23.3	23.3	23.3
Lochend 10(1)	-	-	-	-	27.7	32.9	35.5	37.2	38.6	38.6	38.6	38.6
Lochend New Build	-	-	-	-	28.1	33.3	35.9	37.6	39.0	39.0	39.0	39.0
Phillips Mains (Nearest)	-	-	-	-	15.0	20.2	22.8	24.5	25.9	25.9	25.9	25.9
Slickly Croft	-	-	-	-	15.7	20.9	23.5	25.2	26.6	26.6	26.6	26.6
Slickly (Nearest)	-	-	-	-	19.4	24.6	27.2	28.9	30.3	30.3	30.3	30.3
Syster	-	-	-	-	29.6	34.8	37.4	39.1	40.5	40.5	40.5	40.5

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 built and operating Stroupster Windfarm alone.

Property	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Brabstermire House	-	-	-	-	20.4	25.6	28.1	29.9	31.2	31.2	31.2	31.2
Kevill	-	-	-	-	22.6	27.8	30.4	32.1	33.5	33.5	33.5	33.5
Lochend 10(1)	-	-	-	-	13.1	18.3	20.9	22.6	24.0	24.0	24.0	24.0
Lochend New Build	-	-	-	-	11.4	16.6	19.2	20.9	22.3	22.3	22.3	22.3
Phillips Mains (Nearest)	-	-	-	-	10.3	15.5	18.1	19.8	21.2	21.2	21.2	21.2
Slickly Croft	-	-	-	-	20.3	25.5	28.1	29.8	31.2	31.2	31.2	31.2
Slickly (Nearest)	-	-	-	-	17.7	22.9	25.4	27.2	28.5	28.5	28.5	28.5
Syster	-	-	-	-	11.5	16.7	19.3	21.0	22.4	22.4	22.4	22.4

Table 11 - 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 Slickly Windfarm alone. These are shown for both day-time and night-time periods at some locations due to differing noise constraints being applied.

Property	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Brabstermire House	-	-	-	20.5	24.9	28.7	30.1	30.1	30.1	30.1	30.1	30.1
Kevill	-	-	-	18.3	22.7	26.5	27.9	27.9	27.9	27.9	27.9	27.9
Lochend 10(1) (day)	-	-	-	15.1	19.5	20.9	20.3	24.1	24.7	24.7	24.7	24.7
Lochend 10(1) (night)	-	-	-	15.1	19.5	23.3	24.0	23.6	24.7	24.7	24.7	24.7
Lochend New Build (day)	-	-	-	12.4	16.8	18.2	17.6	21.4	22.0	22.0	22.0	22.0
Lochend New Build (night)	-	-	-	12.4	16.8	20.6	21.3	20.9	22.0	22.0	22.0	22.0
Phillips Mains (Nearest)	-	-	-	9.1	13.5	17.3	18.7	18.7	18.7	18.7	18.7	18.7
Slickly Croft (day)	-	-	-	28.3	32.7	34.1	33.5	37.3	37.9	37.9	37.9	37.9
Slickly Croft (night)	-	-	-	28.3	32.7	36.5	37.2	36.8	37.9	37.9	37.9	37.9
Slickly (Nearest) (day)	-	-	-	22.9	27.3	28.7	28.1	31.9	32.5	32.5	32.5	32.5
Slickly (Nearest) (night)	-	-	-	22.9	27.3	31.1	31.8	31.4	32.5	32.5	32.5	32.5
Syster (day)	-	-	-	12.3	16.7	18.1	17.5	21.3	21.9	21.9	21.9	21.9
Syster (night)	-	-	-	12.3	16.7	20.5	21.2	20.8	21.9	21.9	21.9	21.9
Noise constraints for Slickly Windfarm apply at 6 m/s, 7 m/s and 8 m/s day-time and at 7 m/s and 8 m/s night-time to enable noise immission levels to remain compliant with the Slickly Windfarm site-specific noise limits recommended by THC at Slickly Croft (see Annex C).												

Table 12 - Predicted $L_{A90,T}$ dB noise immission levels at each of the noise assessment locations as a function of standardised wind speed for the cumulative total (assuming all receptors are downwind of all windfarms and no directional propagation factors are included). These are shown for both day-time and night-time periods at some locations due to differing noise constraints being applied to Slickly Windfarm.

Property	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Brabstermire House	-	-	-	-	31.9	35.9	37.5	37.8	38.1	38.1	38.1	38.1
Kevill	-	-	-	-	29.0	33.3	35.1	35.8	36.5	36.5	36.5	36.5
Lochend 10(1) (day)	-	-	-	-	31.6	36.0	38.0	39.2	40.1	40.1	40.1	40.1
Lochend 10(1) (night)	-	-	-	-	31.6	36.1	38.1	39.1	40.1	40.1	40.1	40.1
Lochend New Build (day)	-	-	-	-	31.1	35.7	37.8	39.1	40.1	40.1	40.1	40.1
Lochend New Build (night)	-	-	-	-	31.1	35.8	37.9	39.1	40.1	40.1	40.1	40.1
Phillips Mains (Nearest)	-	-	-	-	27.9	31.9	33.5	33.7	34.0	34.0	34.0	34.0
Slickly Croft (day)	-	-	-	-	33.6	35.7	36.1	38.8	39.5	39.5	39.5	39.5
Slickly Croft (night)	-	-	-	-	33.6	37.5	38.5	38.5	39.5	39.5	39.5	39.5
Slickly (Nearest) (day)	-	-	-	-	31.6	34.9	36.2	37.4	37.9	37.9	37.9	37.9
Slickly (Nearest) (night)	-	-	-	-	31.6	35.6	37.0	37.2	37.9	37.9	37.9	37.9
Syster (day)	-	-	-	-	32.3	37.0	39.1	40.4	41.5	41.5	41.5	41.5
Syster (night)	-	-	-	-	32.3	37.0	39.2	40.4	41.5	41.5	41.5	41.5
Noise constraints for Slickly Windfarm apply at 6 m/s, 7 m/s and 8 m/s day-time and at 7 m/s and 8 m/s night-time to enable noise immission levels to remain compliant with the Slickly Windfarm site-specific noise limits recommended by THC at Slickly Croft (see Annex C).												

5.7 ETSU-R-97 Assessment

5.7.1 Table 13 to Table 15 show the difference between cumulative predicted noise immission levels and the cumulative ETSU-R-97 noise criteria applicable during day-time and night-time periods. Two tables (Table 13 and Table 14) are provided for the day-time, showing assessment for ETSU-R-97 criteria with the fixed part of the limit set at both 35 dB(A) and 38 dB(A). For the financially involved receptor location Syster, additional comparisons are provided between the limits which would apply were Lochend Windfarm cease to operate (based on 38 dB(A) fixed thresholds day and night) and cumulative predicted noise immission levels which do not include a contribution from Lochend Windfarm.

5.7.2 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.

5.7.3 Figures D1 to D16 (Annex D) show the calculated windfarm noise immission levels at the eight 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.

5.7.4 Firstly, the charts in Annex C show that predicted noise immission levels from the Development in isolation comply with the more stringent noise limits (Table 3 & 5) based on THC preferences at all but Brabstermire House, with a marginal excess of 0.7 dB(A) above the day-time limit. Furthermore at Syster, predicted noise immission levels from the Development in isolation alone do not rely on the financially involved status of this receptor.

Table 13 - Difference between the ETSU-R-97 derived day-time noise limits of Table 3 and the cumulative day-time predicted $L_{A90,T}$ windfarm noise immission levels (Table 12) at each noise assessment location. Values are based on the 35 dB(A) lower day-time limit and negative values indicate the noise immission level is below the limit. For Syster the comparison is with the financially involved limit (fixed 45 dB(A) threshold) as well as non-financially involved limits (comparison for proposed Development alone) based on 35 dB(A). Values in **bold** show excess above the criteria.

Property	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Brabstermire House	-	-	-	-	-3.1	**0.9**	**2.5**	**1.0**	-1.4	-4.4	-7.6	-10.8
Kevill	-	-	-	-	-6.0	-1.7	**0.1**	-1.0	-3.0	-6.0	-9.2	-12.4
Lochend 10(1)	-	-	-	-	-3.4	**1.0**	**2.0**	**0.7**	-1.1	-4.1	-7.2	-10.3
Lochend New Build	-	-	-	-	-3.9	**0.7**	**1.8**	**0.6**	-1.1	-4.1	-7.2	-10.3
Phillips Mains (Nearest)	-	-	-	-	-7.1	-3.1	-1.5	-3.1	-5.5	-8.5	-11.7	-14.9
Slickly Croft	-	-	-	-	-1.4	**0.7**	**1.1**	**0.4**	-4.0	-8.8	-12.1	-13.0
Slickly (Nearest)	-	-	-	-	-3.4	-0.1	**1.2**	**0.9**	-1.6	-4.8	-8.1	-11.3
Syster (FI)	-	-	-	-	-12.7	-8.0	-5.9	-4.6	-3.5	-3.5	-3.5	-3.5
Syster (non-FI)	-	-	-	-	*-6.3*	*-2.3*	*-1.9*	*-4.4*	*-7.1*	*-10.1*	*-13.2*	*-16.3*

Table 14 - Difference between the ETSU-R-97 derived day-time noise limits of Table 4 and the cumulative day-time predicted $L_{A90,T}$ windfarm noise immission levels (Table 12) at each noise assessment location. Values are based on the 38 dB(A) lower day-time limit and negative values indicate the noise immission level is below the limit. For Syster the comparison is with the financially involved limit (fixed 45 dB(A) threshold) as well as non-financially involved limits (comparison for proposed Development alone) based on 38 dB(A). Values in **bold** show excess above the criteria.

Property	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Brabstermire House	-	-	-	-	-6.1	-2.1	-0.5	-0.2	-1.4	-4.4	-7.6	-10.8
Kevill	-	-	-	-	-9.0	-4.7	-2.9	-2.2	-3.0	-6.0	-9.2	-12.4
Lochend 10(1)	-	-	-	-	-6.4	-2.0	0.0	**0.7**	-1.1	-4.1	-7.2	-10.3
Lochend New Build	-	-	-	-	-6.9	-2.3	-0.2	**0.6**	-1.1	-4.1	-7.2	-10.3
Phillips Mains (Nearest)	-	-	-	-	-10.1	-6.1	-4.5	-4.3	-5.5	-8.5	-11.7	-14.9
Slickly Croft	-	-	-	-	-4.4	-2.3	-1.9	**0.4**	-4.0	-8.8	-12.1	-13.0
Slickly (Nearest)	-	-	-	-	-6.4	-3.1	-1.8	-0.6	-1.6	-4.8	-8.1	-11.3
Syster (FI)	-	-	-	-	-12.7	-8.0	-5.9	-4.6	-3.5	-3.5	-3.5	-3.5
Syster (non-FI)	-	-	-	-	*-9.3*	*-5.3*	*-3.9*	*-4.4*	*-7.1*	*-10.1*	*-13.2*	*-16.3*

Table 15 - Difference between the ETSU-R-97 derived night-time noise limits of Table 5 and the cumulative night-time predicted $L_{A90,T}$ windfarm noise immission levels (Table 12) at each noise assessment location. Values are based on the fixed part of the night-time limit being 38 dB(A). Negative values indicate the noise immission level is below the limit. For Syster the comparison is with the financially involved limit (fixed 45 dB(A) threshold) as well as non-financially involved limits (comparison for proposed Development alone) based on 38 dB(A). Values in **bold** show excess above the criteria.

Property	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Brabstermire House	-	-	-	-	-6.1	-2.1	-0.5	-0.2	**0.1**	-3.3	-7.0	-10.9
Kevill	-	-	-	-	-9.0	-4.7	-2.9	-2.2	-1.5	-4.9	-8.6	-12.5
Lochend 10(1)	-	-	-	-	-6.4	-1.9	**0.1**	**0.6**	-1.1	-4.1	-7.2	-10.3
Lochend New Build	-	-	-	-	-6.9	-2.2	-0.1	**0.6**	-1.1	-4.1	-7.2	-10.3
Phillips Mains (Nearest)	-	-	-	-	-10.1	-6.1	-4.5	-4.3	-4.0	-7.4	-11.1	-15.0
Slickly Croft	-	-	-	-	-4.4	-0.5	**0.5**	**0.5**	-1.3	-6.2	-11.0	-15.2
Slickly (Nearest)	-	-	-	-	-6.4	-2.4	-1.0	-0.8	-1.0	-4.4	-7.5	-10.1
Syster (FI)	-	-	-	-	-12.7	-8.0	-5.8	-4.6	-3.5	-3.5	-3.5	-3.5
Syster (non-FI)	-	-	-	-	*-9.3*	*-5.3*	*-3.9*	*-4.4*	*-7.1*	*-10.1*	*-13.2*	*-16.3*

5.7.5 Regarding cumulative levels, the comparisons provided by Table 13 demonstrates that cumulative predicted noise immission levels are clearly above the ETSU-R-97 criteria, based on a choice of a

35 dB(A) lower limit for the day-time, the lowest within the allowed range from 35 dB(A) to 40 dB(A). Comparison with an alternate choice within this allowed range of 38 dB(A) day-time (Table 14) shows that at most locations compliance with the limits can be achieved. There remain some small excesses which could be reduced by applying some constraints to the proposed Development. If the choice had been 40 dB(A) within the range allowed for the day-time, there would be no excess predicted and no requirement to constrain the proposed Development. The suitability of these choices is discussed below.

5.7.6 The comparison for the night-time provides similar outcomes to the day-time, when a choice of 38 dB(A) is made for the fixed threshold, except at Slickly Croft where the consequence of less constraints applied to Slickly Windfarm results in higher overall cumulative predicted noise immission levels, and marginal excess above the night-time criteria of 38 dB(A). Similarly, there would be no excess predicted if the night-time criteria were based on the fixed threshold being set at 43 dB(A), as specified in ETSU-R-97.

5.7.7 The above comparisons were completed by assuming all receptors were simultaneously downwind of all turbines. Additional prediction modelling has been completed which incorporate directional attenuation (discussed above in section 5.5). Annex E provides a series of charts which show for selected receptor locations, wind speeds and time periods, what predicted noise immission levels would be expected should directional propagation effects be accounted for, in accordance with IOA GPG. As discussed above, these directional effects are reasonably precautionary and provide pessimistic estimates of likely directional attenuation effects.

5.7.8 In a similar manner to the non-directional predicted noise immission levels discussed above, constraints which are required to be applied to Slickly Windfarm have been incorporated into the directional modelling (see end of Annex C). Directional constraints are indicated on the charts in Annex E where applicable by dotted lines, indicating the level of noise predicted from Slickly windfarm, if these constraints had not been applied. Cumulative totals on these directional charts are calculated assuming these directional constraints are applied to Slickly Windfarm.

5.7.9 These directional charts are provided for those wind speeds (7 m/s & 8 m/s) and for those receptors where predicted noise immission levels may be above the 38 dB(A) based day-time criteria, or the 38 dB(A) night-time criteria (as indicated in Tables 14 or 15), or for a receptor which lays between the proposed Development and other windfarms. These are included to assist with the choice of the fixed part of the ETSU-R-97 day-time criteria, which includes consideration of the duration of exposure as requested through consultation with THC.

5.7.10 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). Charts for the day-time shown in Annex D provide ETSU-R-97 assessment criteria, showing the fixed part of the limit set at both 35 dB(A) and 38 dB(A). As discussed above, setting this threshold to 35 dB(A) is a preference of THC, within the 35 dB(A) to 40 dB(A) range allowed in accordance with ETSU-R-97. The factors given in ETSU-R-97 to be used to determine where in this range have been discussed above and are discussed further below. It is important to recognise that these factors are not separate or individual criteria and will to some extent need to be considered jointly.

Number of dwellings in the neighbourhood of the wind farm

- the area of the proposed Development and its surroundings is generally of low population density, with a limited number of surrounding properties near to wind energy developments in the area. Where more receptors are present, these tend to be either further from the proposed Development or exposed to lower levels of wind turbine noise.

Duration and level of exposure

- For the majority of receptors to the north and east of the proposed Development, which would be downwind most often under typical prevailing wind conditions, their exposure to noise from the proposed Development would be low. For these receptors, cumulative noise levels meet the lowest of the ETSU-R-97 day-time criteria based on 35 dB(A).
- For receptors near to the Lochend Windfarm, these are potentially exposed to higher noise levels such that an alternate choice of fixed threshold has to be considered. However the proposed Development does not significantly increase the duration of exposure, as these receptors would be downwind of both Lochend Windfarm and the proposed Development. Predicted cumulative noise immission levels remain dominated by the contribution from Lochend Windfarm, which is very close to the 35 dB(A) based day-time criteria on its own, therefore significantly constraining additional energy generation which can be provided by the proposed Development. Lochend Windfarm predictions include an 'appropriate margin' of 2 dB(A), without this margin overall cumulative noise immission levels would reduce any excess above a criteria based on 35 dB(A), estimated to be a maximum of ~1 dB(A) day-time only. Directional charts indicate cumulative levels are at their highest for these receptors in north to easterly winds, which are less frequent in the UK.
- For receptors between the proposed Development and Slickly Windfarm, directional effects are such that it is unlikely these locations would be downwind from both sites at the same time and non-directional predicted cumulative noise immission levels are therefore less representative. Whilst the duration of exposure increases, the level of that exposure remains lower than non-directional predictions much of the time. Where there could be a downwind component of propagation from both scheme, these would be for only a very narrow range of wind directions of approximately north east, less common in the UK. For the Slickly Croft receptor, the addition of the proposed Development in the directional charts (Figure E 15 and E16) causes a very small effect on cumulative totals, being related mainly to noise from Slickly Windfarm and Stroupster Windfarm and show the proposed Development has only a marginal effect on cumulative levels, over a small range of directions.
- For Brabstermire House, it is unlikely to be downwind of Slickly and Stroupster windfarms and the propose Development at the same time, therefore with directional effects it is likely these cumulative levels would be present for a much reduced proportion of the time during south west winds (see Figures E3 and E4 of Annex E).

Effect of noise limits on the number of kWh generated

- 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 the range 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 83 turbines[3] would have been required to achieve a similar generating capacity to that of the proposed Development, thus highlighting the significance of the scheme.
- With a day-time criteria based on 35 dB(A) and non-directional predictions, the reduction required for noise immissions from the proposed Development can be estimated. Table 13 above indicates reductions in cumulative levels of around 2 dB(A) required at Lochend 10(1) and Lochend New Build and approximately 2.5 dB(A) at Brabstermire House. These cumulative reductions translate to reductions from the proposed Development alone to approximately 8~9 dB(A) at Lochend locations and approximately 4 dB(A) at Brabstermire House. To achieve this would require of the order of

3 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 5.0 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.

three turbines to be stopped in westerly winds[4] and six turbines to be stopped in easterly winds[5]. Essentially the proposed Development would pragmatically consist of approximately five turbines rather than ten turbines. Albeit some constraints will be required to meet even a 38 dB(A) choice for the day-time criteria, however the constraints will not be as significant as those required to meet a 35 dB(A) criteria.

5.7.11 Overall, maintaining the day-time limit based upon a the fixed threshold set at 35 dB(A) cumulatively has a disproportionate effect on potential energy generation for the proposed Development, with only marginal increases in duration and level of exposure for those receptors which are exposed to noise from existing/consented schemes. It is considered that a choice of 38 dB(A) for the fixed part of the day-time criteria represents a reasonable increase compared with a choice of 35 dB(A). It is also considered that the choice of THC for fixed part of the night-time limit could be met cumulatively, even though this is not a requirement of ETSU-R-97, which is the assessment method Scottish Planning Guidance commends 'should be used'.

5.7.12 Predicted noise levels at the Mey Data Centre do not exceed 45 dB L_{Aeq}. Internal noise levels within the data centre and office buildings will be lower still as the building façade will provide further sound reduction. Given the low sensitivity to noise of this non-residential receptor, this is considered to represent a negligible effect.

5.8 Mitigation – Proposed Development

5.8.1 Table 14 and Table 15 shows that with a choice for the day-time criteria of 38 dB(A) and the night-time criteria of 38 dB(A) that constraints will be required to enable overall cumulative noise levels to remain within these criteria. A series of partial (or site-specific) noise limits have been calculated and which would apply to the proposed Development operating alone. These have been calculated to reduce values of excess calculated above the total cumulative noise criteria/limits[6]. These partial limits are shown in Tables 16 and table 17 for day-time and night-time periods respectively. An excess of 0.4 dB(A) or smaller is not generally considered acoustically important[7]: for the purposes of calculating these partial limits, the small excess of 0.1 dB(A) at Brabstermire House has been ignored and the partial night-time limit set to be equal to predicted noise levels from the proposed Development at 9 m/s. Where these partial limits would be more than 10 dB(A) below the full cumulative noise limits they were set equal to 10 dB(A) below the full noise limits (applicable at Slickly Croft only), consistent with the advice in the IOA GPG.

5.8.2 For the financially involved receptor Syster, noise limits applicable to the development alone need to account for the potential for Lochend Windfarm coming to the end of its life and being removed, they cannot therefore be calculated in the same way as other locations. Partial noise limits for Syster have been set at a fixed value of 35 dB(A) for both day-time and night-time periods. Such a limit allows the proposed Development to operate without constraint, remains compliant with the overall financially

4 To reduce total cumulative noise levels (assuming NO constraints apply to Slickly Windfarm when Brabstermire House is downwind of the Proposed Development) by ~2.5 dB(A) at 7 m/s requires stopping turbines HM08, HM09 & HM10, resulting in a reduction for the Proposed Development alone of ~4.2 dB(A).

5 To reduce total cumulative noise levels (assuming constraints DO apply to Slickly Windfarm when Lochend 10(1) and Lochend New Build are downwind of the Proposed Development) by ~2.0 dB(A) at 7 m/s requires stopping turbines HM01 to HM06, resulting in a reduction for the Proposed Development alone of ~8.7 dB(A), with an excess of 0.4 dB(A) remaining. Even with all turbines on the Proposed Development stopped, there remains a 0.1 dB(A) excess above the day-time limit at Lochend New Build using a criteria based on 35 dB(A).

6 Total cumulative noise immission levels, which do not include the proposed Development, are logarithmically subtracted from total cumulative noise limits / criteria. This calculation will yield a partial limit which if complied with maintains no excess above a day-time criteria of 38 dB(A).

7 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.

involved noise limits when operating with other windfarms and would meet the non-financially involved noise limit that would apply should Lochend Windfarm cease to be present.

5.8.3 For the receptor locations Kevil, Philips Mains (nearest) and Slickly (Nearest), partial limits during the day-time have been set at those calculated from the above procedure, or based on THC preferred noise limits (based on 35 dB(A) day-time), whichever is lower.

Table 16 – Site-specific partial noise limits ($L_{A90,T}$ dB) which could be applied to the proposed Development at each of the noise assessment locations as a function of standardised wind speed for day-time periods.

Property	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Brabstermire House	37.1	37.1	37.1	37.1	37.1	37.1	36.5	36.1	37.9	41.8	45.4	48.7
Kevill	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.9	37.7	41.7	45.3	48.7
Lochend 10(1)	35.0	35.0	35.0	35.0	35.0	35.0	34.2	31.6	37.4	42.7	46.6	50.1
Lochend New Build	35.0	35.0	35.0	35.0	35.0	35.0	33.5	30.0	36.8	42.5	46.6	50.1
Phillips Mains (Nearest)	35.0	35.0	35.0	35.0	35.0	35.0	35.0	36.8	39.2	42.4	45.6	48.9
Slickly Croft	35.0	35.0	35.0	35.0	35.0	35.0	35.0	28.4	41.6	47.8	51.4	52.3
Slickly (Nearest)	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.4	37.3	41.8	45.6	49.0
Syster (non-FI)	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0

Table 17 - Site-specific partial noise limits ($L_{A90,T}$ dB) which could be applied to the proposed Development at each of the noise assessment locations as a function of standardised wind speed for night-time periods.

Property	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Brabstermire House	37.1	37.1	37.1	37.1	37.1	37.1	36.5	36.1	35.7	40.4	44.7	48.8
Kevill	37.7	37.7	37.7	37.7	37.7	37.2	36.5	35.9	35.1	40.3	44.7	48.8
Lochend 10(1)	37.5	37.5	37.5	37.5	37.5	36.1	33.9	31.7	37.4	42.7	46.6	50.1
Lochend New Build	37.5	37.5	37.5	37.5	37.5	36.0	33.4	30.1	36.8	42.5	46.6	50.1
Phillips Mains (Nearest)	38.0	38.0	38.0	38.0	38.0	37.9	37.8	37.7	37.6	41.2	45.0	49.0
Slickly Croft	36.4	36.4	36.4	36.4	36.4	31.5	28.0	28.0	36.2	44.7	50.2	54.6
Slickly (Nearest)	37.5	37.5	37.5	37.5	37.5	36.6	35.9	35.6	36.2	41.3	44.9	47.7
Syster (non-FI)	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0

5.8.4 For all locations except Lochend 10(1), Lochend New Build and Slickly Croft, predicted noise immission levels without constraints are within these partial limits (consistent with the pattern of observed excess values shown in Tables 14 and 15 for cumulative levels). Constraints can be applied to the proposed Development to provide predicted noise immission levels for the proposed Development alone which are complaint with the site-specific partial limits shown in Tables 16 and 17 for the remaining three receptor locations, which are:-

- Lochend 10(1), a reduction of approximately 0.8 dB(A) at 7 m/s during the night for wind headings of approximately ~340° through north to ~100° and ~3.1 dB(A) at 8 m/s, both day and night for wind headings of approximately ~340° through north to ~100°.
- Lochend New Build, a reduction of approximately ~3.7 dB(A) at 8 m/s both day and night for wind headings of approximately ~20° to ~150°.
- Slickly Croft a ~2.3 dB(A) reduction at 8 m/s day and at 7 m/s & 8 m/s during the night for wind headings of approximately ~20° to ~60°.

