HOARE LEA

Hare Hill Windfarm Repowering & Extension.

Appendix 13.1 Environmental Noise Assessment.

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Contents.

Executive Summary

Hoare Lea (HL) have been commissioned by ScottishPower Renewables (UK) Limited to undertake a noise assessment for the construction and operation of the proposed Hare Hill Windfarm Repowering and Extension (the proposed Development) Environmental Impact Assessment (EIA). The proposed Development will replace and extend the existing Hare Hill Windfarm (HH) and the Hare Hill Windfarm Extension (HHE) in two phases. Phase one of the proposed Development will replace and extend the wind turbines on HH and these would operate together with the existing wind turbines on HHE. Phase two of the proposed Development will complete the development by replacing and extending the wind turbines on HHE. Noise will be emitted by equipment and vehicles used during construction and decommissioning of the windfarm and by the turbines during operation. The level of noise emitted by the sources and the distance from those sources to the receiver locations are the main factors determining levels of noise at receptor locations.

Construction Noise

Construction noise has been assessed by a desk-based study of a potential construction programme and by assuming the proposed development is constructed using standard and common methods. Noise levels have been calculated for receiver locations closest to the areas of work and compared with guideline and baseline values. Construction noise, by its very nature, tends to be temporary and highly variable and therefore much less likely to cause adverse effects. Factors including in particular the restrictions of hours of working have been taken into consideration. It is concluded that noise generated through construction activities would have a minor impact and considered not significant in EIA terms.

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

Operational Noise

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

Noise levels from operation of the turbines have been predicted for those locations around the Site most likely to be affected by noise. Noise surveys for adjacent wind energy developments have already sufficiently established existing baseline noise levels at a number of these properties. Noise limits have been derived from data about the existing noise environment following the method stipulated in national planning guidance. Predicted noise levels take full account of the potential combined effect of the noise from the proposed Development along with Afton Windfarm (operational), Pencloe Windfarm (consented), Sanqhuar Windfarm (operational), Sanquhar II Windfarm (consented), Sandy Knowe Windfarm (operational), Sandy Knowe Windfarm Extension (Proposed) and the single wind turbine at High Park Farm (operational). 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 proposed Development will be within levels recommended in national guidance for wind energy schemes.

The proposed Development would also include a substation, 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 Executive Summary until this report has been read in its entirety.

1. Introduction

1.1 This report presents an assessment of the potential construction and operational noise impacts of the Hare Hill Repowering and Extension EIA (the proposed Development) on the residents of nearby dwellings. The proposed Development will replace and extend the existing HH and HHE in two phases, comprising up to 23 wind turbines once both phases are completed. There are a number of existing operational wind turbines located within the Site of the proposed Development, related to the operational HH and HHE. Phase one of the proposed Development will replace and extend the wind turbines on HH and these would operate together with the existing wind turbines on HHE. Phase two of the proposed Development will complete the development by replacing and extending the wind turbines on HHE.

1.2 The assessment considers both the construction and operation of the proposed Development and also the likely impacts of its de-commissioning. Assessment of the operational noise accounts for the cumulative effect of the proposed Development as well as other windfarms nearby. Phase one of the proposed Development would operate cumulatively with the existing wind turbines on HHE as one complete windfarm. Other windfarms considered cumulatively were those closest and consisted of: Afton Windfarm (operational, approximately 3.3 km south west), Pencloe Windfarm (consented approximately 4 km south west), Sanqhuar Windfarm (operational, adjacent to the south east), Sanquhar II Windfarm (consented, adjacent to the south), Sandy Knowe Windfarm (operational, adjacent to the east), Sandy Knowe Windfarm Extension (proposed, adjacent to the east) and the single wind turbine at High Park Farm (operational, approximately 2.2 km north west). Other, more distant windfarms were not considered because their potential noise contribution was not considered acoustically important. The proposed Development would also include a substation which would emit some noise during operation (e.g. electrical plant and air conditioning systems).

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

1.4 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.

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

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

2. Policy and Guidance Documents

2.1 Planning Policy and Advice Relating to Noise

2.1.1 The Scottish National Planning Framework 4 (NPF4)[1] provides advice on how the planning system should manage the process of encouraging, approving and implementing renewable energy proposals including onshore windfarms. NPF4 suggests that renewable energy developments must demonstrate how impacts including noise are to be addressed through design and mitigation, going on to advise that *"In considering these impacts, significant weight will be placed on the contribution of the proposal to renewable energy generation targets and on greenhouse gas emissions reduction targets."*; however, NPF4 provides no specific advice on noise. Planning Advice Note PAN1/2011[2] provides general advice on the role of the planning system in preventing and limiting the adverse effects of noise without prejudicing investment in enterprise, development and transport. PAN1/2011 provides general advice on a range of noise related planning matters, including references to noise associated with both construction activities and operational 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[3] provides further advice on noise and confirms that the recommendations of 'The Assessment and Rating of Noise from Wind Farms' (ETSU-R-97)[4] *"should be followed by applicants and consultees, and used by planning authorities to assess and rate noise from wind energy developments"*. The aim of ETSU-R-97 is:

> *'This document describes a framework for the measurement of windfarm noise and gives indicative noise levels thought to offer a reasonable degree of protection to windfarm neighbours, without placing unreasonable restrictions on windfarm development or adding unduly to the costs and administrative burdens on windfarm 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 windfarm 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

1 Scottish National Planning Framework 4, Scottish Government. Adopted 13 February 2023 (updated 2024).
2 Planning Advice Note 1/2011: Planning & Noise, Scottish Government, March 2011.
3 Scottish Government, Online Renewables Planning Advice, Onshore Wind Turbines (https://www.gov.scot/publications/onshore-wind-turbines-planning-advice). Updated 28 May 2014.
4 ETSU-R-97, the Assessment and Rating of Noise from Wind Farms, Final ETSU-R-97 Report for the Department of Trade & Industry. The Working Group on Noise from Wind Turbines, 1997.

within the UK. Guidance on good practice on the application of ETSU-R-97 has been provided by the Institute of Acoustics (IOA Good Practice Guide or GPG)[5]. This was subsequently endorsed by the Scottish Government[6] which advised in the Online Renewables Planning Advice on Onshore Wind Turbines 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 Renewables Planning Advice 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 The Scottish Government Onshore Wind Policy Statement 2022[7] mentions the potential for the advice in ETSU-R-97 to be modified in future based on a review from the UK Government, but continues to support its use in the meantime, confirming the advice from the Online Renewables Planning Advice set out above. Although a report on this topic commissioned by the UK Government has been published (WSP BEIS Report)[8], its recommendations for updates to some aspects of the ETSU-R-97 methodology will need to be considered by the national governments. The WSP BEIS report does not provide a replacement or update to ETSU-R-97 and until it is replaced or updated, the Scottish Government has confirmed in the Onshore Wind Policy Statement 2022 that the ETSU-R-97 methodology continues to be applicable. Although the UK Government published in July 2025[9] a draft for consultation of a revision of the ETSU-R-97 guidelines, it noted that this draft guidance should not be used until a response to this consultation is published.

2.1.6 For assessing noise from non-wind turbines sources associated with the proposed Development, such as fixed plant associated with the substation, PAN1/2011 advises the use of the BS 4142 standard. Although PAN1/2011 references the 1997 version of the standard, the more recent 2019 version[10] is now applicable.

2.1.7 PAN1/2011 and the Technical Advice Note[11] 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[12]. The CoPA provides two means of controlling construction noise and vibration. Section 60 provides the Local Authority with the power to impose at any time operating conditions on the development site. Section 61 allows the developer to negotiate a prior consent for a set of operating procedures with the Local Authority before commencement of site works.

2.1.8 For detailed guidance on construction noise and its control, the Technical Advice Note refers to British Standard BS 5228[13] '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)[14] (BS 5228-1) for airborne noise and BS 5228-2: 2009 (amended 2014)[15] (BS 5228-2)

5 A Good Practice Guide to the Application of ETSU-R-97 for the Assessment and Rating of Wind Turbine Noise, M. Cand, R. Davis, C. Jordan, M. Hayes, R. Perkins, Institute of Acoustics, May 2013.
6 Letter from John Swinney MSP, Scottish Government, 29/05/2013
7 Scottish Government (2021) - Onshore wind - policy statement 2022, December 2022.
8 WSP, A Review of Noise Guidance for Onshore Wind Turbines, report for the UK Department for Business, Energy & Industrial Strategy, October 2022 (published 10 February 2023).
9 Assessment and rating of wind turbine noise guidance: proposed updates, Department for Energy Security and Net Zero, 4 July 2025 https://www.gov.uk/government/consultations/assessment-and-rating-of-wind-turbine-noise-guidance-proposed-updates.
10 British Standard 4142: 2014+A1 2019 Method for rating and assessing industrial and commercial sound. British Standards Institution. 2019.
11 PAN1/2011 Technical Advice Note – Assessment of Noise, Scottish Government, March 2011.
12 Control of Pollution Act, Part III, HMSO, 1974.
13 BS 5228 Noise and Vibration Control on Construction and Open Sites, Parts 1 to 4.
14 BS 5228-1:2009-A:2014 'Code of practice for noise and vibration control on construction and open sites – Part 1: Noise'.
15 BS 5228-2:2009-A:2014 'Code of practice for noise and vibration control on construction and open sites – Part 2: Vibration'.

for ground-borne vibration. These updated versions have therefore been adopted as the relevant versions upon which to base this assessment.