5.8.5 These constraint requirements overlap and can be combined, however the exact pattern of constraints would be determined during turbine procurement based on the chosen turbine model, the available noise control modes and associated sound power levels. As an example for the purposes of this assessment, reductions shown above could be achieved by:-

- 7 m/s: running turbine HM04 in noise mode NR1-5.0MW to reduce levels at Lochend 10(1) and once wind directions move towards north run turbines HM03 and HM06 in noise mode NR8-5.0MW to meet the limits at Slickly Croft.
- 8 m/s: for northerly winds run turbines HM03 and HM06 in noise mode NR8-5.0MW to meet the limits at Slickly Croft. As winds move towards the north east run turbines HM03 and HM04 in noise mode NR8-5.0MW to meet the limits at Lochend 10(1). Once winds are from the east the largest reductions are required by running turbines HM01, HM03 and HM04 in noise mode NR8-5.0MW and turbine HM02 in noise mode NR1-5.0MW to meet the limits at Lochend New Build.

5.8.6 Revised predicted noise immission levels are provided in Table 18 for these three receptors, which incorporate constraints at the relevant wind speeds.

5.8.7 Tables 19 and 20 provide a comparison of the predicted noise immission levels for the proposed Development operating alone (Table 8 or Table 18) with the site-specific partial limits shown in Table 16 and Table 17, which demonstrates that these site-specific partial noise limits can be achieved using the candidate turbine and the example operational constraints presented above. The criteria of Table 16 and Table 17 would represent suitable partial noise limits which could be applied to control noise immission levels from the proposed Development in isolation for the relevant assessment locations, whilst maintaining compliance with the overall cumulative ETSU-R-97 criteria.

5.8.8 Figures F1 to F6 in Annex F provide a series of charts demonstrating how compliance with the overall cumulative noise limits is achieved with constraints applied to the proposed Development at these three key receptor locations. These charts assume the fixed part of the cumulative day-time and night-time limits are set at 38 dB(A). As noted above, if cumulative limits had been based on the upper end of the range of the day-time limit allowed in ETSU-R-97 of 40 dB(A) and the fixed part of the night-time limit based on 43 dB(A), as specified in ETSU-R-97, then partial limits for the proposed Development would be higher and result in no constraints being required.

5.8.9 It should be noted that the choice of the cumulative noise limits / criteria above were a compromise between the aspirations of THC and those provided in ETSU-R-97 (see paragraph 4.3.5). Had the cumulative noise limits / criteria been based instead solely on the recommendations contained within ETSU-R-97, it may be appropriate to set the choice for the fixed element of the cumulative day-time and night-time limits at 40 dB(A) and 43 dB(A) respectively. With noise limits derived on this basis, the derived site specific noise limits (which would apply to the proposed Development alone) would not require any constraints to be applied to the proposed Development.

Table 18 – Predicted $L_{A90,T}$ dB noise immission levels at key noise assessment locations as a function of standardised wind speed for the proposed Development alone which include constraints. Constraints are applied for specific wind speeds highlighted in **bold**, otherwise are the same as unconstrained operation shown in Table 8.

Property	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Lochend 10(1) day	-	-	-	25.2	28.8	32.8	34.2	**31.1**	34.2	34.2	34.2	34.2
Lochend 10(1) night				25.2	28.8	32.8	**33.4**	**31.1**	34.2	34.2	34.2	34.2
Lochend New Build day & night	-	-	-	24.0	27.6	31.6	33.0	**29.3**	33.0	33.0	33.0	33.0
Slickly Croft (day)	-	-	-	21.0	24.6	28.6	30.0	**27.8**	30.0	30.0	30.0	30.0
Slickly Croft (night)	-	-	-	21.0	24.6	28.6	**27.8**	**27.8**	30.0	30.0	30.0	30.0
Values shown bold indicate predicted noise immission levels which are reduced by having constraints imposed. These are simplistic reductions based on operating selected turbines in particular reduced noise modes and showing the constrained prediction at just the wind speeds required to reduce predicted noise immission levels.												

Table 19 - Difference between the site-specific day-time limit and predicted noise immission levels for the proposed Development alone and which incorporate constraints where relevant. Negative values indicate the noise immission level is below the limit. Values in **bold** show excess above the criteria (none identified).

Property	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Brabstermire House	-	-	-	-10.3	-6.7	-2.7	-0.7	-0.3	-2.2	-6.0	-9.6	-13.0
Kevill	-	-	-	-12.4	-8.8	-4.8	-3.4	-4.4	-6.1	-10.1	-13.8	-17.2
Lochend 10(1)	-	-	-	-9.9	-6.3	-2.3	0.0	-0.5	-3.2	-8.5	-12.5	-15.9
Lochend New Build	-	-	-	-11.0	-7.4	-3.4	-0.5	-0.8	-3.8	-9.5	-13.6	-17.1
Phillips Mains (Nearest)	-	-	-	-11.2	-7.6	-3.6	-2.2	-4.0	-6.4	-9.6	-12.9	-16.1
Slickly Croft	-	-	-	-14.0	-10.4	-6.4	-5.0	-0.6	-11.6	-17.7	-21.3	-22.3
Slickly (Nearest)	-	-	-	-9.8	-6.2	-2.2	-0.8	-1.2	-3.1	-7.6	-11.4	-14.9
Syster (non-FI)	-	-	-	-9.9	-6.3	-2.3	-0.9	-0.9	-0.9	-0.9	-0.9	-0.9

Table 20 - Difference between the site-specific night-time limit and predicted noise immission levels for the proposed Development alone and which incorporate constraints where relevant. Negative values indicate the noise immission level is below the limit. Values in **bold** show excess above the criteria (none identified).

Property	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Brabstermire House	-	-	-	-10.3	-6.7	-2.7	-0.7	-0.3	0.0	-4.7	-9.0	-13.1
Kevill	-	-	-	-15.2	-11.6	-7.0	-5.0	-4.4	-3.6	-8.8	-13.1	-17.3
Lochend 10(1)	-	-	-	-12.3	-8.7	-3.4	-0.5	-0.6	-3.2	-8.5	-12.5	-15.9
Lochend New Build	-	-	-	-13.5	-9.9	-4.4	-0.4	-0.8	-3.8	-9.5	-13.6	-17.1
Phillips Mains (Nearest)	-	-	-	-14.2	-10.6	-6.5	-5.0	-4.9	-4.8	-8.4	-12.2	-16.2
Slickly Croft	-	-	-	-15.3	-11.7	-2.9	-0.2	-0.2	-6.2	-14.6	-20.2	-24.6
Slickly (Nearest)	-	-	-	-12.3	-8.7	-3.8	-1.8	-1.4	-2.1	-7.1	-10.8	-13.6
Syster (non-FI)	-	-	-	-9.9	-6.3	-2.3	-0.9	-0.9	-0.9	-0.9	-0.9	-0.9

5.9 Substation, Energy Storage & Solar 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 and solar installation would arise from ventilation/air conditioning systems, modular inverters and lower-voltage transformers and higher-voltage transformers associated with grid connection (where this not to be shared with the main substation).

5.9.2 The proposed substation is located approximately 560 m from the nearest residential property (West Lodge near the site entrance at approximately 328899, 972263). Depending on the transformer hardware used for the substation, the noise levels from the substation at the property could be close to 30 dB L_{Aeq}. The energy storage facility is proposed in close proximity of the substation. Limited details are available at this stage, but based on experience of similar installations, it is considered likely that this would generate noise levels of less than 30 dB L_{Aeq} at the nearest receptor. The solar installation is at greater distance of approximately ~900 m and considered likely to generate noise levels much less than 30 dB L_{Aeq} at the nearest receptor.

5.9.3 If noise levels from the proposed substation, energy storage facility and solar installation were limited to a 'rated noise level' of 30 dB L_{Aeq} at the nearest receptor location, this would be marginally above typical existing background L_{A90} noise levels in the general area (based on the 'Generic' baseline assumed) during quiet periods at low wind speeds. Despite this rated level being higher than background levels in quiet conditions, this is considered to represent a very low level in absolute terms, which BS 4142 advises is a relevant consideration particularly when background levels are low. This would therefore represent a minor effect which is not significant.

5.9.4 It is therefore proposed that combined noise levels from electrical plant at this facility should be limited to a rated noise level of no more than 30 dB L_{Aeq} at the nearest residential property. This can be achieved through selection of suitable plant, and/or may require the use of specific noise mitigation measures, such as solid screening, depending on the equipment and systems chosen.

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 21 – 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, solar installation 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 13:00 Saturdays. 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.
- 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 16:00. 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.

6.2.2 The substation and battery storage should be designed such that the total noise level produced at the nearest property does not exceed 30 dB L_{Aeq}. This may require implementing specific mitigation measures, such as solid screening, depending on the transformer plant used.

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 1.3 km. 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 Siemens SG5.0-132 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 Hollandmey Renewable Energy Development, EIA Topic Information Sheet, 05 Noise, July 2020, ScottishPower Renewables.

xix Onshore Wind Energy Supplementary Guidance, November 2016 (with addendum, December 2017. The Highland Council

xx E-mail from Robin Fraser Environmental Health Officer, Highland Council to Robert Beck, RSK Senior Environmental Consultant, EIA, Planning & Design, RSK on 25/08/2020 15:33.

xxi 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.

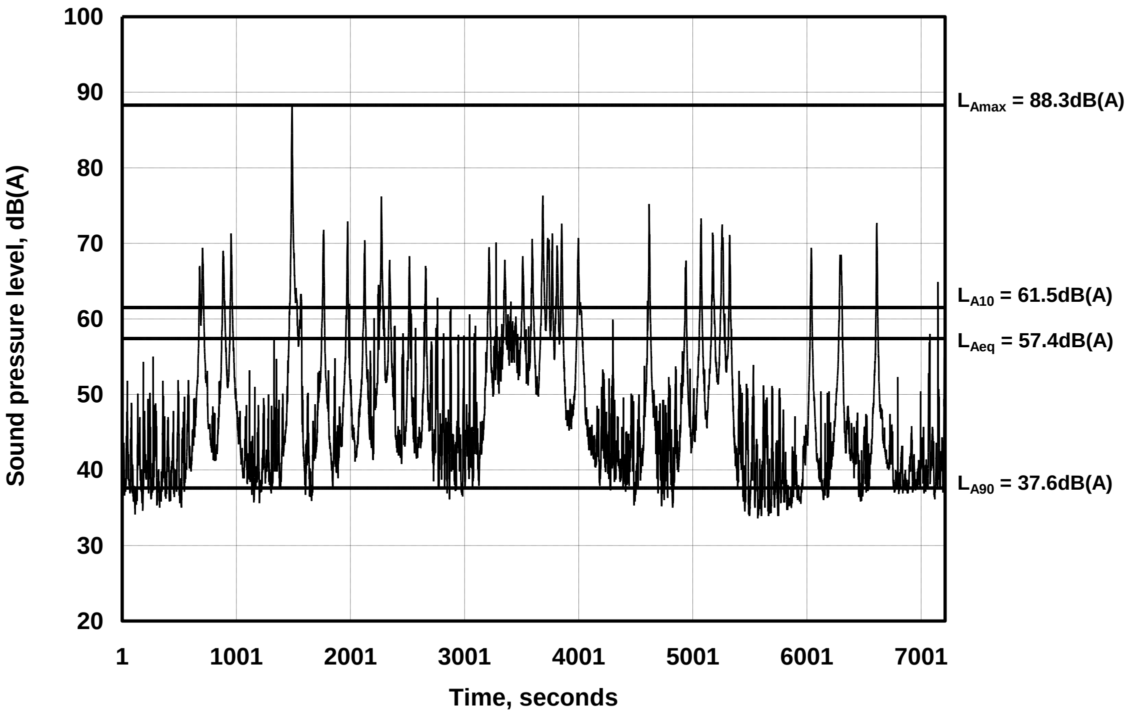
A.5 Before reviewing the potential effects of environmental sound on people, it is useful first to consider the means by which physical sound can be quantified.

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 a pressure amplitude range of approximately 1,000,000:1. 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.

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[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

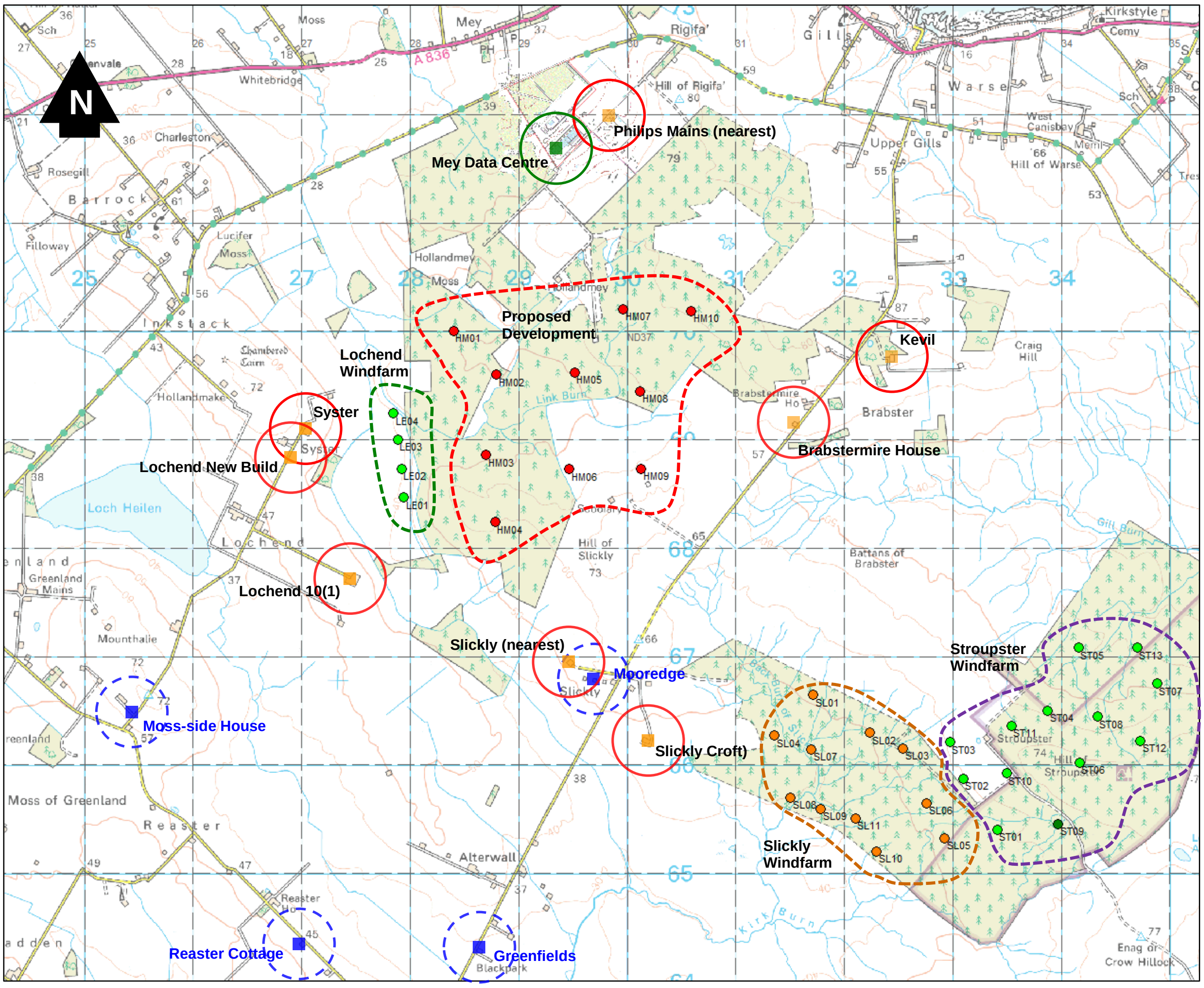
Terminology	Description
A-weighting	a filter that down-weights low frequency and high frequency sound to better represent the frequency response of the human ear when assessing the likely effects of noise on humans
acoustic character	one or more distinctive features of a sound (e.g. tones, whines, whistles, 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 'HM') and the other windfarms which have been considered in this assessment: Lochend Windfarm (green circles, prefixed 'LE'), Slickly Windfarm (orange circles, prefixed 'SL') and Stroupster Windfarm (green circles, prefixed 'ST'). Also shown are the nearby noise assessment locations (orange square within red circles). Four baseline background noise survey locations for the Lyth Windfarm are shown with a blue square within dashed blue outlines. Also indicated is the approximate position of the Mey Data Centre (green square within a green circle).



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Turbine & Propagation Details: the Proposed Development

Table B1 – Turbine coordinates – the proposed Development

Turbine	Easting	Northing	Turbine	Easting	Northing
HM01	328397	970004	HM06	329467	968729
HM02	328796	969598	HM07	329963	970204
HM03	328700	968860	HM08	330120	969444
HM04	328781	968240	HM09	330129	968731
HM05	329515	969620	HM10	330588	970185
All turbines modelled using the hub height of 84 m and operating in Mode AM0-5.0MW, unless otherwise noted (see main text).					

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	Noise Sensitive Receptor							
	Phillips Mains (Nearest)	Lochend New Build	Syster	Lochend 10(1)	Slickly (Nearest)	Kevill	Brabstermire House	Slickly Croft
HM01	0	0	0	0	0	0	0	0
HM02	0	0	0	0	0	0	0	0
HM03	0	0	0	0	0	0	0	0
HM04	0	0	0	0	0	0	0	0
HM05	0	0	0	0	0	0	0	0
HM06	0	0	0	0	0	0	0	0
HM07	0	0	0	0	0	0	0	0
HM08	0	0	0	0	0	0	0	0
HM09	0	0	0	0	0	0	0	0
HM10	0	0	0	0	0	0	0	0

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

Turbine make / model	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Siemens SG5.0-132 Mode AM0-5.0MW	-	-	-	99.2	102.8	106.8	108.2	108.2	108.2	108.2	108.2	108.2
Siemens SG5.0-132 Mode NR1-5.0MW	-	-	-	99.2	102.8	105.4	105.4	105.4	105.4	105.4	105.4	105.4
Siemens SG5.0-132 Mode NR8-5.0MW	-	-	-	97.8	97.8	97.8	97.8	97.8	97.8	97.8	97.8	97.8
Derived from: Siemens Gamesa General Characteristics Manual GD417868-en Rev 0, 07/08/19, with 'DinoTails' attached to the blades. Values shown here include 2 dB added to the values in the reference document to account for uncertainty, as advised by Siemens Gamesa in the document. Values here are converted from those specified at hub height by using standardised ten metre wind speeds for a 84 m hub height.												

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
Siemens SG5.0-132 Mode AM0-5.0MW	82.3	89.0	92.4	93.0	94.3	93.2	87.1	76.9	100.0
Derived from: Siemens Gamesa General Characteristics Manual GD417868-en Rev 0 07/08/19, with ‘DinoTails’ attached to the blades. Values are converted to octave bands and normalised to 100 dB from one-third octave band values provided in the document. These were for a hub height wind speed of 11 m/s, closest to 8 m/s for a standardised 10 m height wind speed for a 84 m hub height.									

Turbine & Propagation Details: Stroupster

Table B5 – Turbine coordinates – Stroupster Windfarm

Turbine	Easting	Northing	Turbine	Easting	Northing
ST01	333407	965407	ST08	334332	966445
ST02	333094	965875	ST09	333971	965457
ST03	332972	966211	ST10	333496	965923
ST04	333874	966504	ST11	333540	966365
ST05	334158	967082	ST12	334728	966224
ST06	334167	966020	ST13	334697	967082
ST07	334881	966749			
All turbines modelled using a hub height of 75 m					

Table B6 - Propagation attenuation effects due to terrain (dB) – Stroupster Windfarm. 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	Noise Sensitive Receptor							
	Phillips Mains (Nearest)	Lochend New Build	Syster	Lochend 10(1)	Slickly (Nearest)	Kevill	Brabstermire House	Slickly Croft
ST01	2	0	0	0	0	0	0	0
ST02	2	0	0	0	0	-3	0	0
ST03	2	0	0	0	0	-3	0	0
ST04	2	0	0	0	0	-3	0	0
ST05	2	0	0	0	2	-3	0	0
ST06	2	0	0	0	0	-3	-3	0
ST07	2	0	0	0	2	-3	0	0
ST08	2	0	0	0	0	-3	0	0
ST09	2	0	0	0	0	-3	0	0
ST10	2	0	0	0	0	-3	0	0
ST11	2	0	0	0	0	-3	0	0
ST12	2	0	0	0	0	-3	-3	0
ST13	2	0	0	0	2	-3	0	0

Turbine & Propagation Details: Slickly Windfarm

Table B7 – Turbine coordinates – Slickly Windfarm

Turbine	Easting	Northing	Turbine	Easting	Northing
SL01	331715	966646	SL07	331697	966143
SL02	332238	966297	SL08	331502	965700
SL03	332542	966151	SL09	331781	965598
SL04	331354	966272	SL10	332298	965206
SL05	332926	965325	SL11	332100	965510
SL06	332758	965648			
All turbines modelled using a hub height of 89.5 m except SL05 & SL10 which are 72 m.					

Table B8-Propagation attenuation effects due to terrain (dB) – Slickly Windfarm. 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	Noise Sensitive Receptor							
	Phillips Mains (Nearest)	Lochend New Build	Syster	Lochend 10(1)	Slickly (Nearest)	Kevill	Brabstermire House	Slickly Croft
SL01	2	0	0	0	0	0	0	0
SL02	2	0	0	0	0	0	0	0
SL03	2	0	0	0	0	0	0	0
SL04	2	0	0	0	0	0	0	0
SL05	2	0	0	0	0	0	0	0
SL06	2	0	0	0	0	0	0	0
SL07	2	0	0	0	0	0	0	0
SL08	2	0	0	0	0	0	0	0
SL09	2	0	0	0	0	0	0	0
SL10	2	0	0	0	0	0	0	0
SL11	2	0	0	0	0	0	0	0

Turbine & Propagation Details: Lochend Windfarm

Table B9 – Turbine coordinates – Lochend Windfarm

Turbine	Easting	Northing
LE01	327939	968468
LE02	327918	968734
LE03	327884	969002
LE04	327845	969242
All turbines modelled using a hub height of 64 m		

Table B10-Propagation attenuation effects due to terrain (dB) – Lochend Windfarm. 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	Noise Sensitive Receptor							
	Phillips Mains (Nearest)	Lochend New Build	Syster	Lochend 10(1)	Slickly (Nearest)	Kevill	Brabstermire House	Slickly Croft
LE02	0	0	0	0	0	0	0	0
LE03	0	0	0	0	0	0	0	0
LE04	0	0	0	0	0	0	0	0

Annex C – Baseline Information, Derived Noise Limits/Criteria & Cumulative Windfarm Information

Slickly Wind Farm

C.1 The December 2019 EIA Report[8] for Slickly Windfarm assessed noise levels at nearby noise sensitive receptor locations using noise limits derived in accordance with ETSU-R-97 from background noise levels measured at a single location at Slickly Croft (330192, 966236). These baseline background noise levels, and consequently the ETSU-R-97 derived noise limits, were related to standardised ten metre wind speeds on Slickly Wind Farm for a hub height of 83.5 m. These 83.5 m wind speeds were derived from those measured on Slickly Wind Farm using LIDAR wind sensor data at 81 and 91 metres. This method of measuring wind speeds accords with best practice guidance (IOA GPG). Measured background noise levels at Slickly Croft are shown in Table C1.

Table C1 – Baseline background noise levels and measured at Slickly Croft for the Slickly Wind Farm noise assessment, related to standardised ten metre wind speeds derived from those at a height of 83.5 m.

Location	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Slickly Croft (day)	19.8	19.8	19.8	20.2	21.7	24.5	28.5	33.4	38.5	43.3	46.6	47.5
Slickly Croft (night)	17.6	17.6	17.6	18.4	20.2	23.0	26.7	31.0	35.8	40.7	45.5	49.7

C.2 ETSU-R-97 noise limits were derived in the Slickly Windfarm noise assessment for considering cumulative noise levels when operating Slickly Windfarm with the existing and operating Stroupster Windfarm and the existing and operating Lochend Windfarm. Derivation of these noise limits followed the preferred approach of The Highland Council (THC), being based on fixed part of the noise limits set at 35 dB(A) day-time and 38 dB(A) night-time. The derived cumulative noise limits are shown in Table C2.

Table C2 – ETSU-R-97 assessment criteria (noise limits) derived from background noise levels measured at Slickly Croft and applied to all noise sensitive receptor locations to assess cumulative levels of wind turbine noise in the Slickly Windfarm EIA Report.

Location	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Slickly Croft (day)	35.0	35.0	35.0	35.0	35.0	35.0	35.0	38.4	43.5	48.3	51.6	52.5
Slickly Croft (night)	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	40.8	45.7	50.5	54.7

C.3 Site-specific noise limits were derived in the Slickly Windfarm EIA Report by a process of logarithmic subtraction: subtracting levels of noise predicted to arise (including appropriate margins) from operation of both Stroupster Windfarm and Lochend Windfarm from the cumulative criteria shown in Table C2. This process is discussed in the IOA GPG and referred to as 'apportioned noise limits'. These site specific criteria are shown in Table C3 for the Slickly Croft receptor location only.

Table C3 – Site specific assessment criteria (noise limits) derived from the ETSU-R-97 noise limits and used to assess noise from Slickly Windfarm alone, as set out in Table 11.6 of the Slickly Windfarm EIA Report.

Location	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Slickly Croft (day)	-	-	-	34.8	34.8	34.3	33.7	37.5	43.2	48.2	51.5	52.5
Slickly Croft (night)	-	-	-	37.9	37.9	37.7	37.4	37.0	40.1	45.5	50.5	54.7

8 Slickly Windfarm Environmental Impact Assessment Report, Volume 1 – Text, Arcus Consultancy Services / Statkraft, December 2009.

C.4 It is only necessary to consider here the site-specific noise criteria at Slickly Croft, as this location is between the Proposed Development and Slickly Windfarm and is the location nearest to Slickly Windfarm and most likely to control noise immission levels from Slickly Windfarm.

C.5 Comments from THC for the Slickly Windfarm application were provided by an officer from Environmental Health[9] ('the EHO') who recommended that alternate limits be applied, should consent be granted for Slickly Windfarm. These were based upon the limits shown above in Table C3 or 2 dB(A) above predicted levels for Slickly Windfarm alone (shown in the Slickly EIA), whichever is the lower. A revised assessment has been submitted for Slickly Windfarm (Slickly SEI[10]), with turbine positions, hub heights and sound power levels amended. The SEI assessment remains based upon the same apportioned noise limits taken from the Slickly EIA. Further comments from the THC EHO[11] confirmed the approach of limiting noise to the apportioned limits shown or 2 dB above predicted noise levels remains acceptable. It has been assumed that THC limits would be based upon 2 dB above predicted noise levels shown in the Slickly SEI, as it was the Slickly SEI that was the subject of these further consultation comments from the EHO. Based on the latest consultation response from the THC EHO and using predicted noise levels presented in the Slickly Windfarm SEI, noise limits to be applied to Slickly Windfarm alone have been derived and are presented in rows 1 & 2 of Table C4.

Table C4 – Noise limits to be applied to Slickly Windfarm operating alone (first two rows of the table), as recommended by Environmental Health Dept. of The Highland Council in their consultation response of 12 May 2021. These would apply to control noise levels when wind directions result in downwind propagation towards Slickly Croft. For wind directions where Slickly Croft is not downwind (rows 3 & 4 in the table), it is assumed that Slickly Windfarm would meet noise levels 2 dB(A) above those predicted in the Slickly Windfarm SEI at Slickly Croft. Values shown in **bold** indicate where these values (rows 1 & 2) are lower than those recommended by THC (rows 1 & 2).

Location	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Slickly Croft (day) *Meeting THC Limit*	-	-	-	28.50	32.9	**34.3**	**33.7**	**37.5**	38.1	38.1	38.1	38.1
Slickly Croft (night) *Meeting THC Limit*	-	-	-	28.5	32.9	36.7	**37.4**	**37.0**	38.1	38.1	38.1	38.1
Slickly Croft (day) *Predicted + 2 dB(A)*	-	-	-	28.5	32.9	36.7	38.1	38.1	38.1	38.1	38.1	38.1
Slickly Croft (night) *Predicted + 2 dB(A)*	-	-	-	28.5	32.9	36.7	38.1	38.1	38.1	38.1	38.1	38.1

C.6 For the purposes of the present assessment, it has been assumed that noise immission levels from operation of Slickly Windfarm alone would be restricted to the noise limits shown in Table C4 (rows 1 & 2) when wind directions would result in downwind propagation towards Slickly Croft. This has also been assumed to be the case for other noise sensitive receptor locations which also lay in the same general direction as Slickly Croft, but are more distant from Slickly Windfarm, such as those receptors in Slickly nearest to the Proposed Development as well as those receptors nearest to Lochend Windfarm.

C.7 For other receptor locations not in the general downwind direction towards Slickly Croft, these requirements can be reduced, with noise from Slickly Windfarm assumed to be 2 dB(A) above noise immission levels predicted from Slickly Windfarm, as shown in the Slickly Windfarm SEI. These alternate levels are also shown in rows 3 & 4 of Table C4. Noise levels 2 dB(A) above those shown in the Slickly

9 Planning Application Consultation – Environmental Health Response, 19/05624/FUL, 27 March 2020, from Robin Fraser, Environmental Health Officer *"I have no objection to the application subject to a standard wind farm noise condition being attached to any consent. Limits to be as per Table 11.6 of the EIA report or 2dB above predicted levels whichever is the lower".*

10 Slickly Windfarm Supplementary Environmental Information, Chapter 8 Noise, Arcus Consultancy Services Ltd March 2021.

11 Planning Application Consultation – Environmental Health Response, 19/05624/FUL, 12 May 2021, from Robin Fraser, Environmental Health Officer *"I have no objection to the application subject to a standard wind farm noise condition being attached to any consent. Limits to be as per Table 11.6 of the EIA report or 2dB above predicted levels whichever is the lower".*

Windfarm SEI are considered to allow for an 'appropriate margin' in accordance with the IOA GPG when considering cumulative effects.

C.8 Noise immission levels shown in Table C4 have been used to calculate source sound power levels for the turbines on Slickly Windfarm which would be required to meet these criteria, when allowing for propagation effects for predictions at Slickly Croft. These turbine sound power levels are shown in Table C5. Propagation effects were accounted for using a single value calculated[12] from the difference at 8 m/s between sound power level and predicted noise level at Slickly Croft, as presented in the Slickly Windfarm SEI. In addition to overall sound power levels, data for octave band noise emissions from the turbines on Slickly Windfarm reference data provided in SEI Table 8.5 of the Slickly Windfarm SEI and are shown here in Table C6. For noise modelling using sound power levels shown in Table C5, the wind turbines are assumed to all have a hub height of 83.5 m.

Table C5 – Turbine sound power levels assumed to apply to the wind turbines on Slickly Windfarm, calculated by adding the single value propagation attenuation related to propagation at Slickly Croft to noise immission /limit levels shown in Table C4. The first two rows of the table show sound power levels applicable for predictions where Slickly Croft is downwind and row 3 & 4 for other wind directions where Slickly Croft is not downwind. Values shown in **bold** indicate where the values in rows 1 & 2 are lower than those in rows 3 & 4.

Location	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Downwind of Slickly Croft (day)	-	-	-	98.8	103.2	**104.6**	**104.0**	**107.8**	108.4	108.4	108.4	108.4
Downwind of Slickly Croft (night)	-	-	-	98.8	103.2	107.0	**107.7**	**107.3**	108.4	108.4	108.4	108.4
Not Downwind of Slickly Croft (day)	-	-	-	98.8	103.2	107.0	108.4	108.4	108.4	108.4	108.4	108.4
Not Downwind of Slickly Croft (night)	-	-	-	98.8	103.2	107.0	108.4	108.4	108.4	108.4	108.4	108.4

Table C6 - Octave band sound power spectrum (dB L_{Aeq}) for reference wind speed conditions (v_{10} = 8 m/s) – Slickly Windfarm.

Turbine make / model	Octave Band Centre Frequency (Hz)								
	63	125	250	500	1000	2000	4000	8000	A
Vestas V126 3.45 MW	90.9	96.6	98.9	99.7	101.5	102.0	99.7	89.1	108.0
Derived from: Slickly Windfarm SEI Table 8.5									

Stroupster Windfarm

C.9 Background noise levels in the Stroupster Windfarm EIA Report[13], and the noise limits derived from these which apply to control noise from Stroupster Windfarm, were related wind speeds measured directly at ten metres height. This wind speed reference is the least preferred according to best practice (IOA GPG), consequently the December 2019 EIA Report for Slickly Windfarm in assessing cumulative noise effects, defined noise limits related to standardised ten metre wind speeds, derived from wind speeds experienced at the hub height of the Slickly wind turbines (83.5 m) and based upon a more recent survey of background noise levels (see section above).

C.10 The Slickly Windfarm EIA Report considered levels of noise from Stroupster Windfarm when determining likely cumulative effects and concluded that there would be significant headroom between predicted

12 The sound power level at 8 m/s shown in SEI Table 8.4 of the Slickly Windfarm SEI is 106.4 dB(A), which includes an allowance for uncertainty. The predicted noise level at 8 m/s for Slickly Croft is 36.1 dB(A) and shown in SEI Table 8.5 of the Slickly Windfarm SEI. The difference between these is 70.3 dB(A). The difference is the same at other wind speeds as that calculated at 8 m/s, as expected.

13 Stroupster Windfarm Environmental Statement Volume 2 – Chapter 11 – Noise. SLR Consulting / Npower Renewables, May 2005 (Planning reference 05/00273/FULCA)

noise immission levels and the noise limits which apply to Stroupster windfarm. Consequently, the Slickly Windfarm EIA Report allowed a margin of 2 dB(A) above typical source sound power levels for the Stroupster wind turbines, when determining cumulative effects. A margin of 2 dB(A) is considered an appropriate margin and use of such margins is discussed in the IOA GPG. The approach adopted for consideration of cumulative effects of Stroupster Windfarm has been accepted by The Highland Council as detailed in their consultation response on noise for assessment of Slickly Windfarm[14].

C.11 Consistent with the approach in the Slickly Windfarm EIA Report, the same sound power levels have been assumed for the purposes of this assessment. Overall sound power levels at shown in Table C7 and are taken from the Slickly Windfarm EIA Report. These are provided in the Slickly Windfarm EIA Report for two hub heights, with data for 64 m and 75 m being used for this assessment.

C.12 Based on data available to ourselves, the source sound power levels presented in the Slickly Windfarm EIA Report are considered reasonably representative of the make and model of turbine installed at Stroupster Windfarm and include a suitable margin for uncertainty. As stated above, a further 2 dB(A) has been added representing an 'appropriate margin' when considering cumulative effects. In addition to overall sound power levels, a frequency spectrum has been referenced to allow predicted noise levels to be calculated, as shown in Table C8.

Table C7 – Turbine sound power levels assumed to apply to the wind turbines on Stroupster Windfarm, which include a 2 dB(A) 'appropriate margin' in accordance with the IOA GPG. The values shown are related to standardised ten metre wind speeds derived from those at the hub height of the turbines for the hub heights indicated.

Turbine make / model	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Enercon E70 2.3 MW OMII (64 m hub height)	-	-	-	-	96.6	101.8	104.4	106.1	107.5	107.5	107.5	107.5
Enercon E70 2.3 MW OMII (75 m hub height)	-	-	-	-	96.9	102.2	104.5	106.4	107.5	107.5	107.5	107.5
Derived from: Slickly Windfarm EIA Report Table A11.4.3 with values shown having a 1 dB(A) margin added for uncertainty and a further 2 dB(A) added as an 'appropriate margin', in accordance with IOA GPG when considering cumulative effects.												

Table C8 - Octave band sound power spectrum (dB L_{Aeq}) for reference wind speed conditions (v_{10} = 8 m/s) assumed to apply to the wind turbines on Stroupster Windfarm.

Turbine make / model	Octave Band Centre Frequency (Hz)								
	63	125	250	500	1000	2000	4000	8000	A
Enercon E70 2.3 MW	84.3	91.7	95.5	94.5	91.0	86.9	81.0	74.1	100.0
Derived from: WINDTest WICO 314SEA05/02 2005-12-01 at 8 m/s for the 2.3 MW version of the Enercon E70 and normalised to 100 dB(A)									

Lochend Windfarm

C.13 Noise limits shown in the July 2013 Lochend Windfarm EIA Report[15], were derived from background noise measurements at a single location at Syster (327029, 969084), which was surveyed for the Earl's Cairn Windfarm application[16]. These baseline background noise levels are shown in Table C9 and were

14 Planning Application Consultation – Environmental Health Response, 19/05624/FUL, 27 March 2020.

15 Lochend Windfarm Environmental Statement, Volume 1: Text – Chapter 5 – Noise, Wind Harvest, July 2013 (Planning reference 13/02682/FUL)

16 Further details of the Earl's Cairn application were not available to ourselves but sufficient data and suitable analysis results are presented in the Lochend Windfarm EIA Report to derived ETSU-R-97 noise limits.

calculated from the equations given for the lines of best-fit in the Lochend Windfarm EIA Report (Appendix 5.1).

C.14 Noise limits which apply to control noise from Lochend Windfarm were defined in the planning appeal decision notice[17]. These noise limits are stated to relate to standardised ten metre wind speeds, which are hub height wind speeds converted or 'standardised' to ten metres height, which therefore accord with best practice. The maximum tip height allowed by the appeal decision notice (99.5 m) would equate to a hub height of approximately 65 m for the Enercon E70 2.3 MW turbines assumed to be installed. This is consistent with the Lochend Windfarm EIA Report which assumed 64 m hub height.

C.15 Assessment of the contribution to cumulative noise levels from operation of the Lochend Windfarm assumes the sound power levels shown above in Tables C7 and C8, for a hub height of 64 m. This approach is consistent with that used in the Slickly Windfarm EIA Report.

Table C9 – Baseline background noise levels measured at Syster (327029, 969084) for the Earl's Cairn Windfarm application and used as the basis for the assessment of noise presented in the Lochend Windfarm EIA Report.

Location	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Syster (day)	29.2	27.5	26.7	26.8	27.6	29.1	31.1	33.5	36.2	39.2	42.3	45.4
Syster (night)	22.0	21.8	22.3	23.4	25.0	27.0	29.2	31.7	34.2	36.8	39.3	41.5

Table C10 – Noise limits which apply to Lochend Windfarm to control operational noise, derived from the Reporters decision letter.

Location	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Syster (day)	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0
Lochend 10 (1) (day)	35.0	35.0	35.0	35.0	35.0	35.0	36.0	38.5	41.2	44.2	47.3	50.4
Syster (night)	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0
Lochend 10 (1) (night)	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.5	41.2	44.2	47.3	50.4
Financially involved noise limits which apply at Syster (327029,969084) also apply at Lochend 1 and 3 (326821, 968997) & Lochend (326670, 968150). Non-financially involved noise limits which apply at Lochend 10 (1) (327495, 967732) also apply at Lochend 10 (2) (327426, 967739), Lochend 7 (326562, 968264) & Lochend 9 (327337, 967323).												

C.16 It is noted that the noise limits presented in Table C10 are not numerically equivalent to those which would be derived by calculation from the background noise levels given in Table C9, however for the purposes of this assessment they are assumed to remain valid.

Lyth Windfarm Baseline

C.17 The May 2013 EIA Report for Lyth Windfarm[18] provided results of a baseline survey at four locations: Moss-side (325453,966507), Reaster (327032, 964392), Mooredge (329784, 966792) and Greenfields (328640, 964307). These baseline background noise levels are shown in Table C11 and were calculated from the equations given for the lines of best-fit in Appendix 10.2 of the Lyth Windfarm EIA Report.

17 Appeal Decision Notice PPA-270-2108. Decision by David Liddell, a Reporter appointed by the Scottish Ministers, 11 December 2014, Directorate for Planning and Environmental Appeals, The Scottish Government.

18 Lyth Windfarm Environmental Statement, Volume 2: Written Statement– Chapter 10 – Noise, Eurowind / Hayes McKenzie Partnership Limited, May 2013 (Planning reference 13/01832/FUL).

These locations are in the same general area as the noise sensitive receptor locations near to the proposed Development and considered likely to be similar in their setting, likely exposure to the wind as well as likely exposure to noise sources (road traffic noise etc.). These survey positions are therefore considered to offer a source of baseline background noise levels which are reasonably representative for the purposes of an assessment in accordance with ETSU-R-97 and best practice (IOA GPG).

Table C11 – Baseline background survey data (day and night) for the four survey locations shown in the Lyth Windfarm EIA Report, related to standardised ten metre wind speeds derived from those at a height of 64 metres. Also shown (in bold) are arithmetic averages of the values at each location, shown separately for the day-time and night-time.

Location	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Moss-side (day)	21.4	21.8	22.8	24.3	26.1	28.3	30.6	33.1	35.6	38.1	40.4	42.4
Reaster (day)	22.9	23.0	23.5	24.4	25.7	27.4	29.3	31.6	34.1	36.8	39.7	42.8
Mooredge (day)	22.3	21.6	21.8	22.7	24.2	26.2	28.7	31.5	34.5	37.7	41.0	44.2
Greenfields (day)	26.6	25.4	24.8	24.8	25.5	26.7	28.5	30.9	33.9	37.5	41.6	46.3
Average (day)	***23.3***	***23.0***	***23.2***	***24.1***	***25.4***	***27.1***	***29.3***	***31.8***	***34.5***	***37.5***	***40.7***	***43.9***
Moss-side (night)	22.8	21.8	21.5	21.9	22.9	24.6	26.9	29.7	33.1	36.9	41.2	45.9
Reaster (night)	21.8	20.8	20.6	21.0	22.1	23.7	26.0	28.7	31.9	35.6	39.6	44.0
Mooredge (night)	23.5	21.0	20.1	20.4	21.9	24.2	27.1	30.4	33.9	37.3	40.4	43.0
Greenfields (night)	22.2	20.7	20.2	20.5	21.7	23.5	25.9	28.8	32.1	35.6	39.3	43.1
Average (night)	***22.6***	***21.1***	***20.6***	***21.0***	***22.1***	***24.0***	***26.5***	***29.4***	***32.7***	***36.3***	***40.1***	***44.0***

C.18 Additional rows are shown in Table C11, which provide an average value at each wind speed, calculated from the values at the four survey locations, for both day-time and night-time periods. Figure C1 and Figure C2 provide a comparison of background noise levels measured at these four survey locations with the average values and also those obtained from the survey for Lochend Windfarm at Syster as well as the survey results from Slickly Windfarm at Slickly Croft.

C.19 These charts indicate that these average background noise levels values are reasonably comparable with other surveys completed or are lower generally compare with data from these other surveys, over mid to upper wind speeds (~7 m/s upwards), despite having been derived from measurements at a height of 64 m. These wind speeds are most relevant for an assessment in accordance with ETSU-R-97 as values at these wind speeds would directly determine the noise limits/criteria, whereas background noise levels at lower wind speeds are not directly used, with limits/criteria derived from the fixed thresholds of 35 dB(A) to 40 dB(A) day-time and 43 dB(A) night-time according to ETSU-R-97).

Figure C1 - Chart showing a comparison of background noise levels surveyed at four locations for Lyth Windfarm (and an average of these), at one location for Slickly Windfarm and at one location for Lochend Windfarm during quiet day-time periods in accordance with ETSU-R-97.

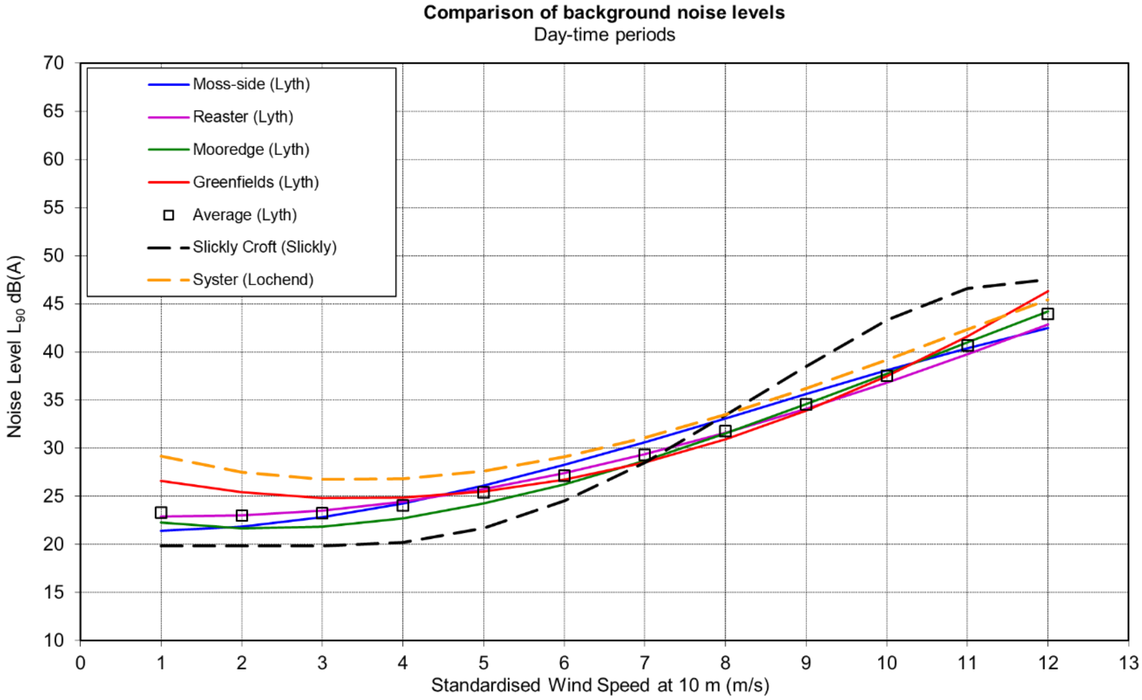
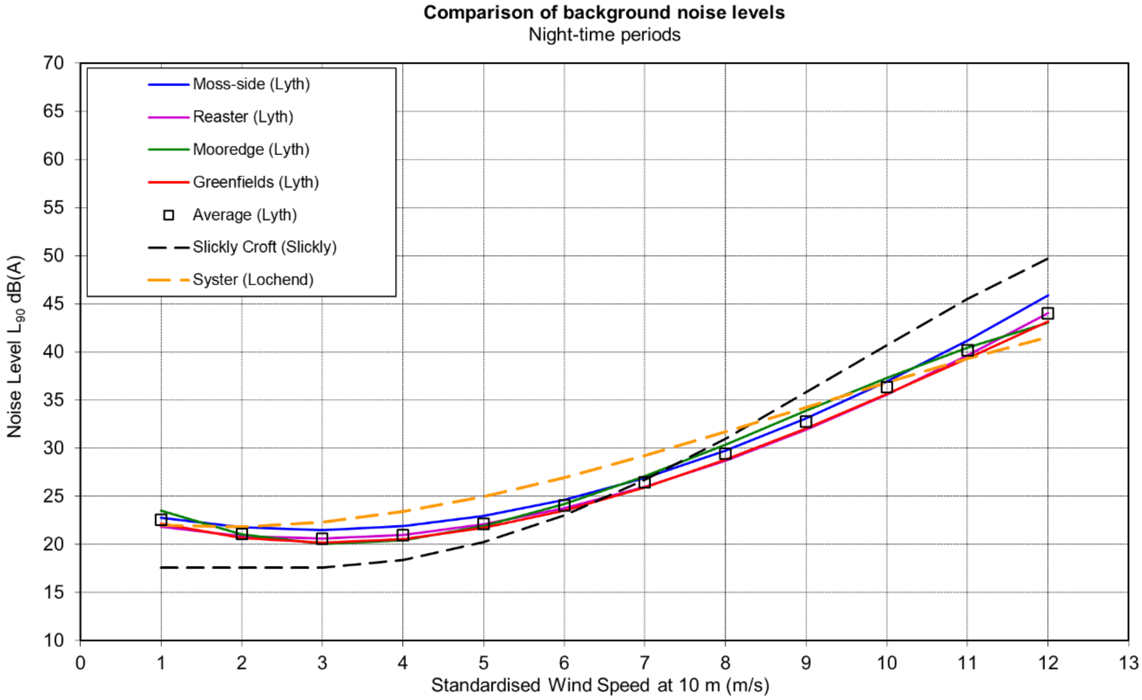


Figure C2 - Chart showing a comparison of background noise levels surveyed at four locations for Lyth Windfarm (and an average of these), at one location for Slickly Windfarm and at one location for Lochend Windfarm during night-time periods in accordance with ETSU-R-97.



Assessment Baseline Background Noise Levels

C.20 Based on background noise levels discussed and presented in the previous sections, set out below are the final set of background noise levels to be used in the assessment of the proposed Development, from which noise limits/criteria are derived in accordance with ETSU-R-97.

C.21 The three baseline background noise surveys (Lyth, Slickly & Lochend) were related to different wind speed sources and at different heights (all standardised to ten metres) however comparison of the results (see Figures C1 and C2) suggests some similarity between the values. This indicates that these data are likely to be reasonably representative for assessment of the proposed Development for standardised ten metre height wind speeds using a hub height of ~84 m. The survey for Slickly Windfarm has a larger deviation from data for other locations but were related to standardised wind speeds for a taller hub height than the Lyth and Lochend surveys, which would normally yield results which remain lower at higher wind speeds, whereas the charts indicate the opposite trend. This does not invalidate these data but would indicate additional sources of background noise at high wind speed at that property, and so on a precautionary basis, baseline surveyed at Slickly Croft would be used only at Slickly Croft when assessing the proposed Development.

C.22 Data presented in previous sections has been rationalised to list only those data required for this noise assessment and shown in Table C12. For the Slickly Croft receptor, background noise data from Slickly Croft is included. For receptors in Slickly which are nearest to the proposed Development, data surveyed at Mooredge for the Lyth Windfarm is included. For receptor locations near to Lochend Windfarm, background noise data measured at Syster and which determine the Lochend Windfarm noise limits are included. For other receptor locations ‘generic’ background noise data, derived from an average of the four survey positions for Lyth Windfarm, are included.

C.23 Shown in Tables C13, C14 and C15 are noise limits which are used for assessment of the proposed Development. Table C13 shows day-time noise limits derived following the preferred approach of The Highland Council, which is to choose the lowest value of 35 dB(A) (within the range from 35 dB(A) to 40 dB(A) allowed by ETSU-R-97) for the fixed part of the day-time noise limit at lower wind speeds. Similarly, Table C14 shows noise limits derived by choosing an alternate value of 38 dB(A) for this fixed threshold during daytime periods. Table C15 shows the night-time noise limits which are used for assessment of the proposed Development. These follow the preferred approach of The Highland Council, using a value of 38 dB(A) for the fixed part of the night-time noise limit at lower wind speeds instead of the value of 43 dB(A) stipulated in ETSU-R-97. It should be noted (as discussed above) that noise limits which apply to receptors near to Lochend Windfarm do not numerically relate precisely to background noise levels presented in Table C12 (which are used to define background noise levels at these receptors for EIA purposes as measured at Syster). Noise criteria/limits at these receptor locations are instead derived from the noise limits imposed in the appeal decision letter for Lochend Windfarm.

Table C12 – Baseline background survey data (quiet day-time and night-time) for the survey locations required for assessment of the proposed Development and taken from the Lyth Windfarm EIA Report, the Lochend Windfarm EIA Report and the Slickly Windfarm EIA Report, related to standardised ten metre wind speeds.

Property	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Slickly Croft (day) (Slickly WF)	19.8	19.8	19.8	20.2	21.7	24.5	28.5	33.4	38.5	43.3	46.6	47.5
Mooredge (day) (Lyth WF)	22.3	21.6	21.8	22.7	24.2	26.2	28.7	31.5	34.5	37.7	41.0	44.2
Generic (day) (Lyth WF)	23.3	23.0	23.2	24.1	25.4	27.2	29.3	31.8	34.5	37.5	40.7	43.9
Syster (day) (Lochend WF)	29.2	27.5	26.7	26.8	27.6	29.1	31.1	33.5	36.2	39.2	42.3	45.4
Slickly Croft (night) (Slickly WF)	17.6	17.6	17.6	18.4	20.2	23.0	26.7	31.0	35.8	40.7	45.5	49.7
Mooredge (night) (Lyth WF)	23.5	21.0	20.1	20.4	21.9	24.2	27.1	30.4	33.9	37.3	40.4	43.0
Generic (night) (Lyth WF)	22.6	21.1	20.6	21.0	22.2	24.0	26.5	29.4	32.8	36.4	40.1	44.0
Syster (night) (Lochend WF)	22.0	21.8	22.3	23.4	25.0	27.0	29.2	31.7	34.2	36.8	39.3	41.5

Table C13 – ETSU-R-97 noise limits during day-time periods following THC preference for the fixed part of the day-time limit to be based on 35 dB(A), within the range from 35 dB(A) to 40dB(A) allowed by ETSU-R-97, shown related to standardised ten metre wind speeds. This choice has no relevance for the financially involved limits for Syster.

Property	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Slickly Croft (Slickly WF)	35.0	35.0	35.0	35.0	35.0	35.0	35.0	38.4	43.5	48.3	51.6	52.5
Mooredge (Lyth WF)	35.0	35.0	35.0	35.0	35.0	35.0	35.0	36.5	39.5	42.7	46.0	49.2
Generic (Lyth WF)	35.0	35.0	35.0	35.0	35.0	35.0	35.0	36.8	39.5	42.5	45.7	48.9
Syster (Lochend WF)	35.0	35.0	35.0	35.0	35.0	35.0	36.0	38.5	41.2	44.2	47.3	50.4
Syster (Lochend WF FI)	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0

Table C14 – ETSU-R-97 noise limits during day-time periods with the fixed part of the limit to set to 38 dB(A), within the range from 35 dB(A) to 40dB(A) allowed by ETSU-R-97, shown related to standardised ten metre wind speeds. This choice has no relevance for the financially involved limits for Syster.

Property	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Slickly Croft (Slickly WF)	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.4	43.5	48.3	51.6	52.5
Mooredge (Lyth WF)	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	39.5	42.7	46.0	49.2
Generic (Lyth WF)	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	39.5	42.5	45.7	48.9
Syster (Lochend WF)	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.5	41.2	44.2	47.3	50.4
Syster (Lochend WF FI)	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0

Table C15 – ETSU-R-97 noise limits during night-time periods following THC preference for the fixed part of the night-time limit to be based on 38 dB(A), rather than 43 dB(A) according to ETSU-R-97, shown related to standardised ten metre wind speeds.

Property	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Slickly Croft (Slickly WF)	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	40.8	45.7	50.5	54.7
Mooredge (Lyth WF)	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.9	42.3	45.4	48.0
Generic (Lyth WF)	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	41.4	45.1	49.0
Syster (Lochend WF)	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.5	41.2	44.2	47.3	50.4
Syster (Lochend WF FI)	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0

Slickly Wind Farm – Directional Constraints

C.24 Slickly Windfarm noise limits recommended by The Highland Council (THC) are assumed to be applied to control operational noise from Slickly Windfarm for the purposes of assessing cumulative effects, when operated together with the proposed Development. Discussed above were the noise limits which THC suggested, and how these would result in constraints being required to the turbines on Slickly Windfarm for wind directions where Slickly Croft would be downwind. However, for other wind directions constraints are assumed to no longer be required.

C.25 When considering in detail how wind direction may affect the level and exposure of assessment locations to noise from different windfarms, it is feasible to consider this in detail using the wind direction attenuation factors set out in the IOA GPG[19]. The first phase of calculating predictions which include directional attenuation is to consider what constraints are required to be applied to Slickly Windfarm so that operational noise levels remain within the noise limits recommended by THC. Wind-directional based noise predictions were calculated in one degree increments for Slickly Windfarm alone and for the single receptor location at Slickly Croft. As discussed above, constraints would apply to control noise at Slickly Croft and would reduce noise levels for locations further from Slickly Windfarm. Table C4 shows that constraints should only be required at wind speeds of 6 m/s & 7 m/s day-time and at 8 m/s night-time.

C.26 Three charts are shown at figures C3, C4 and C5 which provide wind direction based predictions at Slickly Croft and compare these to the noise limits assumed to be imposed upon Slickly Windfarm for the three wind speeds of 6 m/s, 7 m/s and 8 m/s respectively. These predictions are based on sound power levels shown in Table C5 (for unconstrained operation, rows 3 & 4) and the frequency spectrum in Table C6. For each chart there are also lines shown which indicate the magnitude and wind direction extents of the required constraints.

C.27 Where wind-directional based predictions are to be calculated for any noise sensitive receptor location around the proposed Development, the constraint corrections calculated from the above process are applied, so that the contribution from Slickly Windfarm is based on Slickly Windfarm remaining compliant with the noise limits which should apply at Slickly Croft, as recommended by The Highland Council.

19 The IOA GPG sets out in 4.4.2 directional attenuation factors used in this assessment: *'Based on evidence from the Joule project in conjunction with advice in BS 8233 and ISO 9613-2, current practice suggests that for a range of headings from directly downwind (0°) up to 10 degrees from crosswind (80°), there may be little to no reduction in noise levels; once in crosswind directions (90°) then the reduction may be around 2 dB(A); and when at sufficient distance upwind the reduction would be at least 10 dB(A). For intermediate directions between crosswind to upwind, a simple linear or polynomial interpolation can be used. Such reductions (due to "shadow zone" refraction effects) will in practice only progressively come into play at distances of between 5 and 10 turbine tip heights'.*

Figure C3 - Chart showing a comparison of directional based predicted noise immission levels for Slickly Windfarm alone at the noise sensitive receptor location of Slickly Croft, for a wind speed of 6 m/s. Also shown are the day-time and night-time noise limits as well as the calculated attenuation (constraints) values required to be applied to maintain noise immission levels within the noise limits (day-time = ‘Corr-D’ & night-time = ‘Corr-N’).

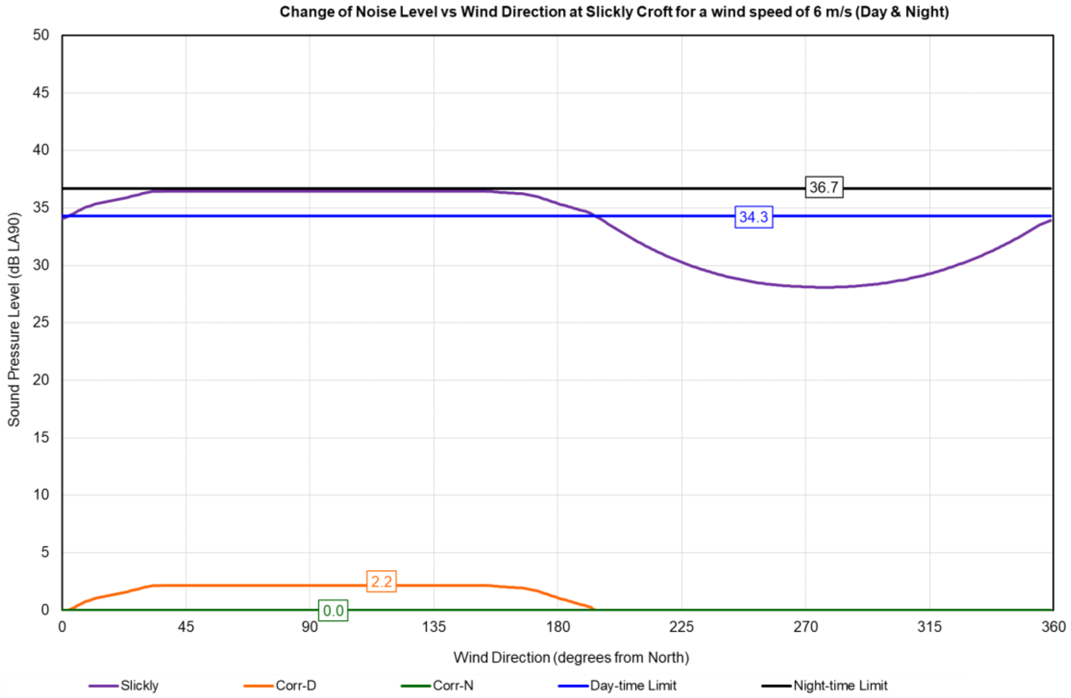


Figure C4 - Chart showing a comparison of directional based predicted noise immission levels for Slickly Windfarm alone at the noise sensitive receptor location of Slickly Croft, for a wind speed of 7 m/s. Also shown are the day-time and night-time noise limits as well as the calculated attenuation (constraints) values required to be applied to maintain noise immission levels within the noise limits (day-time = ‘Corr-D’ & night-time = ‘Corr-N’).

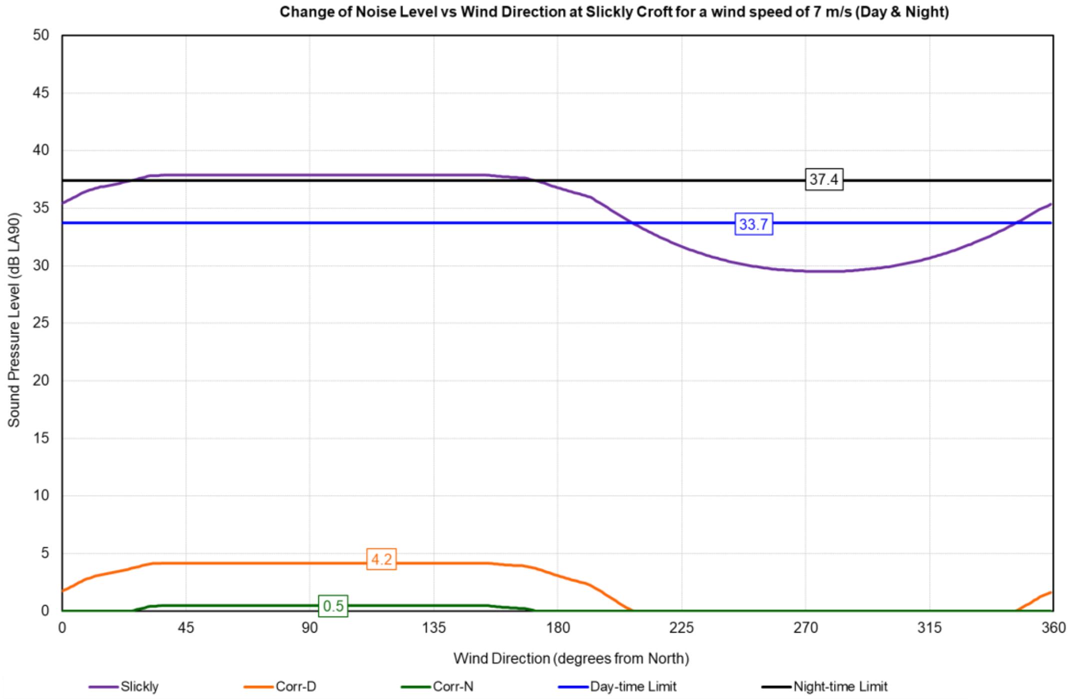
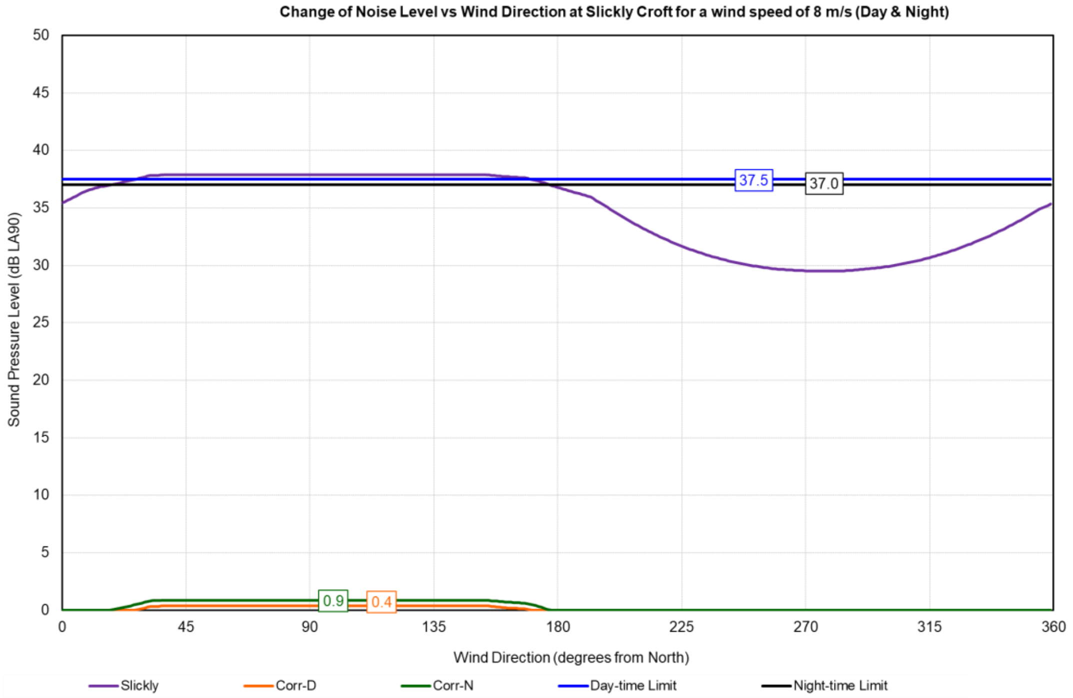


Figure C5 - Chart showing a comparison of directional based predicted noise immission levels for Slickly Windfarm alone at the noise sensitive receptor location of Slickly Croft, for a wind speed of 8 m/s. Also shown are the day-time and night-time noise limits as well as the calculated attenuation (constraints) values required to be applied to maintain noise immission levels within the noise limits (day-time = ‘Corr-D’ & night-time = ‘Corr-N’).



Annex D – Predicted Noise and Noise Limits/Criteria

Figure D1 - Chart of both the 35 dB(A) and 38 dB(A) ETSU-R-97 based noise criteria / limit curves appropriate for the assessment location of Brabstermire House as well as background noise levels, during day-time periods. Predicted noise immission levels are shown for the proposed Development (unconstrained), the other windfarms considered as well as the cumulative total.

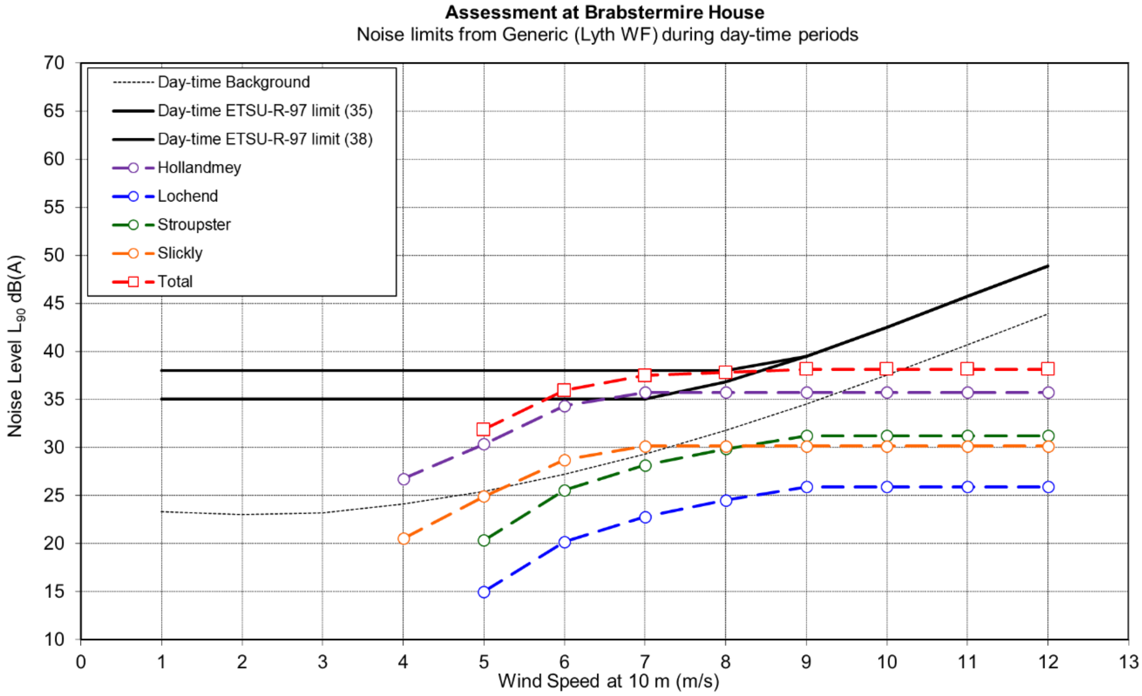


Figure D2 - Chart of the 38 dB(A) ETSU-R-97 based noise criteria / limit curve appropriate for the assessment location of Brabstermire House as well as background noise levels, during night-time periods. Predicted noise immission levels are shown for the proposed Development (unconstrained), the other windfarms considered as well as the cumulative total.

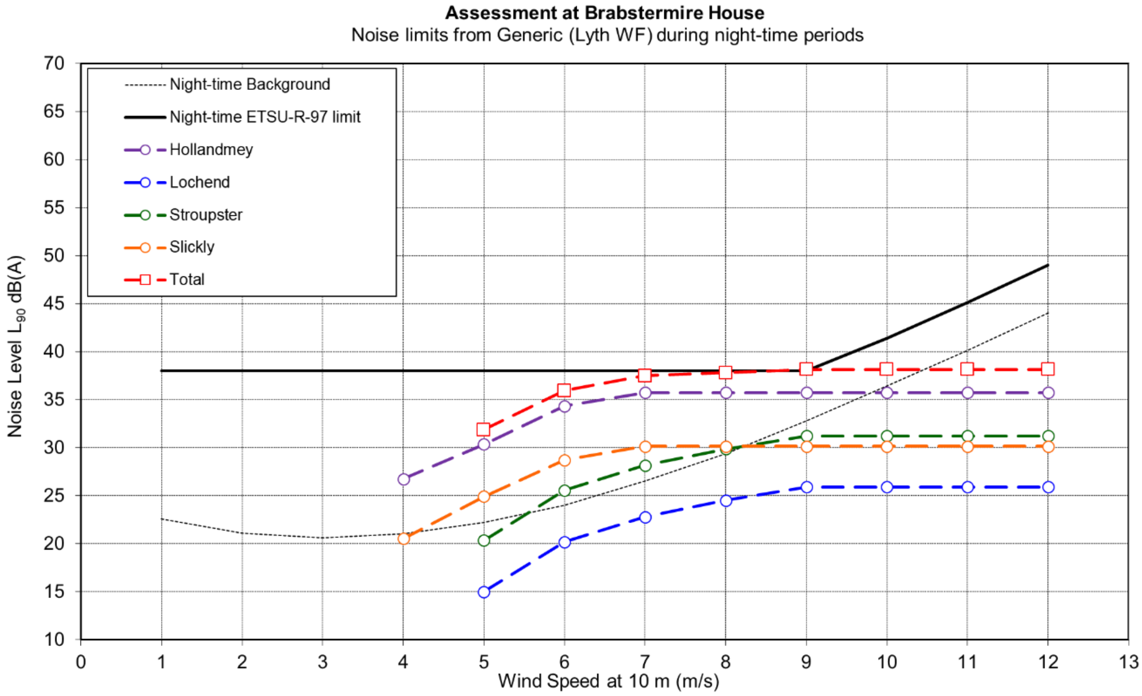


Figure D3 - Chart of both the 35 dB(A) and 38 dB(A) ETSU-R-97 based noise criteria / limit curves appropriate for the assessment location of Kevill as well as background noise levels, during day-time periods. Predicted noise immission levels are shown for the proposed Development (unconstrained), the other windfarms considered as well as the cumulative total.

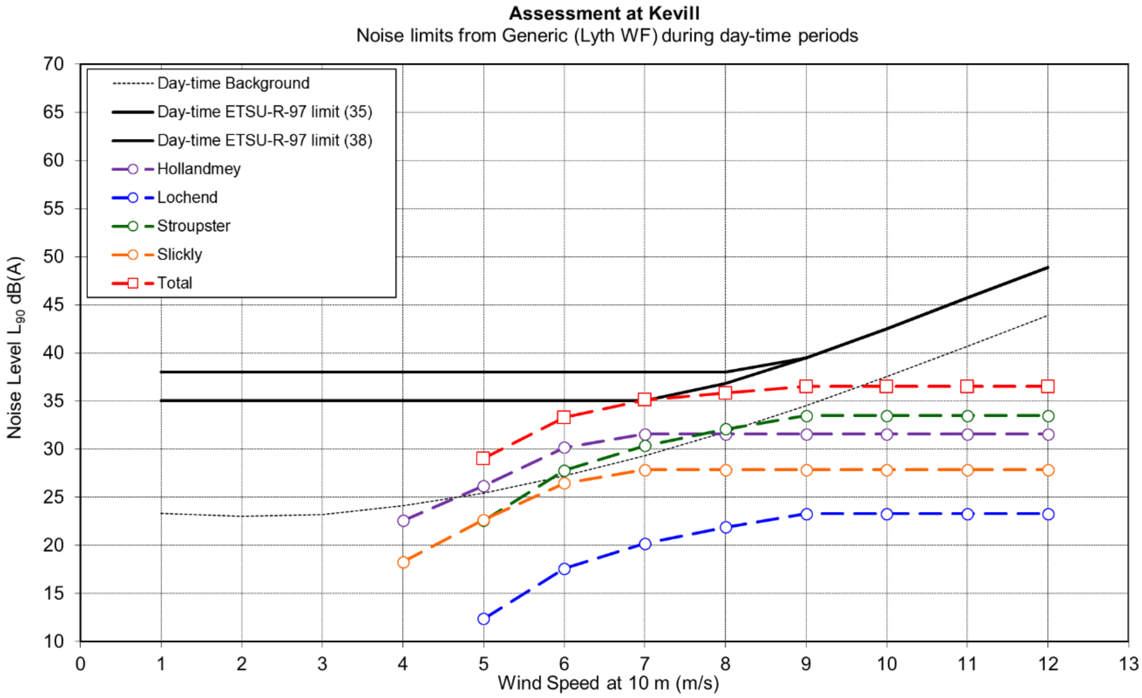


Figure D4 - Chart of the 38 dB(A) ETSU-R-97 based noise criteria / limit curve appropriate for the assessment location of Kevill as well as background noise levels, during night-time periods. Predicted noise immission levels are shown for the proposed Development (unconstrained), the other windfarms considered as well as the cumulative total.

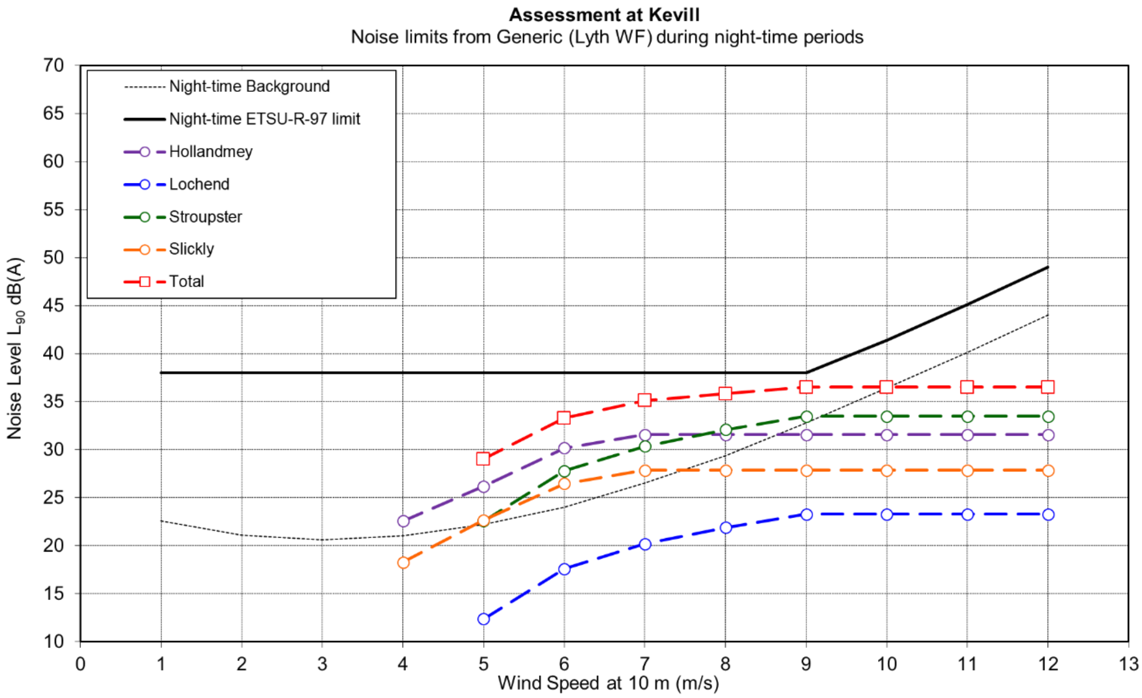


Figure D5 - Chart of both the 35 dB(A) and 38 dB(A) ETSU-R-97 based noise criteria / limit curves appropriate for the assessment location of Lochend 10(1) as well as background noise levels, during day-time periods. Predicted noise immission levels are shown for the proposed Development (unconstrained), the other windfarms considered as well as the cumulative total.

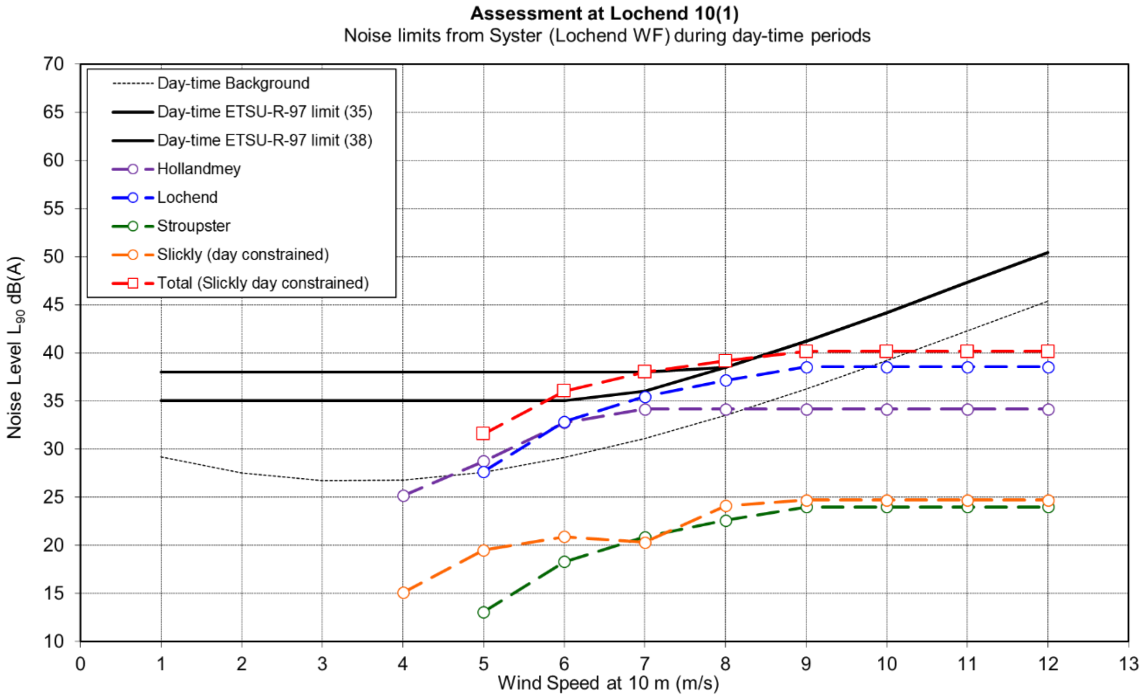


Figure D6 - Chart of the 38 dB(A) ETSU-R-97 based noise criteria / limit curve appropriate for the assessment location of Lochend 10(1) as well as background noise levels, during night-time periods. Predicted noise immission levels are shown for the proposed Development (unconstrained), the other windfarms considered as well as the cumulative total.

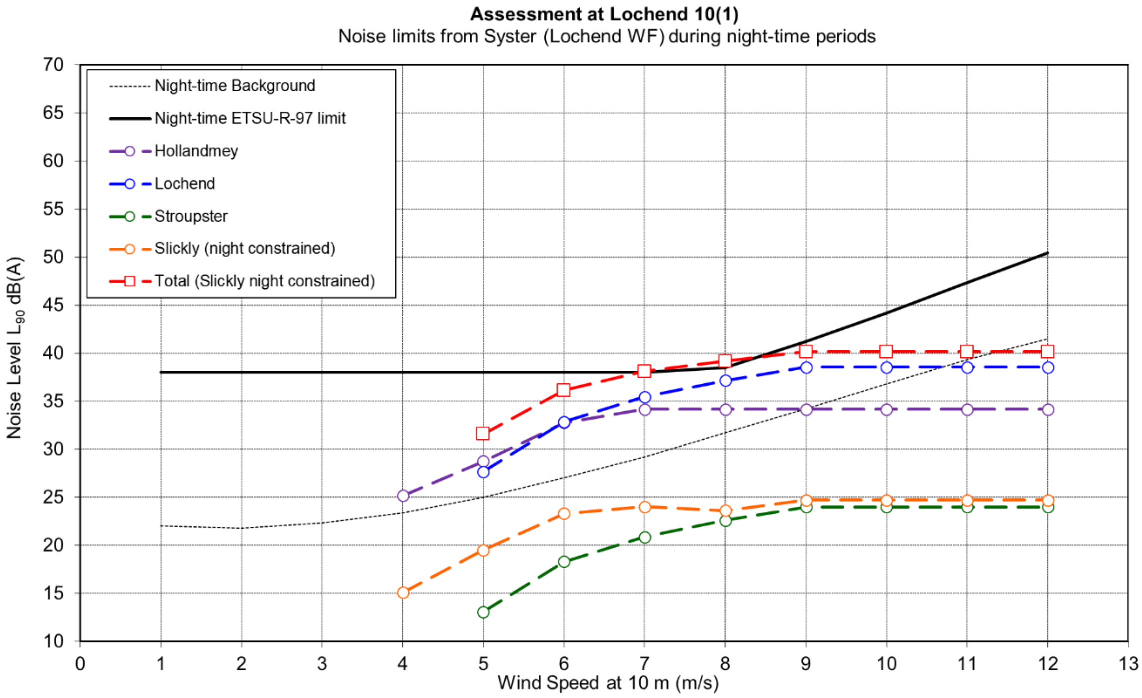


Figure D7 - Chart of both the 35 dB(A) and 38 dB(A) ETSU-R-97 based noise criteria / limit curves appropriate for the assessment location of Lochend New Build as well as background noise levels, during day-time periods. Predicted noise immission levels are shown for the proposed Development (unconstrained), the other windfarms considered as well as the cumulative total.

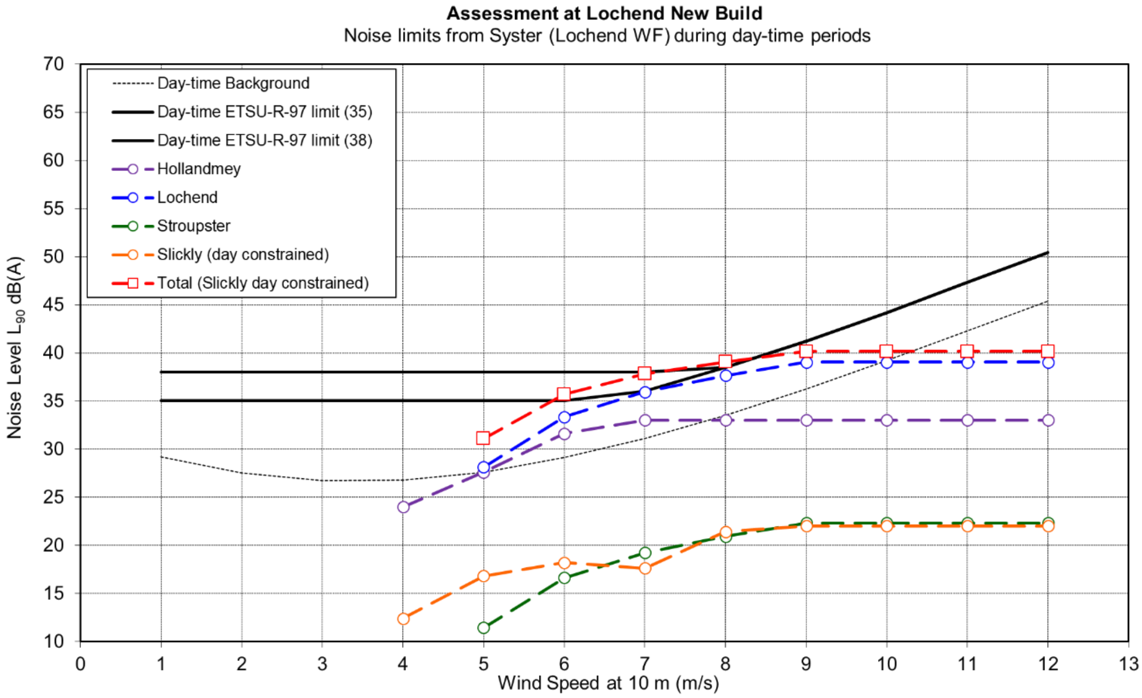


Figure D8 - Chart of the 38 dB(A) ETSU-R-97 based noise criteria / limit curve appropriate for the assessment location of Lochend New Build as well as background noise levels, during night-time periods. Predicted noise immission levels are shown for the proposed Development (unconstrained), the other windfarms considered as well as the cumulative total.

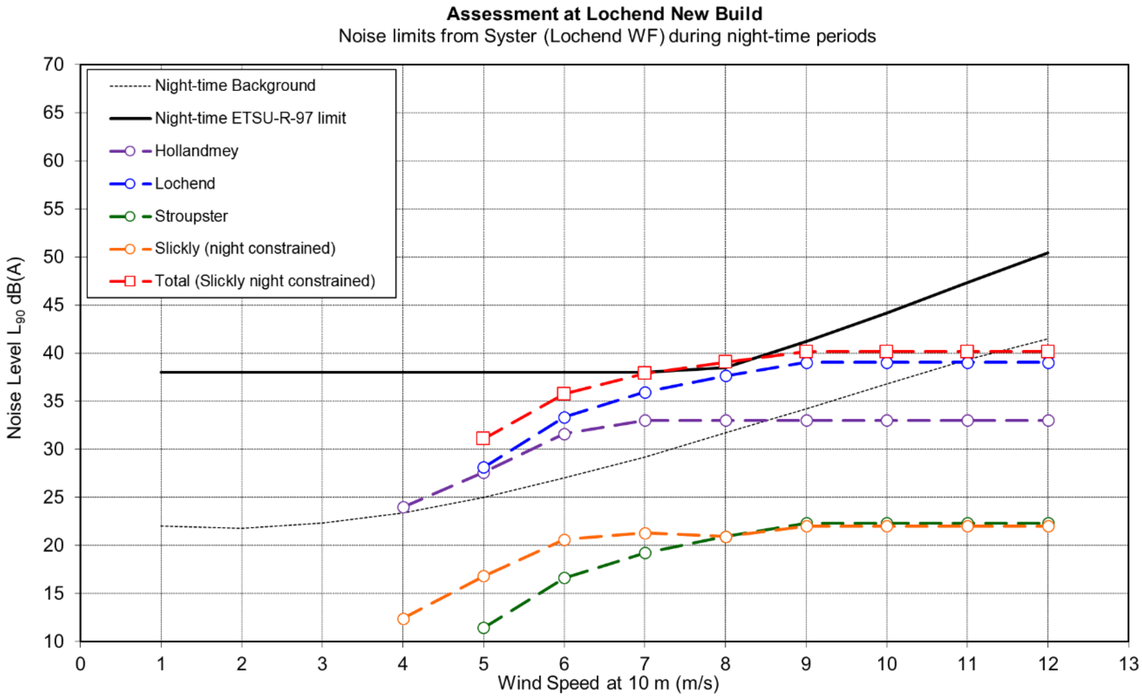


Figure D9 - Chart of both the 35 dB(A) and 38 dB(A) ETSU-R-97 based noise criteria / limit curves appropriate for the assessment location of Philips Mains (Nearest) as well as background noise levels, during day-time periods. Predicted noise immission levels are shown for the proposed Development (unconstrained), the other windfarms considered as well as the cumulative total.

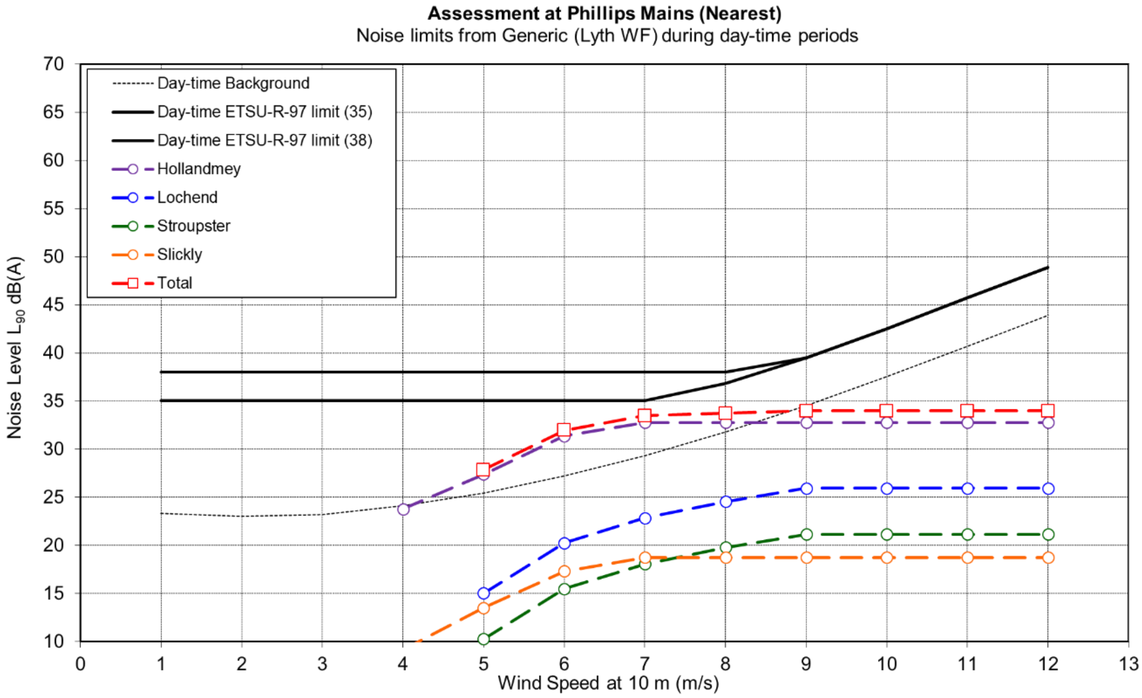


Figure D10 - Chart of the 38 dB(A) ETSU-R-97 based noise criteria / limit curve appropriate for the assessment location of Philips Mains (Nearest) as well as background noise levels, during night-time periods. Predicted noise immission levels are shown for the proposed Development (unconstrained), the other windfarms considered as well as the cumulative total.

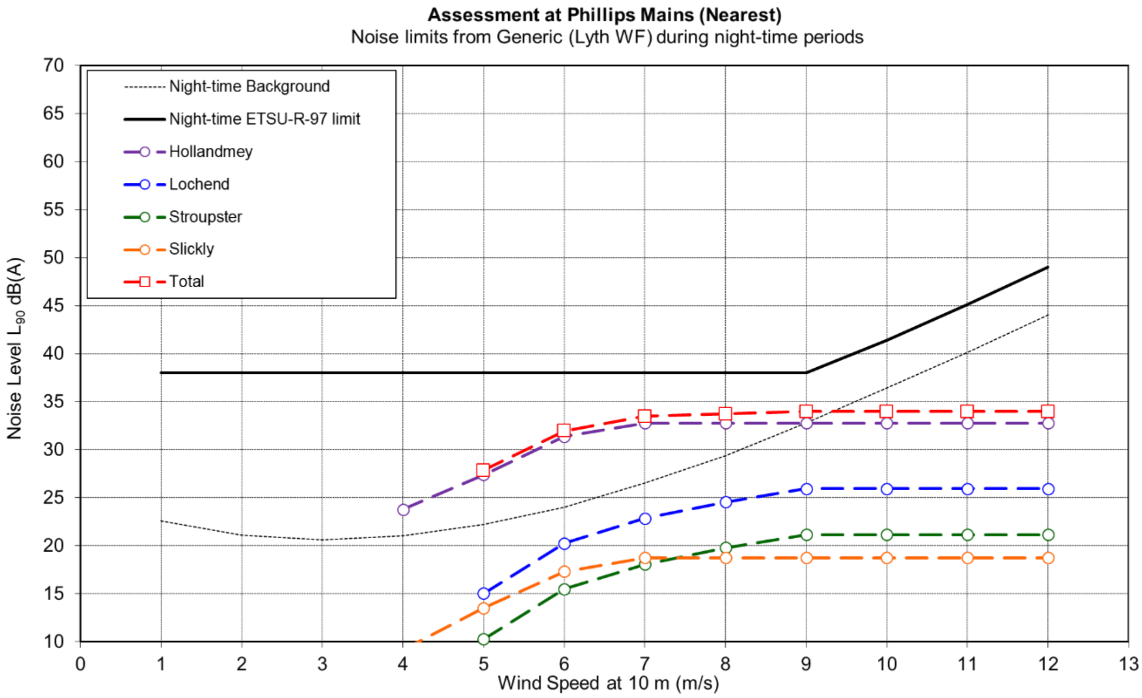


Figure D11 - Chart of both the 35 dB(A) and 38 dB(A) ETSU-R-97 based noise criteria / limit curves appropriate for the assessment location of Slickly Croft as well as background noise levels, during day-time periods. Predicted noise immission levels are shown for the proposed Development (unconstrained), the other windfarms considered as well as the cumulative total.

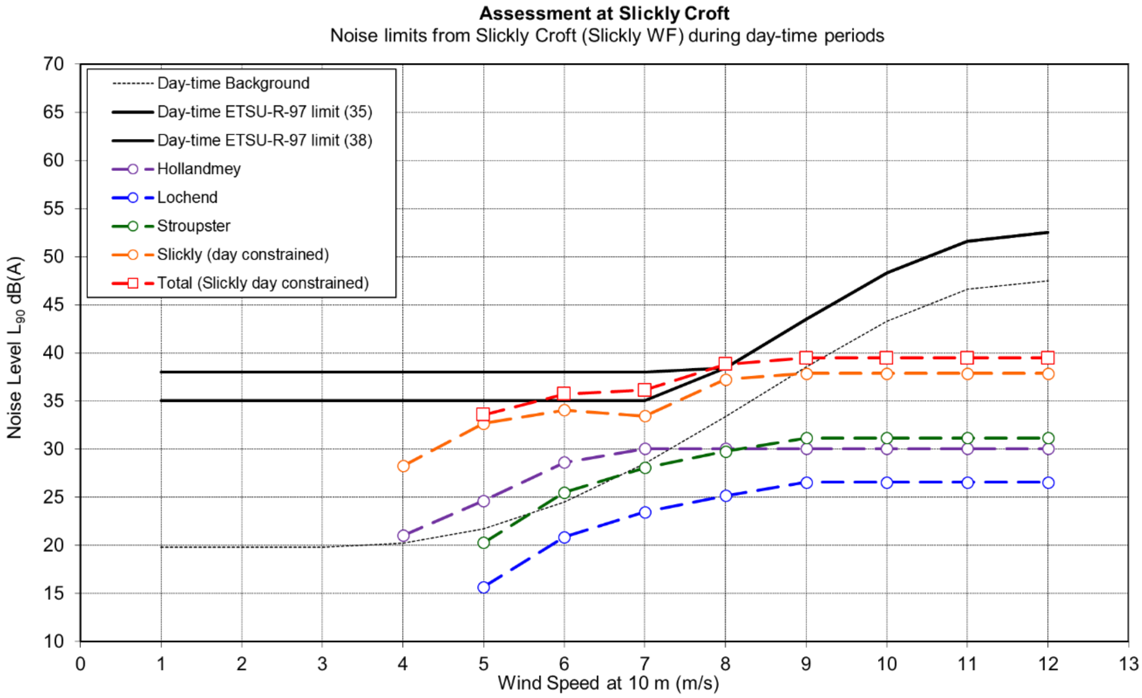


Figure D12 - Chart of the 38 dB(A) ETSU-R-97 based noise criteria / limit curve appropriate for the assessment location of Slickly Croft as well as background noise levels, during night-time periods. Predicted noise immission levels are shown for the proposed Development (unconstrained), the other windfarms considered as well as the cumulative total.

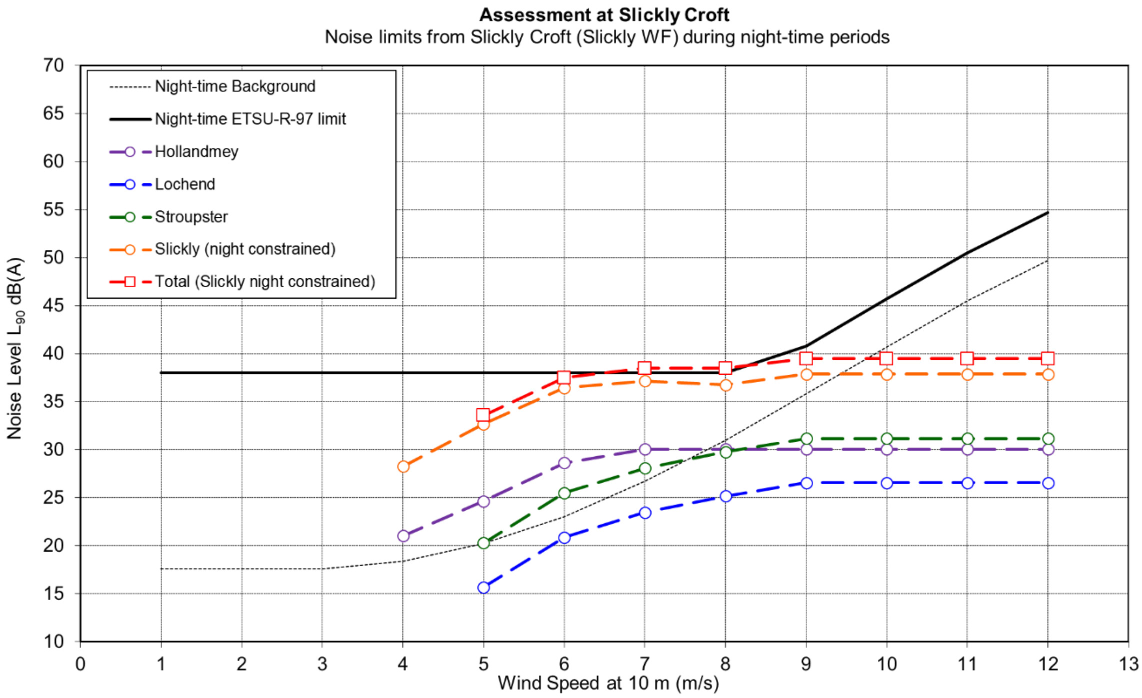


Figure D13 - Chart of both the 35 dB(A) and 38 dB(A) ETSU-R-97 based noise criteria / limit curves appropriate for the assessment location of Slickly (Nearest) as well as background noise levels, during day-time periods. Predicted noise immission levels are shown for the proposed Development (unconstrained), the other windfarms considered as well as the cumulative total.

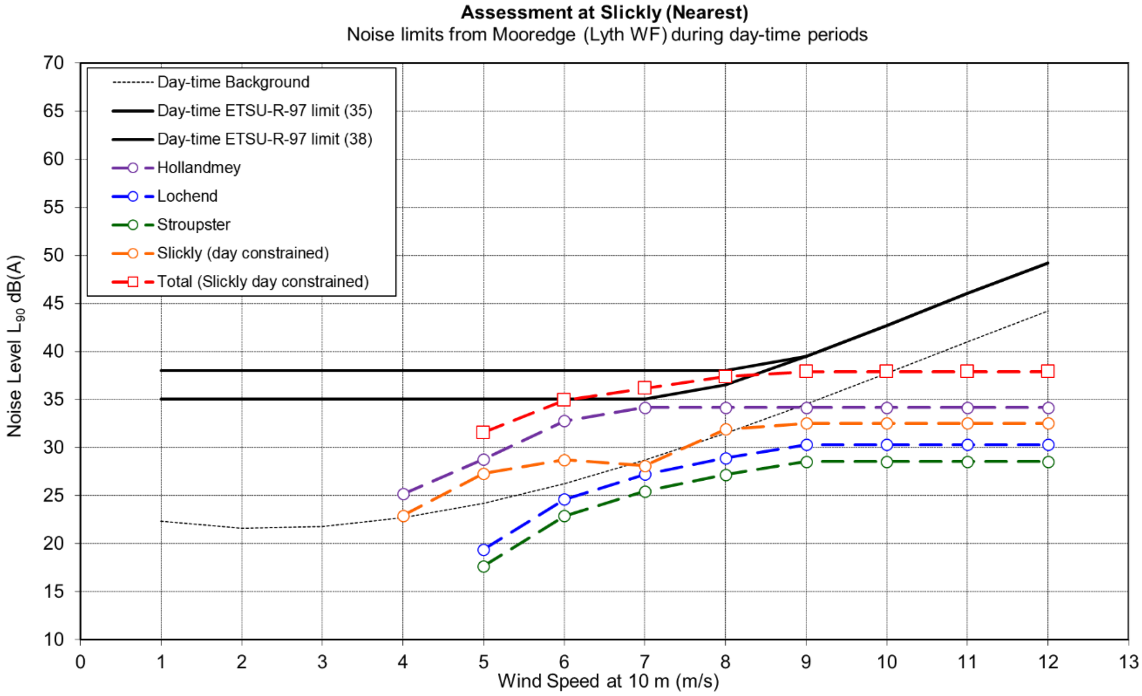


Figure D14 - Chart of the 38 dB(A) ETSU-R-97 based noise criteria / limit curve appropriate for the assessment location of Slickly (Nearest) as well as background noise levels, during night-time periods. Predicted noise immission levels are shown for the proposed Development (unconstrained), the other windfarms considered as well as the cumulative total.

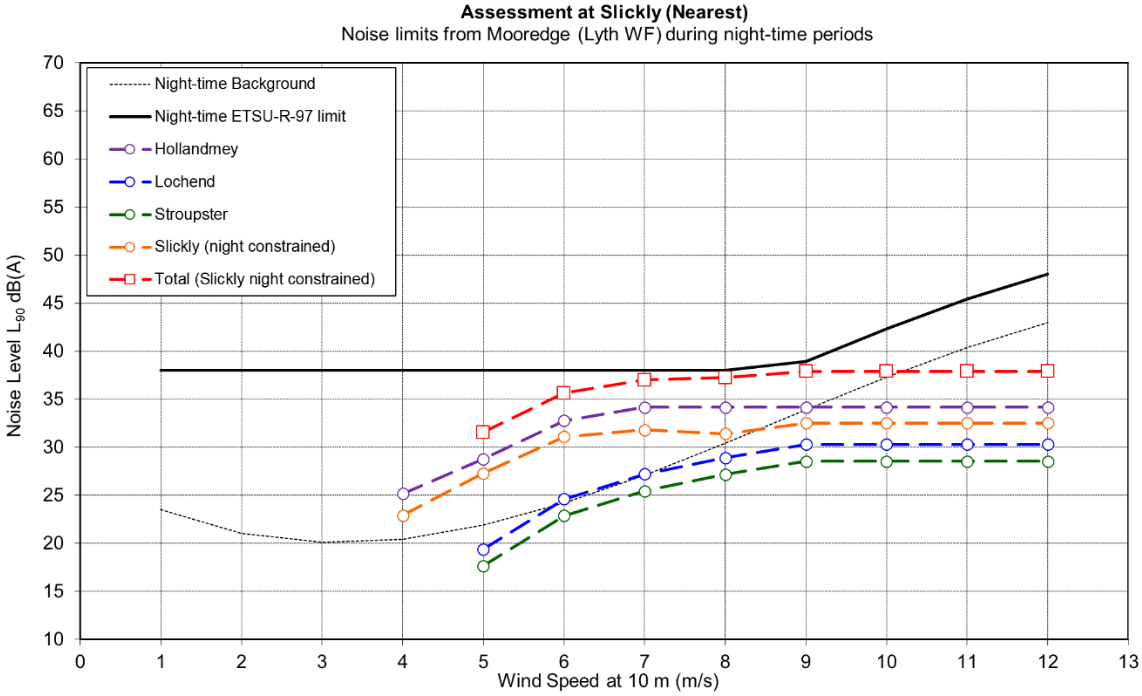


Figure D15 - Chart of both the 35 dB(A) non-financially involved and 45 dB(A) financially involved ETSU-R-97 based noise criteria / limit curves appropriate for the assessment location of Syster as well as background noise levels, during day-time periods. Predicted noise immission levels are shown for the proposed Development (unconstrained), the other windfarms considered as well as the cumulative total.

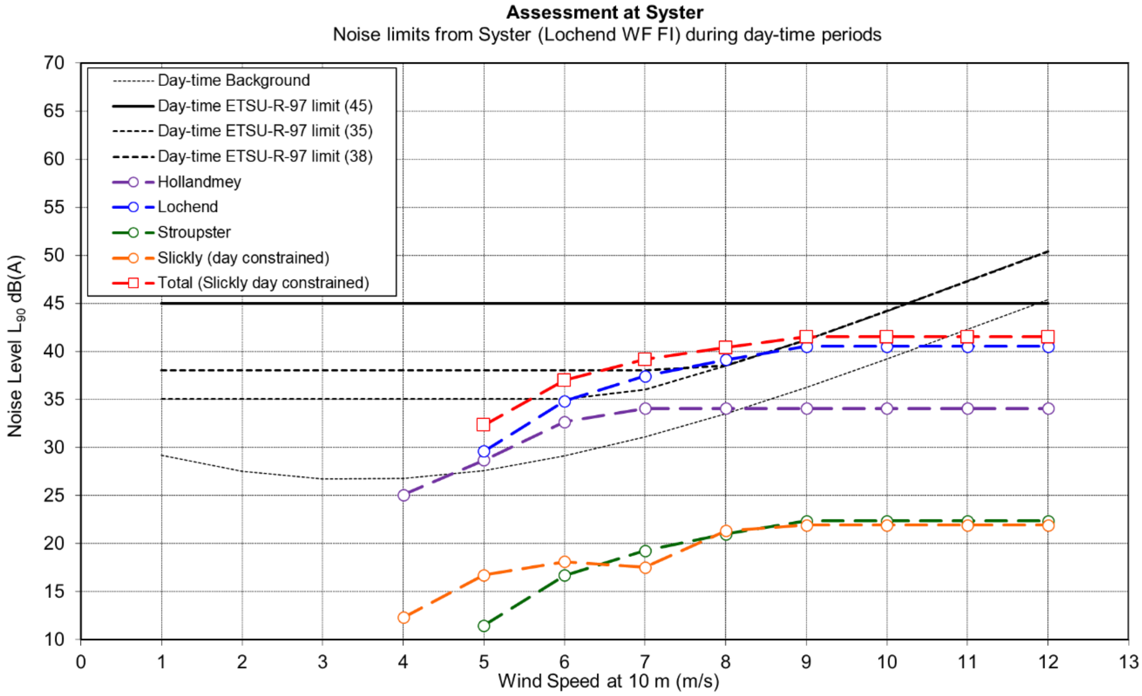
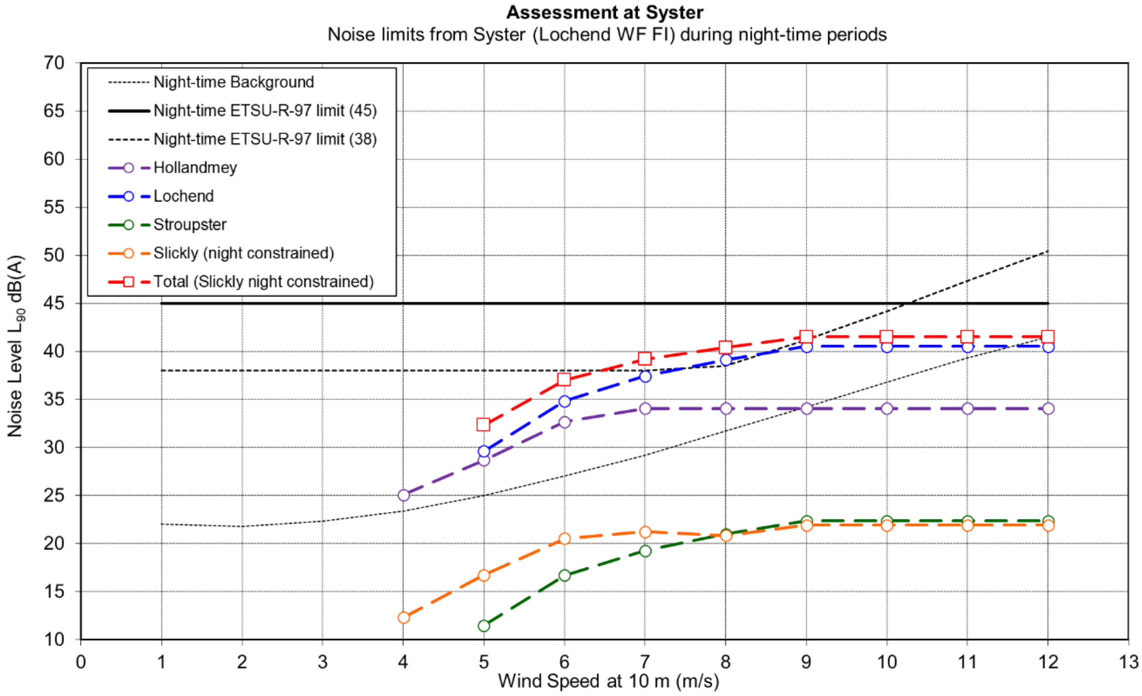


Figure D16 - Chart of both the 38 dB(A) non-financially involved and 45 dB(A) financially involved ETSU-R-97 based noise criteria / limit curves appropriate for the assessment location of Syster as well as background noise levels, during night-time periods. Predicted noise immission levels are shown for the proposed Development (unconstrained), the other windfarms considered as well as the cumulative total.



Annex E – Directional Predictions (Unconstrained)

Figure E1 - Chart of 38 dB(A) ETSU-R-97 based noise criteria / limit curve appropriate for the assessment location of Brabstermire House during day-time periods, as well as predicted noise immission levels shown by wind direction for the proposed Development (unconstrained), the other windfarms considered as well as the cumulative total. Data presented at a wind speed of 7 m/s.

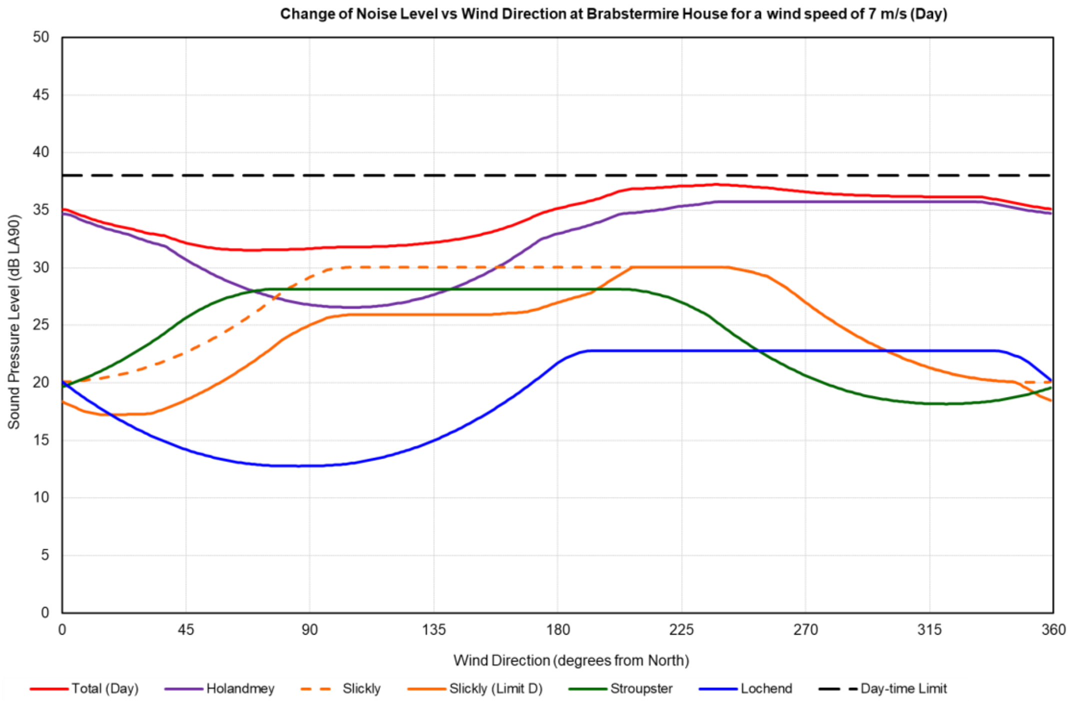


Figure E2 - Chart of 38 dB(A) ETSU-R-97 based noise criteria / limit curve appropriate for the assessment location of Brabstermire House during night-time periods, as well as predicted noise immission levels shown by wind direction for the proposed Development (unconstrained), the other windfarms considered as well as the cumulative total. Data presented at a wind speed of 7 m/s.

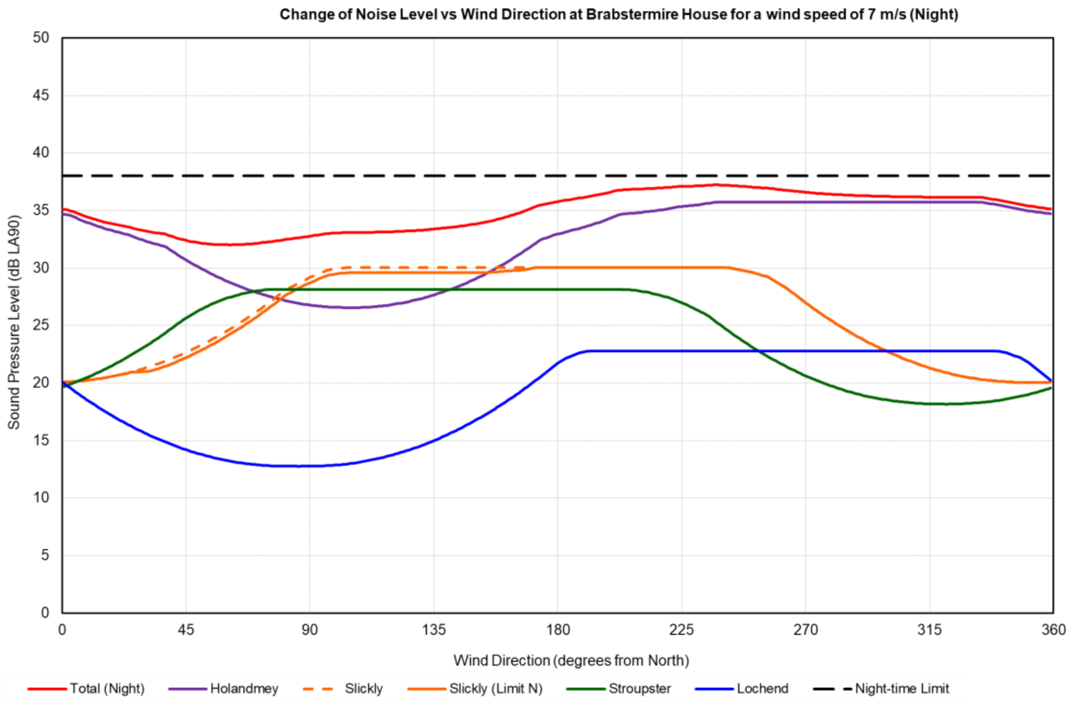


Figure E3 - Chart of 38 dB(A) ETSU-R-97 based noise criteria / limit curve appropriate for the assessment location of Brabstermire House during day-time periods, as well as predicted noise immission levels shown by wind direction for the proposed Development (unconstrained), the other windfarms considered as well as the cumulative total. Data presented at a wind speed of 8 m/s.

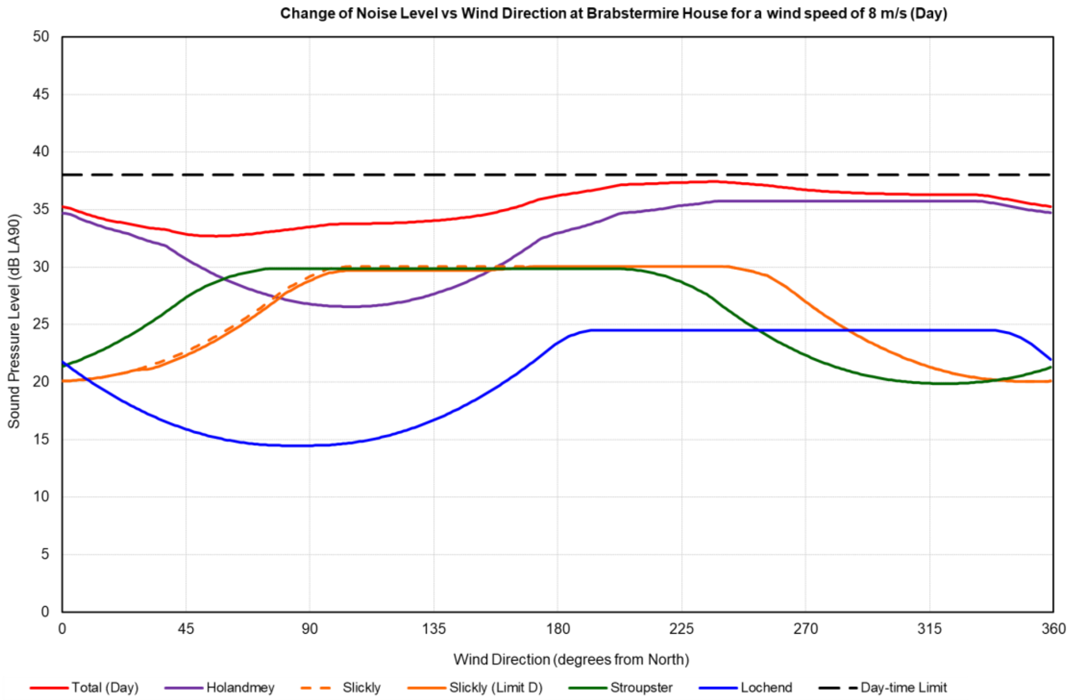


Figure E4 - Chart of 38 dB(A) ETSU-R-97 based noise criteria / limit curve appropriate for the assessment location of Brabstermire House during night-time periods, as well as predicted noise immission levels shown by wind direction for the proposed Development (unconstrained), the other windfarms considered as well as the cumulative total. Data presented at a wind speed of 8 m/s.

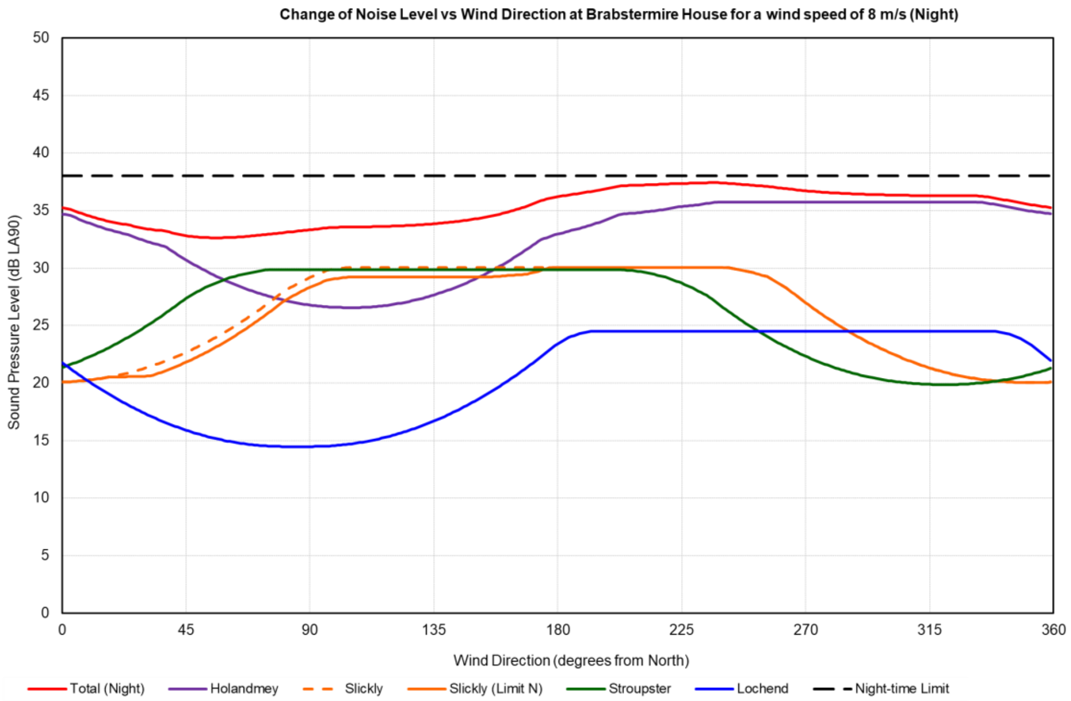


Figure E5 - Chart of 38 dB(A) ETSU-R-97 based noise criteria / limit curve appropriate for the assessment location of Lochend 10(1) during day-time periods, as well as predicted noise immission levels shown by wind direction for the proposed Development (unconstrained), the other windfarms considered as well as the cumulative total. Data presented at a wind speed of 7 m/s.

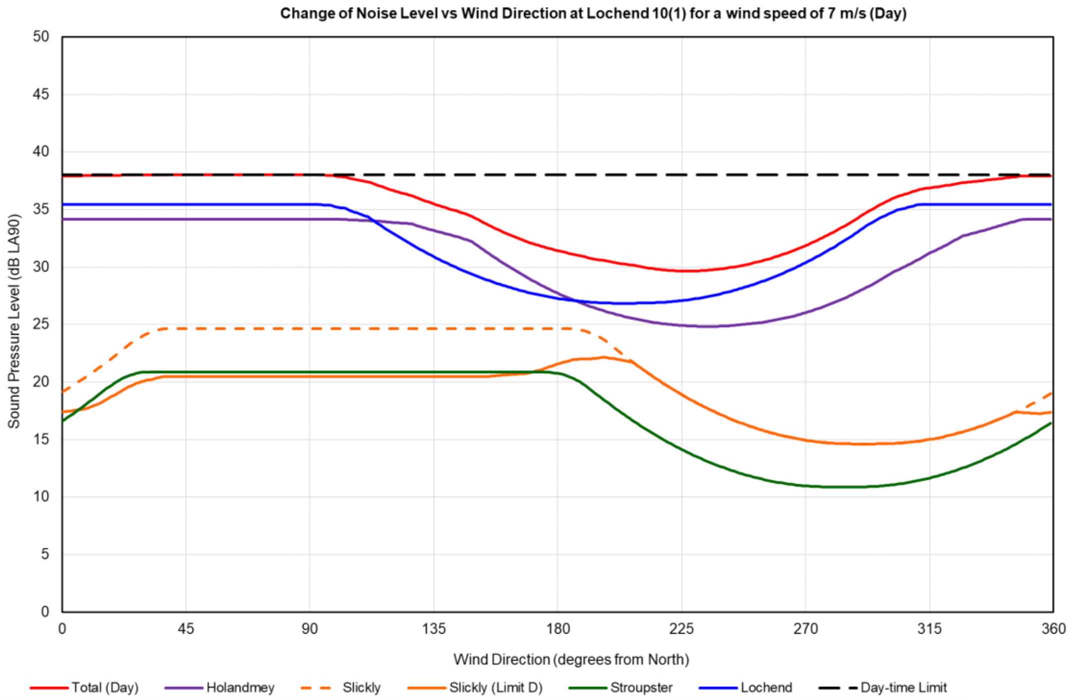


Figure E6 - Chart of 38 dB(A) ETSU-R-97 based noise criteria / limit curve appropriate for the assessment location of Lochend 10(1), during night-time periods, as well as predicted noise immission levels shown by wind direction for the proposed Development (unconstrained), the other windfarms considered as well as the cumulative total. Data presented at a wind speed of 7 m/s.

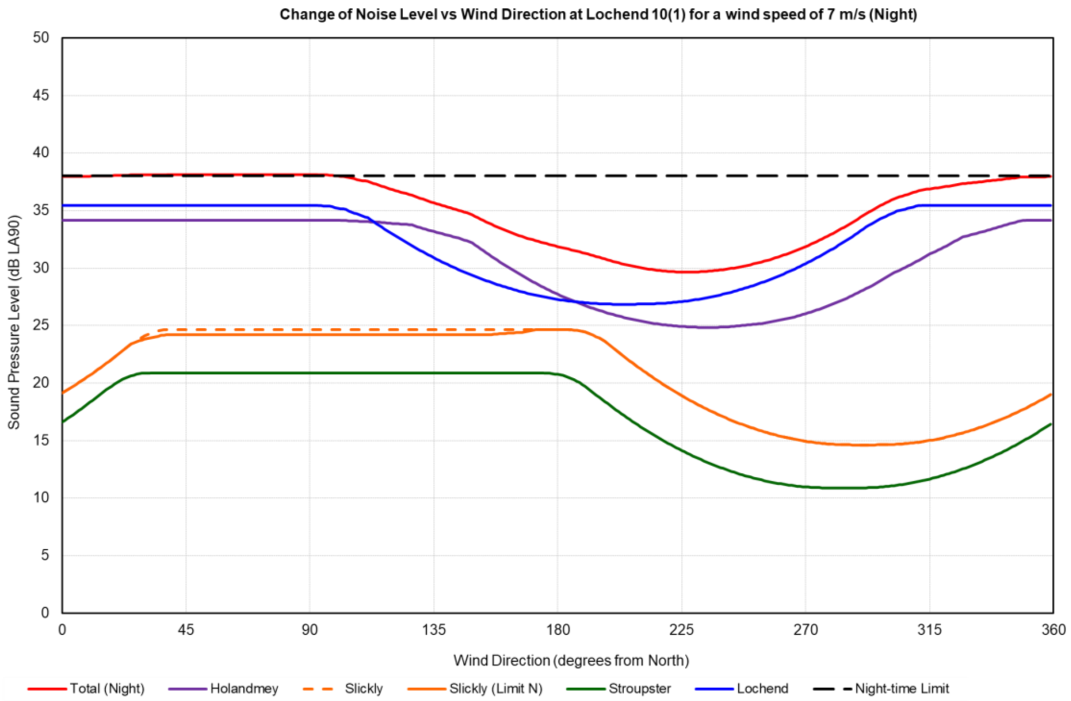


Figure E7 - Chart of 38 dB(A) ETSU-R-97 based noise criteria / limit curve appropriate for the assessment location of Lochend 10(1) during day-time periods, as well as predicted noise immission levels shown by wind direction for the proposed Development (unconstrained), the other windfarms considered as well as the cumulative total. Data presented at a wind speed of 8 m/s.

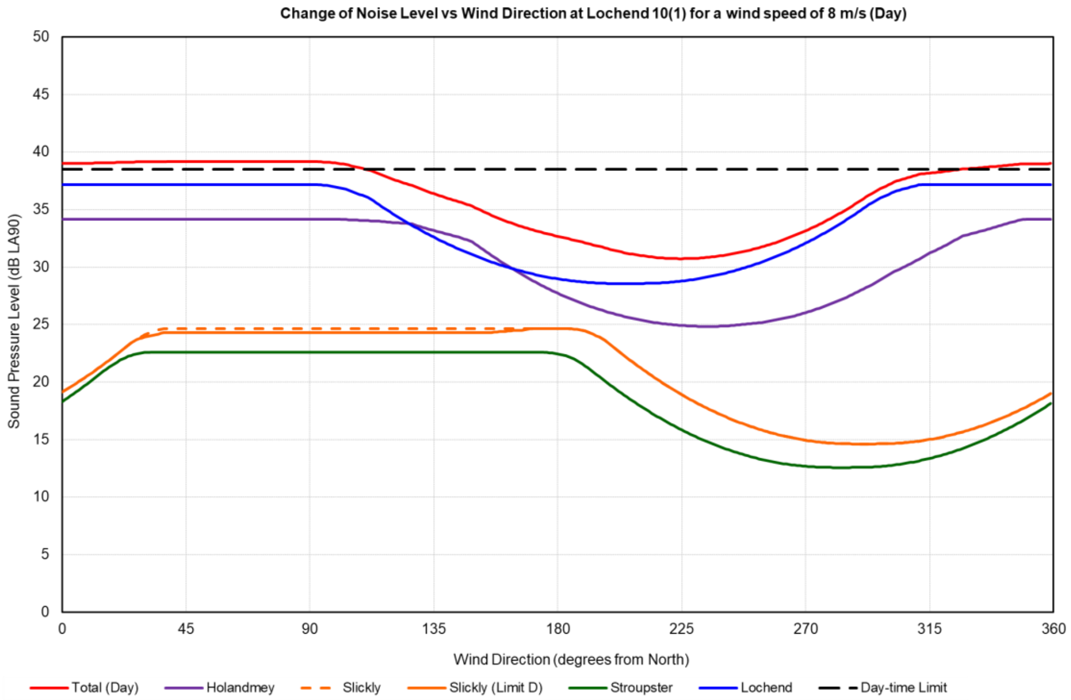


Figure E8 - Chart of 38 dB(A) ETSU-R-97 based noise criteria / limit curve appropriate for the assessment location of Lochend 10(1) during night-time periods, as well as predicted noise immission levels shown by wind direction for the proposed Development (unconstrained), the other windfarms considered as well as the cumulative total. Data presented at a wind speed of 8 m/s.

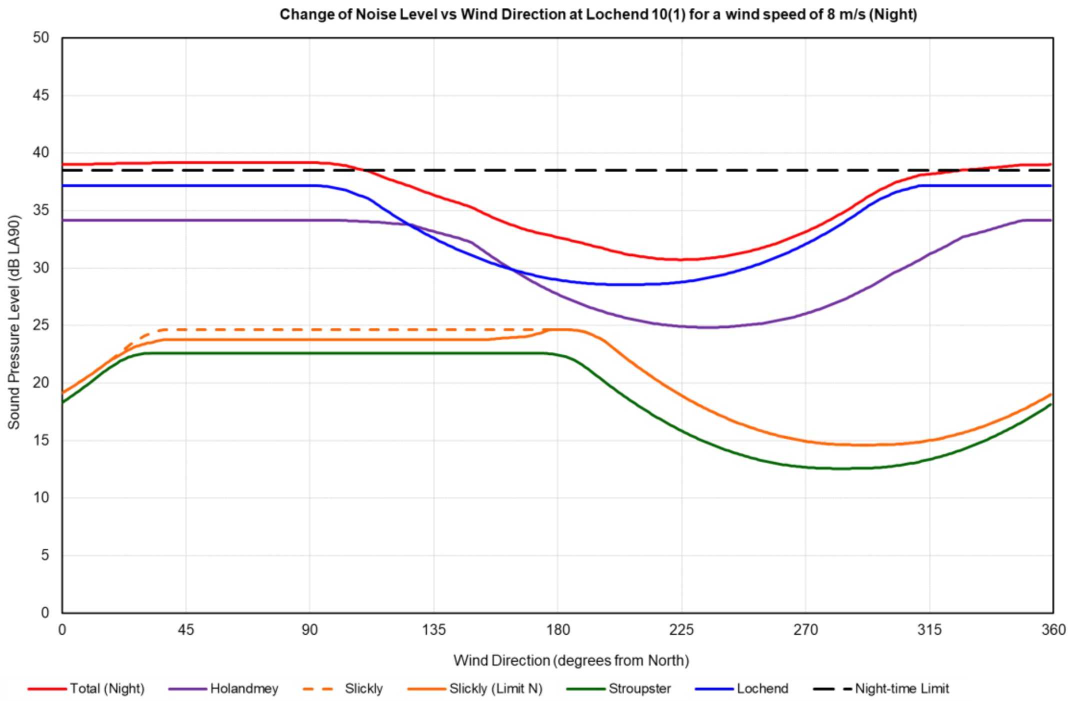


Figure E9 - Chart of 38 dB(A) ETSU-R-97 based noise criteria / limit curve appropriate for the assessment location of Lochend New Build during day-time periods, as well as predicted noise immission levels shown by wind direction for the proposed Development (unconstrained), the other windfarms considered as well as the cumulative total. Data presented at a wind speed of 7 m/s.

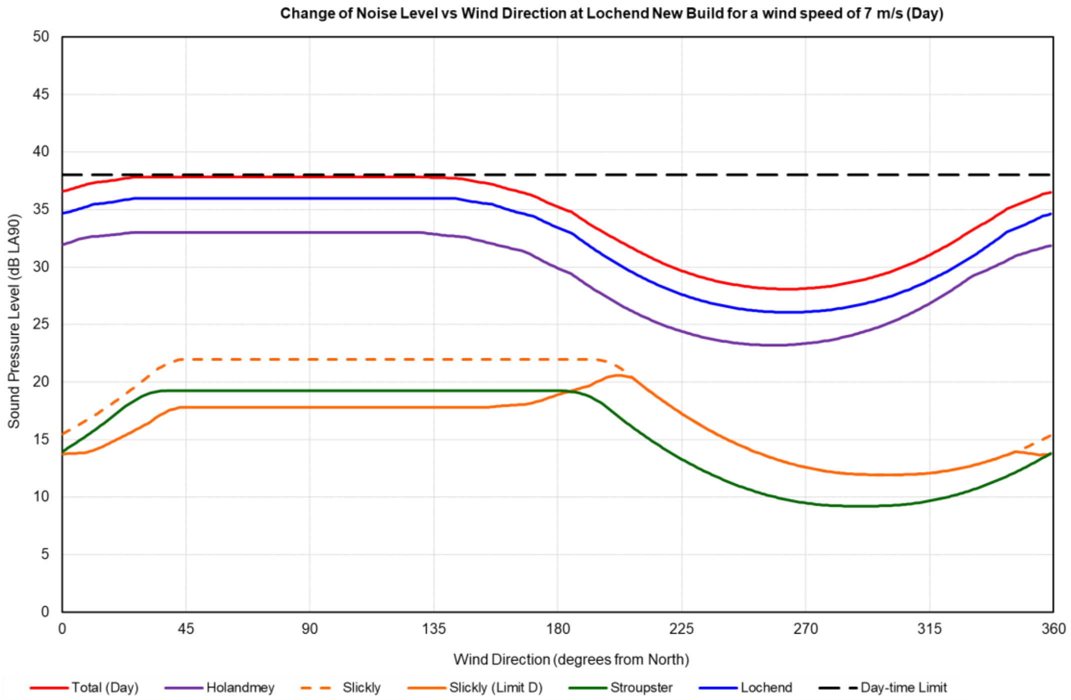


Figure E10 - Chart of 38 dB(A) ETSU-R-97 based noise criteria / limit curve appropriate for the assessment location of Lochend New Build during night-time periods, as well as predicted noise immission levels shown by wind direction for the proposed Development (unconstrained), the other windfarms considered as well as the cumulative total. Data presented at a wind speed of 7 m/s.

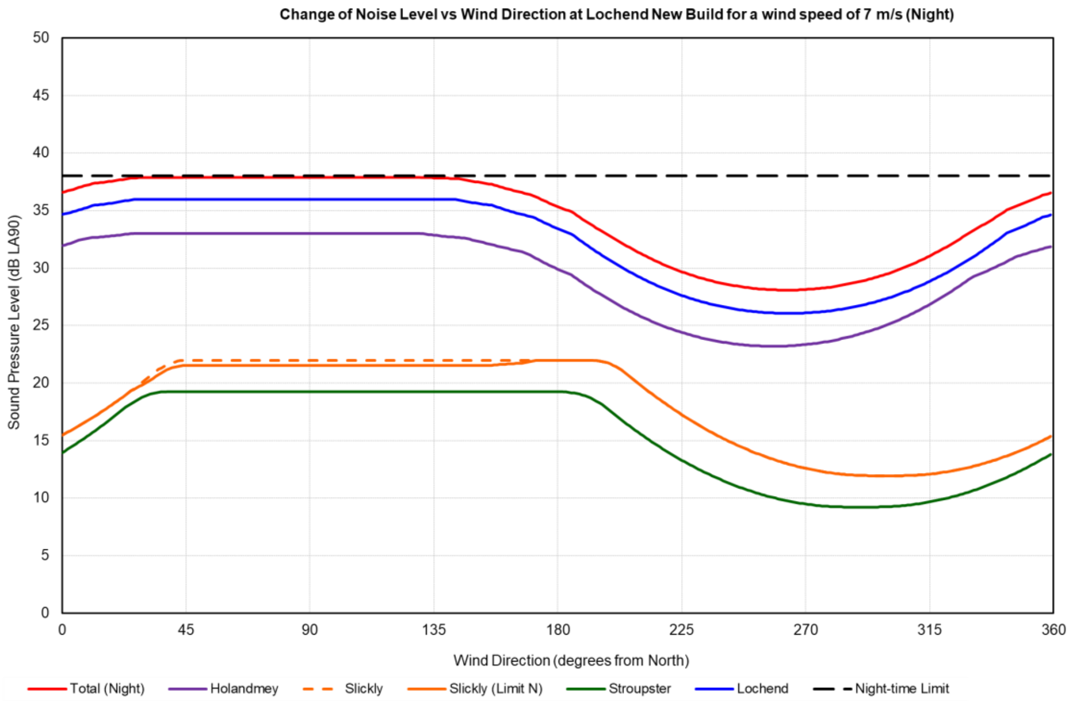


Figure E11 - Chart of 38 dB(A) ETSU-R-97 based noise criteria / limit curve appropriate for the assessment location of Lochend New Build during day-time periods, as well as predicted noise immission levels shown by wind direction for the proposed Development (unconstrained), the other windfarms considered as well as the cumulative total. Data presented at a wind speed of 8 m/s.

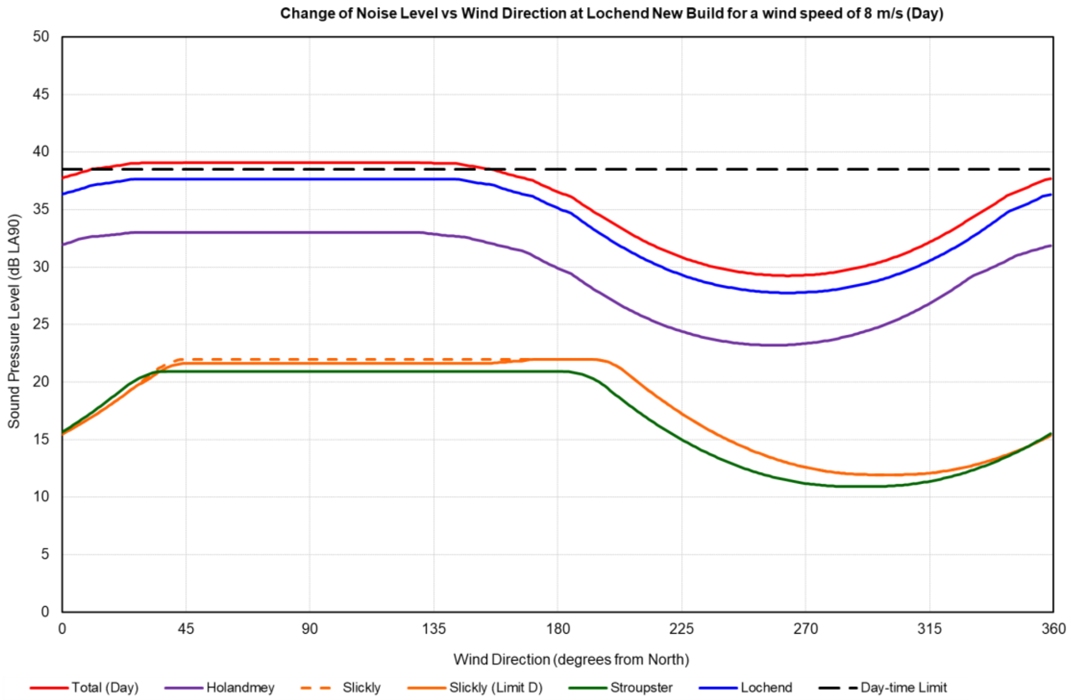


Figure E12 - Chart of 38 dB(A) ETSU-R-97 based noise criteria / limit curve appropriate for the assessment location of Lochend New Build during night-time periods, as well as predicted noise immission levels shown by wind direction for the proposed Development (unconstrained), the other windfarms considered as well as the cumulative total. Data presented at a wind speed of 8 m/s.

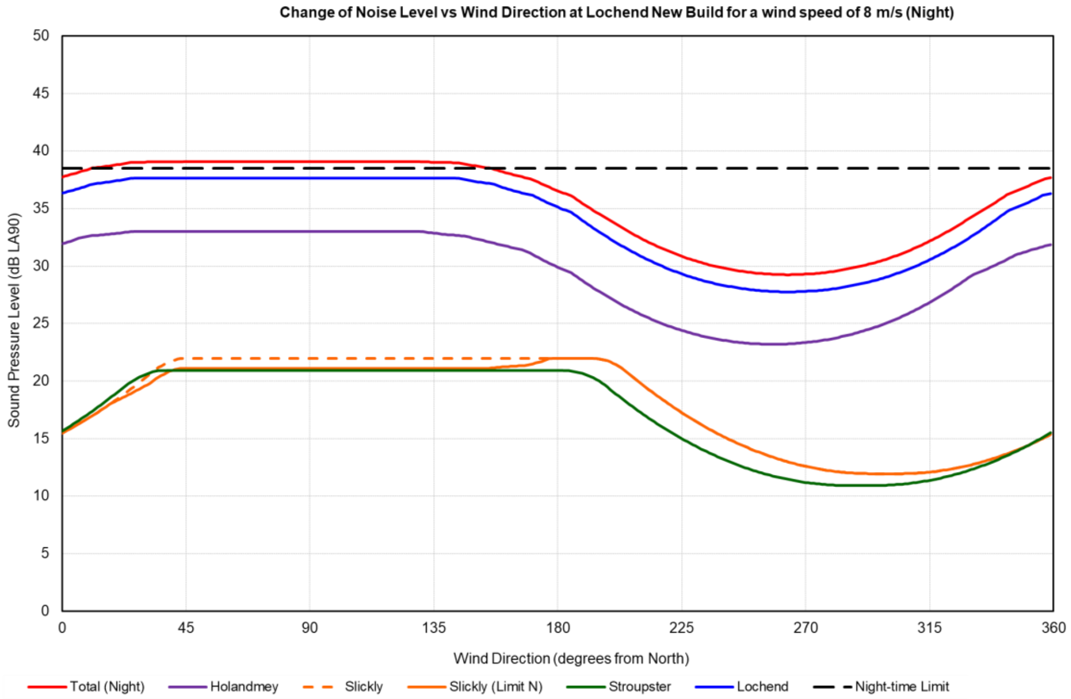


Figure E13 - Chart of 38 dB(A) ETSU-R-97 based noise criteria / limit curve appropriate for the assessment location of Slickly Croft during day-time periods, as well as predicted noise immission levels shown by wind direction for the proposed Development (unconstrained), the other windfarms considered as well as the cumulative total. Data presented at a wind speed of 7 m/s.

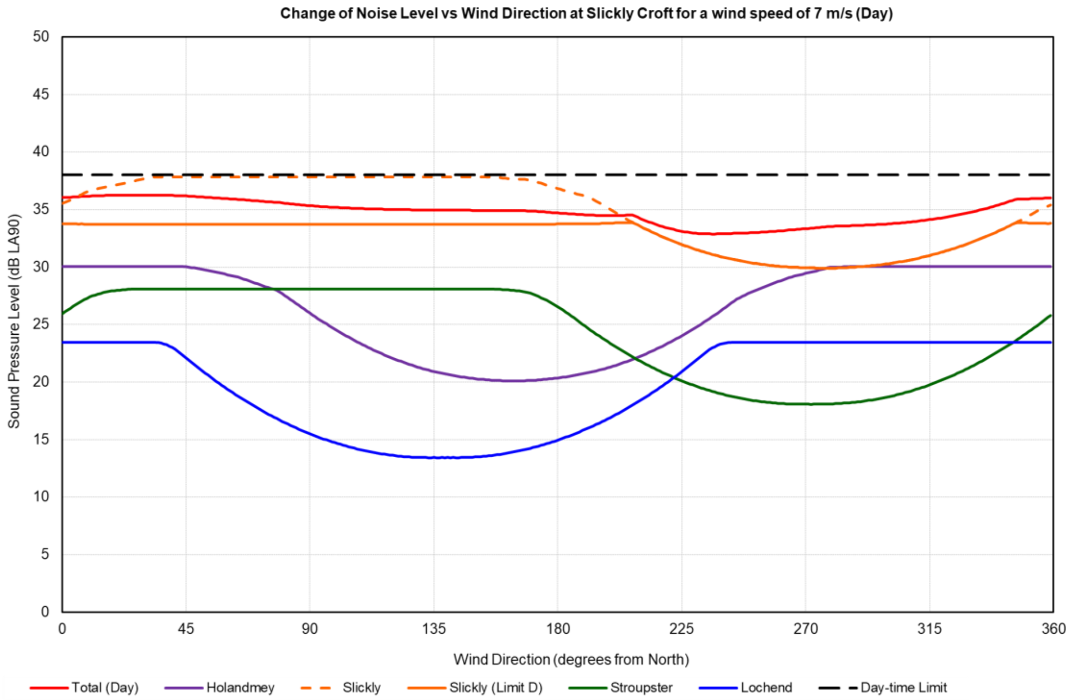


Figure E14 - Chart of 38 dB(A) ETSU-R-97 based noise criteria / limit curve appropriate for the assessment location of Slickly Croft during night-time periods, as well as predicted noise immission levels shown by wind direction for the proposed Development (unconstrained), the other windfarms considered as well as the cumulative total. Data presented at a wind speed of 7 m/s.

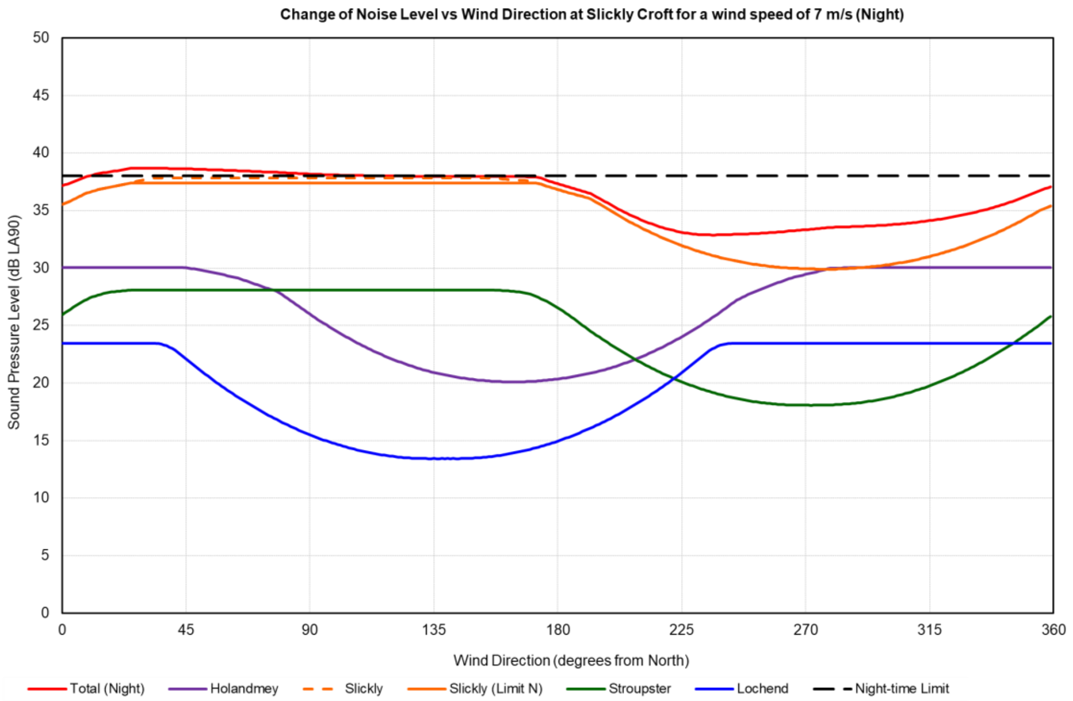


Figure E15 - Chart of 38 dB(A) ETSU-R-97 based noise criteria / limit curve appropriate for the assessment location of Slickly Croft during day-time periods, as well as predicted noise immission levels shown by wind direction for the proposed Development (unconstrained), the other windfarms considered as well as the cumulative total. Data presented at a wind speed of 8 m/s.

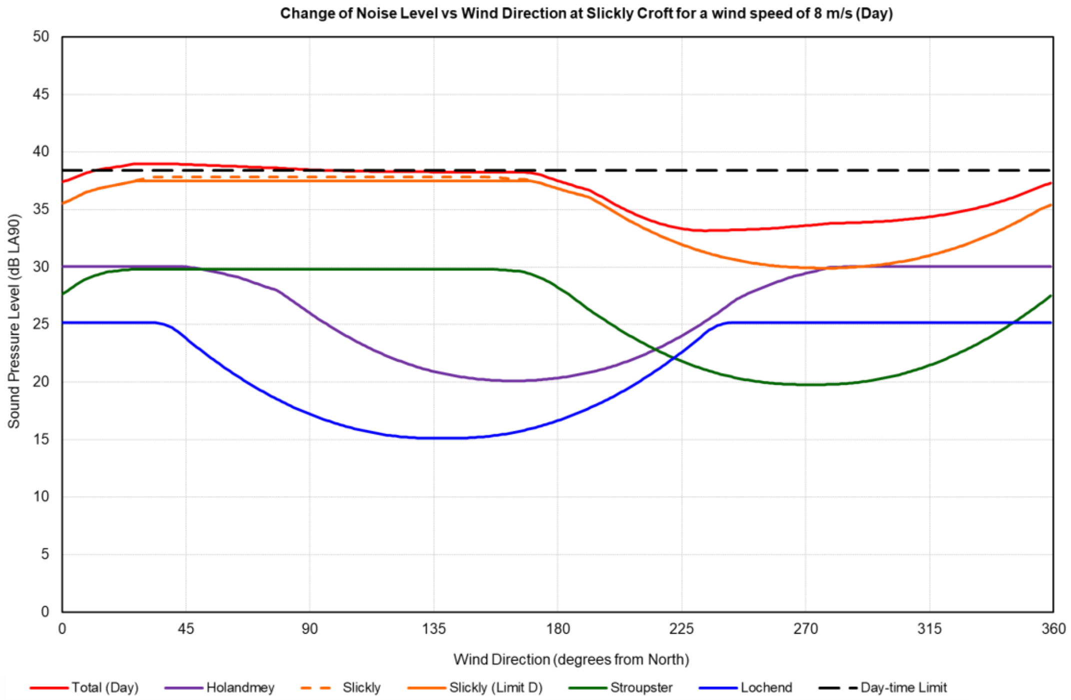


Figure E16 - Chart of 38 dB(A) ETSU-R-97 based noise criteria / limit curve appropriate for the assessment location of Slickly Croft during night-time periods, as well as predicted noise immission levels shown by wind direction for the proposed Development (unconstrained), the other windfarms considered as well as the cumulative total. Data presented at a wind speed of 8 m/s.

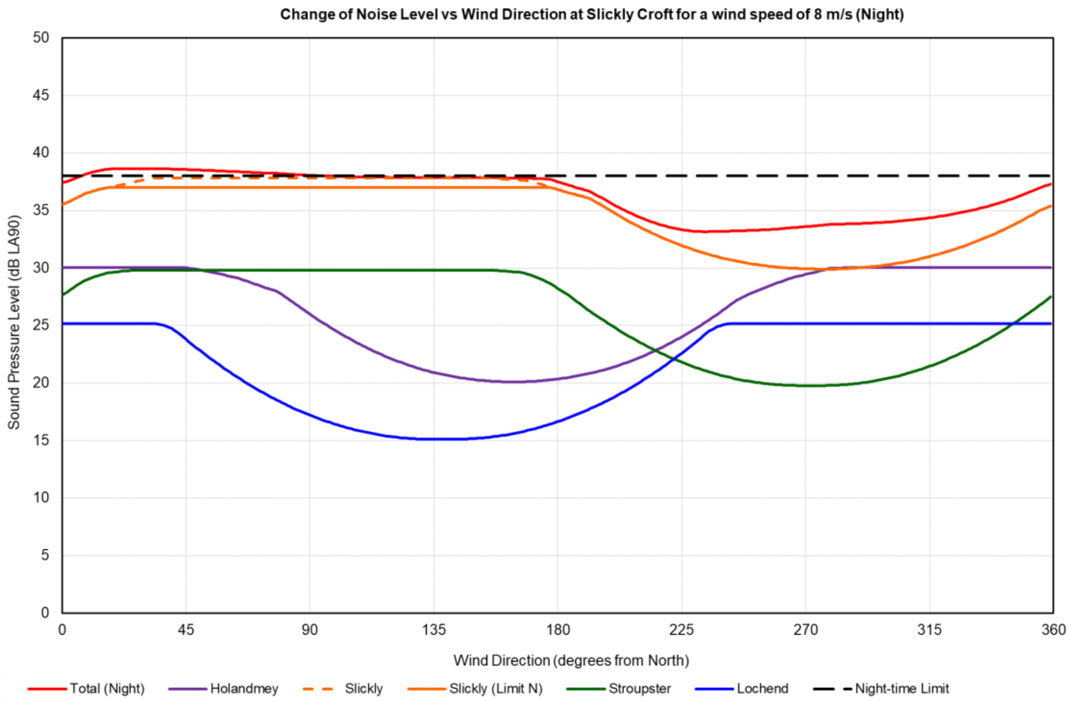


Figure E17 - Chart of 38 dB(A) ETSU-R-97 based noise criteria / limit curve appropriate for the assessment location of Slickly (Nearest) during day-time periods, as well as predicted noise immission levels shown by wind direction for the proposed Development (unconstrained), the other windfarms considered as well as the cumulative total. Data presented at a wind speed of 7 m/s.

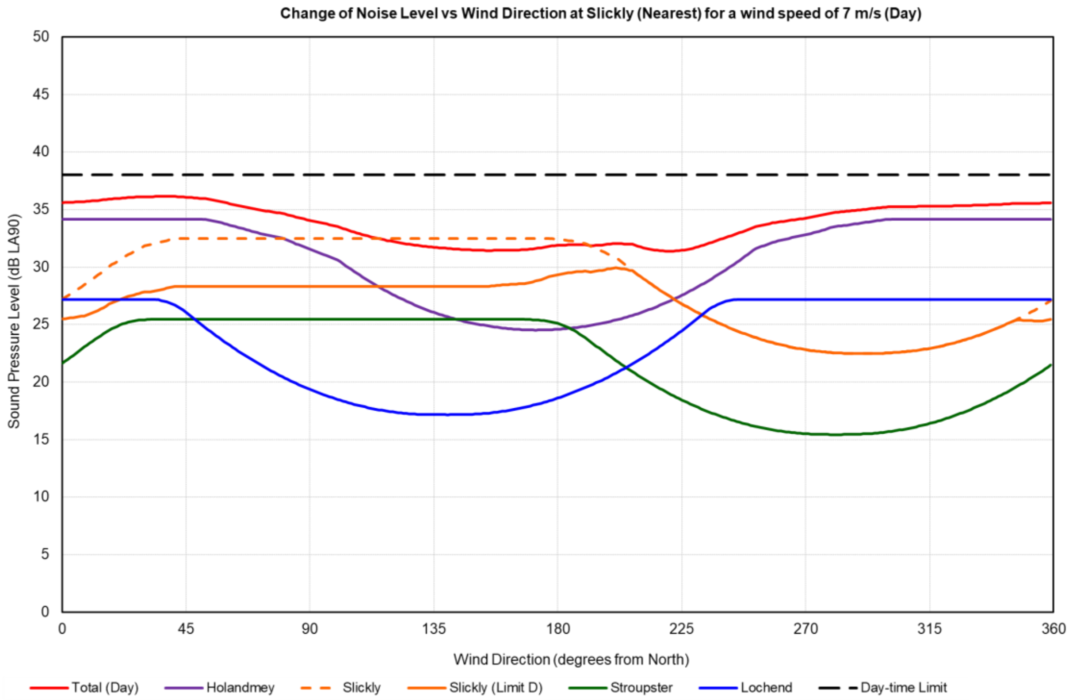


Figure E18 - Chart of 38 dB(A) ETSU-R-97 based noise criteria / limit curve appropriate for the assessment location of Slickly (Nearest) during night-time periods, as well as predicted noise immission levels shown by wind direction for the proposed Development (unconstrained), the other windfarms considered as well as the cumulative total. Data presented at a wind speed of 7 m/s.

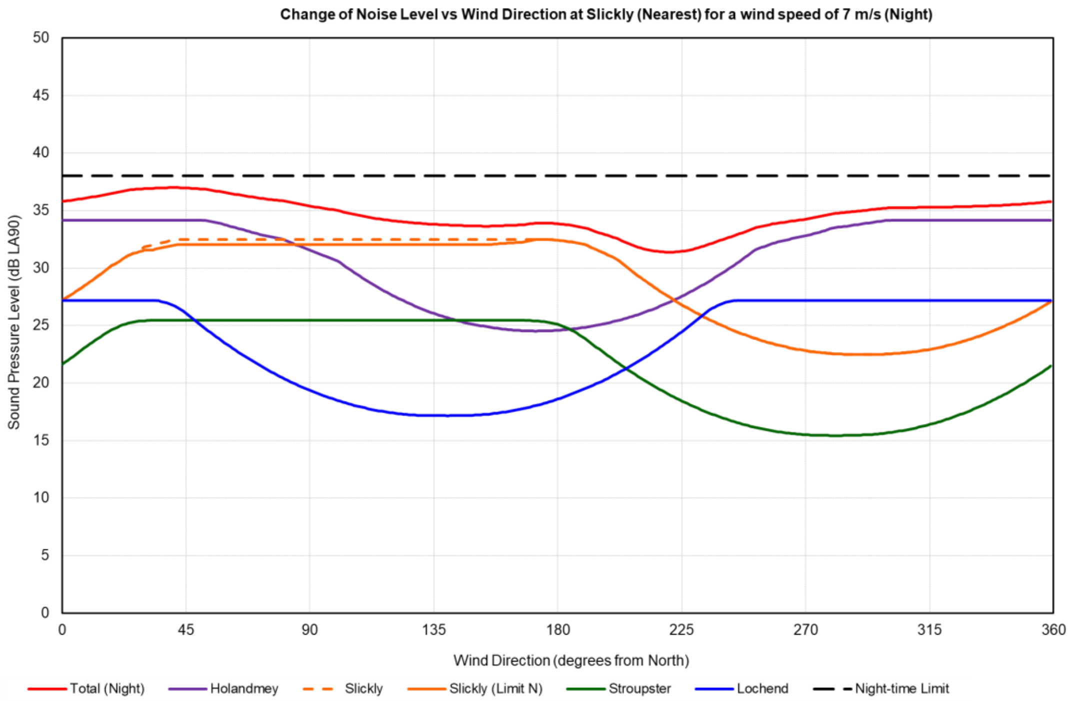


Figure E19 - Chart of 38 dB(A) ETSU-R-97 based noise criteria / limit curve appropriate for the assessment location of Slickly (Nearest) during day-time periods, as well as predicted noise immission levels shown by wind direction for the proposed Development (unconstrained), the other windfarms considered as well as the cumulative total. Data presented at a wind speed of 8 m/s.

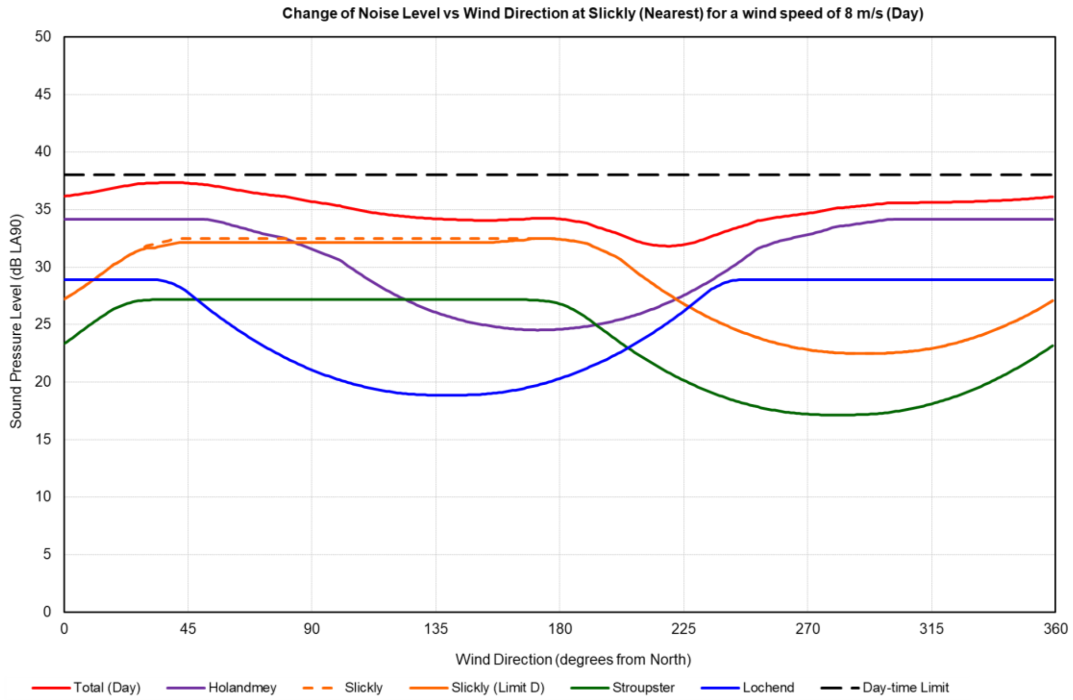
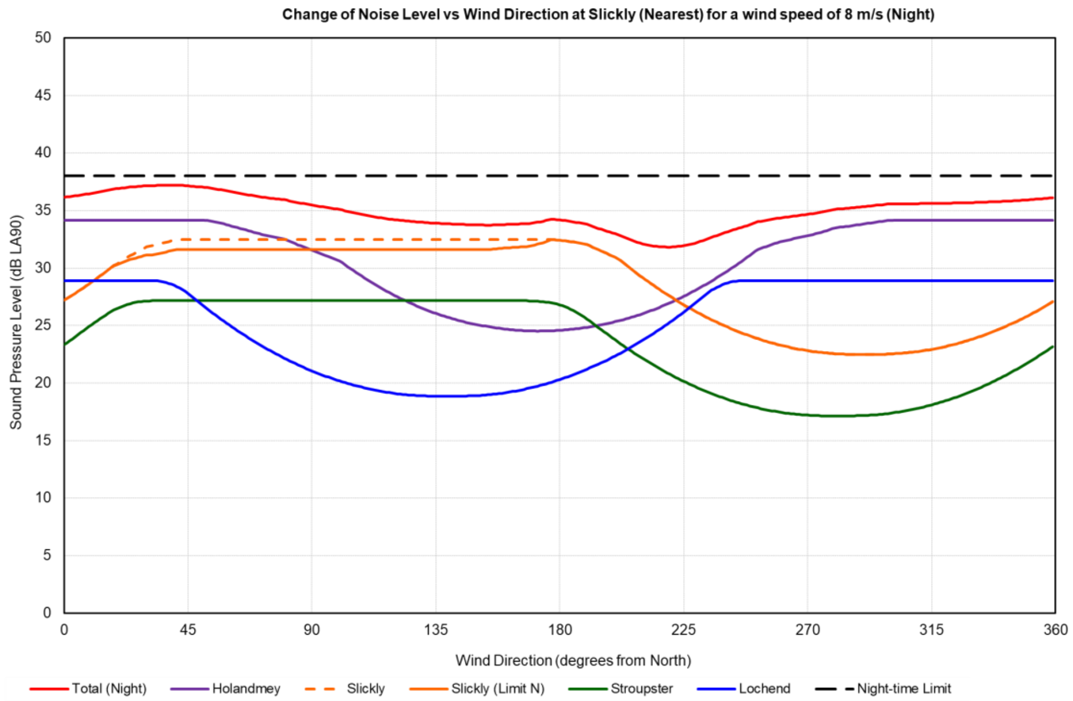


Figure E20 - Chart of 38 dB(A) ETSU-R-97 based noise criteria / limit curve appropriate for the assessment location of Slickly (Nearest) during night-time periods, as well as predicted noise immission levels shown by wind direction for the proposed Development (unconstrained), the other windfarms considered as well as the cumulative total. Data presented at a wind speed of 8 m/s.



Annex F – Predicted Noise and Noise Limits/Criteria (Constrained)

Figure F1 - Chart of both the 35 dB(A) and 38 dB(A) ETSU-R-97 based noise criteria / limit curves appropriate for the assessment location of Lochend 10(1) as well as background noise levels, during day-time periods. Predicted noise immission levels are shown for the proposed Development (constrained), the other windfarms considered as well as the cumulative total.

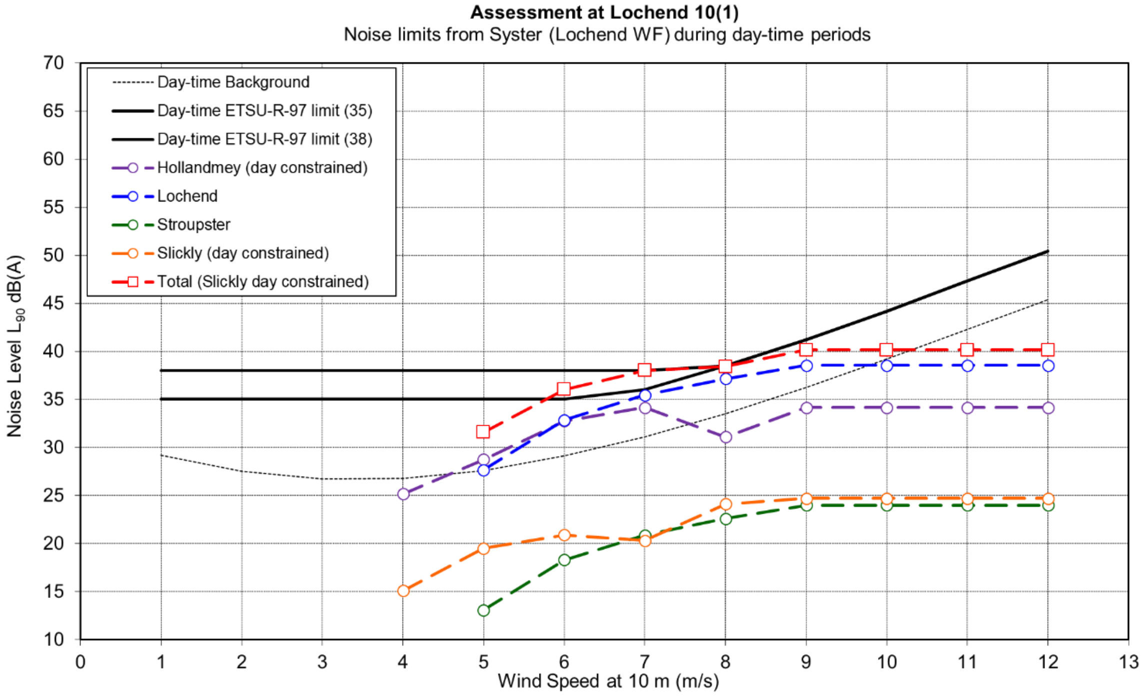


Figure F2 - Chart of the 38 dB(A) ETSU-R-97 based noise criteria / limit curve appropriate for the assessment location of Lochend 10(1) as well as background noise levels, during night-time periods. Predicted noise immission levels are shown for the proposed Development (constrained), the other windfarms considered as well as the cumulative total.

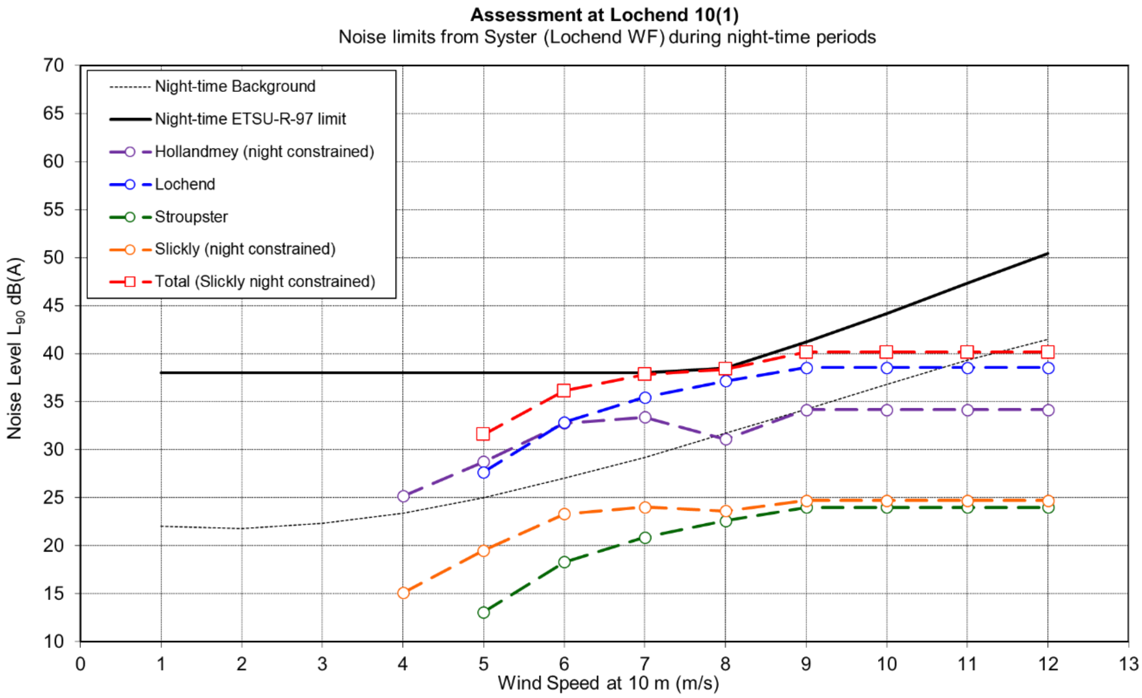


Figure F3 - Chart of both the 35 dB(A) and 38 dB(A) ETSU-R-97 based noise criteria / limit curves appropriate for the assessment location of Lochend New Build as well as background noise levels, during day-time periods. Predicted noise immission levels are shown for the proposed Development (constrained), the other windfarms considered as well as the cumulative total.

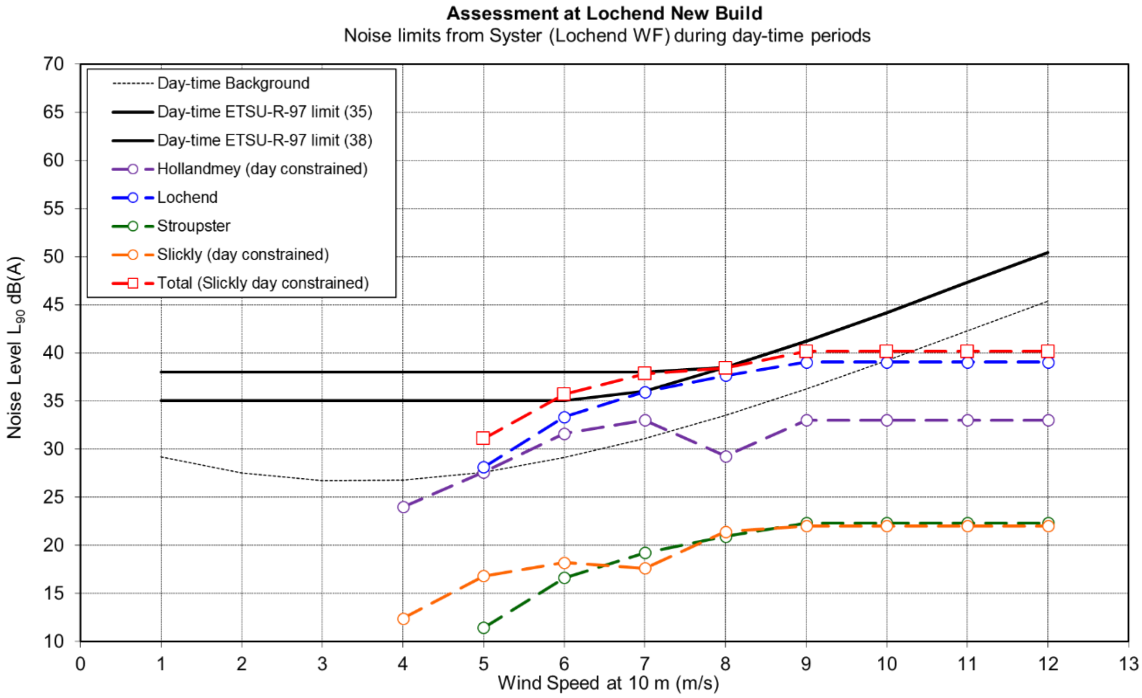


Figure F4 - Chart of the 38 dB(A) ETSU-R-97 based noise criteria / limit curve appropriate for the assessment location of Lochend New Build as well as background noise levels, during night-time periods. Predicted noise immission levels are shown for the proposed Development (constrained), the other windfarms considered as well as the cumulative total.

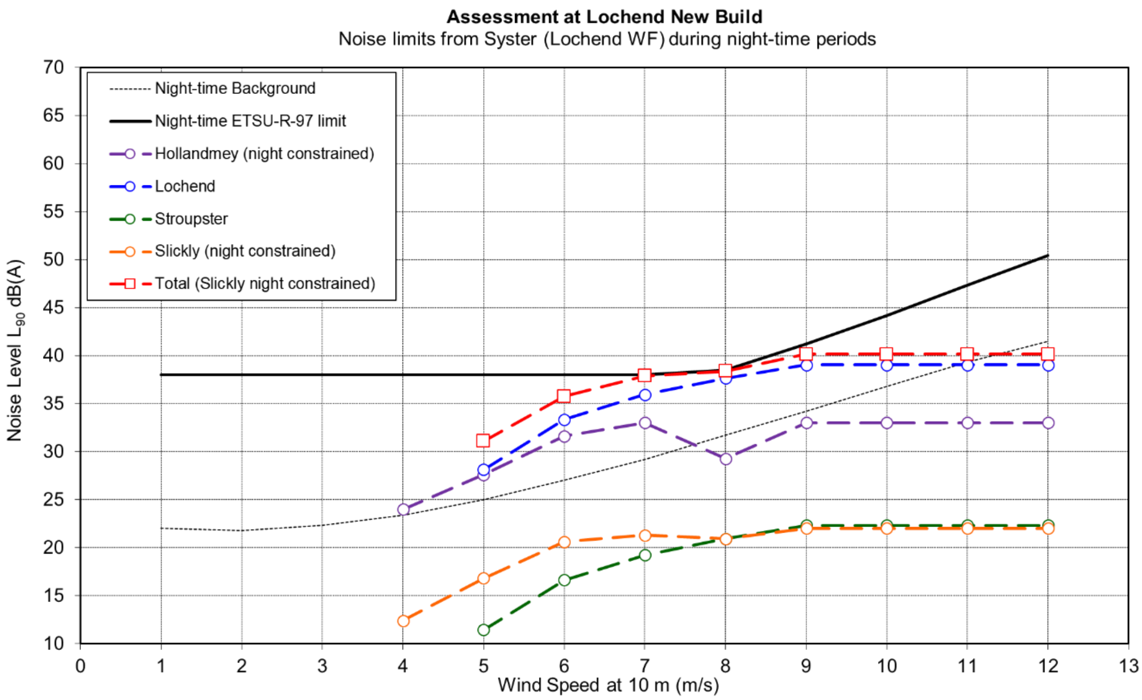


Figure F5 - Chart of both the 35 dB(A) and 38 dB(A) ETSU-R-97 based noise criteria / limit curves appropriate for the assessment location of Slickly Croft as well as background noise levels, during day-time periods. Predicted noise immission levels are shown for the proposed Development (constrained), the other windfarms considered as well as the cumulative total.

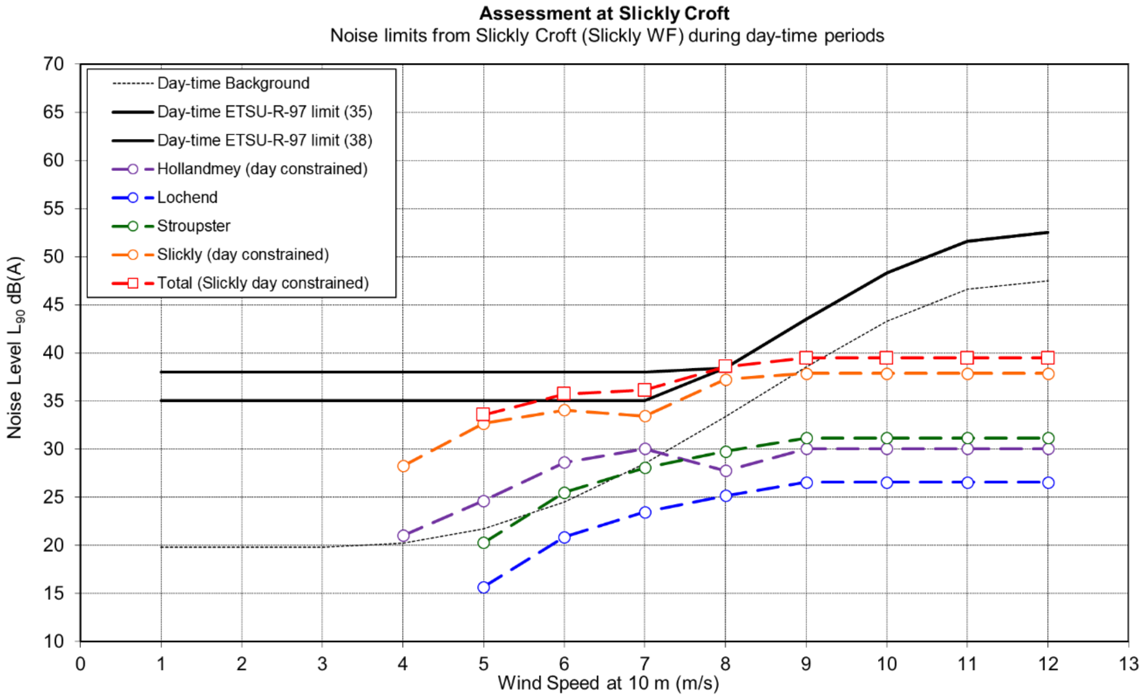
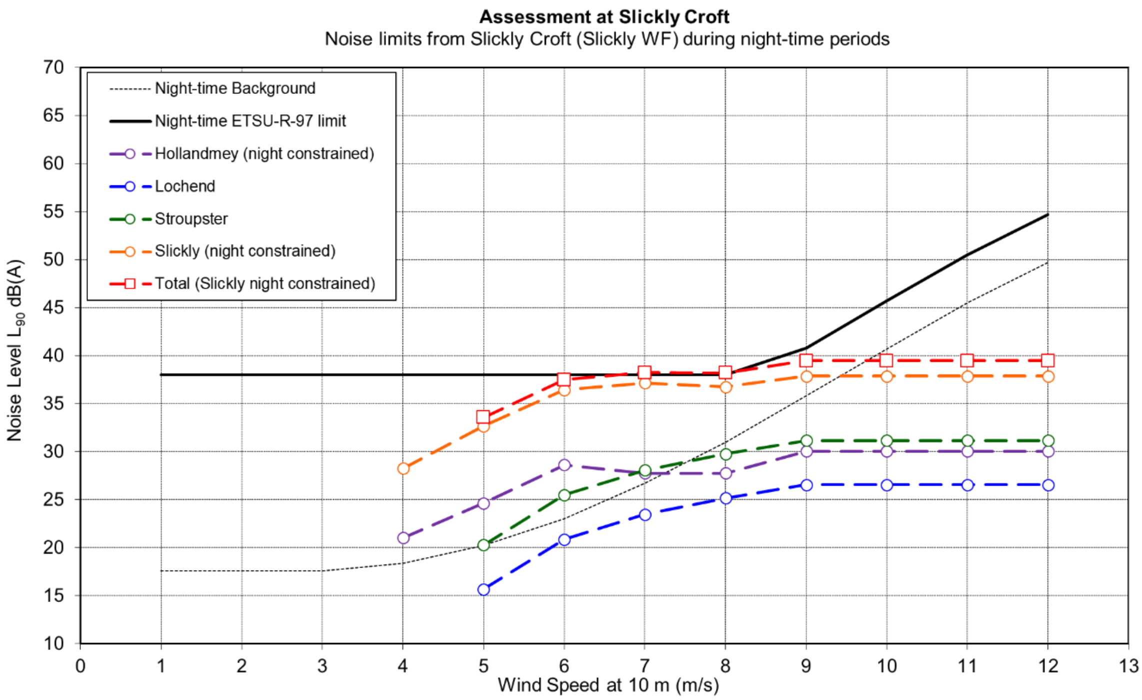


Figure F6 - Chart of the 38 dB(A) ETSU-R-97 based noise criteria / limit curve appropriate for the assessment location of Slickly Croft as well as background noise levels, during night-time periods. Predicted noise immission levels are shown for the proposed Development (constrained), the other windfarms considered as well as the cumulative total.



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