2.1.9 BS 5228-1 provides guidance on a range of considerations relating to construction noise including the legislative framework, general control measures, example methods for estimating construction noise levels and example criteria which may be considered when assessing impact magnitude. Similarly, BS 5228-2 provides general guidance on legislation, prediction, control and assessment criteria for construction vibration.

2.1.10 Planning Advice Note PAN50[16] "Controlling the Environmental Effects of Surface Mineral Workings" gives guidance on the environmental effects of mineral working. The main document summarises the key issues with regard to various environmental effects relating to surface mineral extraction and processing such as road traffic, blasting, noise, dust, visual intrusion etc. In addition, several annexes to the main document have been published which consider specific aspects in more detail: Annex A, "The Control of Noise at Surface Mineral Workings" and Annex D "The Control of Blasting at Surface Mineral Workings". BS 5228-1 and BS 5228-2 also provide guidance relating to surface mineral extraction including the assessment of noise and vibration impacts associated with quarry blasting. BS 6472-2 2008[17] 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'[18] (CRTN).

3.1.5 The nature of works and distances involved in the construction of a windfarm are such that the risk of non-negligible impacts relating to ground borne vibration are very low (excluding blasting). Occasional momentary vibration can arise when heavy vehicles pass dwellings at very short separation distances, but again this is not sufficient to constitute a risk of moderate/major impacts in this instance.

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

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 Wind Turbine Operational Noise

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

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-time).

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

3.2.4 ETSU-R-97 clearly indicates that the day-time limit is intended to lie within the range from 35 dB(A) to 40 dB(A). Therefore, one can conclude that there must be projects where 35 dB(A) is appropriate and conversely, projects where 40 dB(A) is appropriate. Within ETSU-R-97 there is a specific example: *"A single wind turbine causing noise levels of 40 dB(A) at several nearby residences would have less planning merit (…) than 30 wind turbines also causing the same amount of noise at several nearby residences"*. Therefore, where a project offers relatively low power generating potential, the day-time limit should naturally tend towards the lower end of the range, unless the number of noise affected properties and the extent to which those properties would be affected by the higher noise levels is sufficiently low to justify noise limits tending towards the upper end of the range. Conversely, sites with relatively large power generating capacity should naturally justify limits towards the upper end of the range. Further discussion of the 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[19] 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 windfarm 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 ETSU-R-97 also offers an alternative simplified assessment methodology:

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

3.2.8 The noise limits defined in ETSU-R-97 relate to the total noise occurring at a dwelling due to the combined noise of all operational wind turbines. The assessment will therefore need to consider the combined operational noise of the proposed Development with other 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.

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

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

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

3.2.11 Note that in the above, and subsequently in this assessment, the term 'noise emission' relates to the sound power level actually radiated from each wind turbine, whereas the term 'noise immission' relates

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

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 Noise – Non-turbine Sources

3.3.1 The proposed Development also includes a substation, which would emit some noise during operation. Based on experience of similar installations and professional judgement, in conjunction with the large separation distances of more than 2.5 km[20] to the nearest receptor locations, the associated levels of operational noise from these elements are likely to have negligible noise impacts and is not considered further.

3.4 Criteria – Construction Noise

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

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

3.4.3 Based on the range of guidance values set out in BS 5228 Annex E, and other reference criteria provided by the WHO and PAN50 Annex A: The Control of Noise at Surface Mineral Workings (1996), the following impact assessment scale has been derived. The values have been chosen in recognition of the relatively low ambient noise typically observed in rural environments. The presented criteria have been normalised to free-field daytime 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.

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[21]). 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.

20 The substation is to be located within the most westerly of the three northern construction compounds. The closest assessment location to any of these construction compounds is Lochingerroch, which is approximately 2.7 km distance.

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

Table 1 - Construction Noise Impact Assessment

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

3.4.5 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. Because of the difficulties in predicting vibration from blasting operation, this is best controlled in practice where relevant using a testing process, with progressively increased charges, in consultation with the relevant local authority.

3.5 Criteria - Operational Wind Turbine Noise

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

3.6 Consultation

3.6.1 Prior to undertaking the noise assessment, a summary of the proposed approach to determining baseline background noise levels and how the proposed Development would be assessed was forwarded to both Dumfries & Galloway Council (DGC) and East Ayrshire Council (EAC). Through this consultation[22], it was proposed to utilise existing baseline data to complete the noise assessment and set out which baseline data would be utilised for relevant receptor locations near to the proposed Development, rather than undertake supplementary baseline noise surveys. These baseline data are discussed further below. East Ayrshire Council responded that the methodology proposed was acceptable, insofar as it applies to those receptors within the EAC area. No response was received from DGC. The referenced baseline background noise levels and assessment methodology are discussed further below.

Matters Scoped Out of the Assessment

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

4. Baseline & Assessment Criteria

4.1 General Description

4.1.1 The area of the wind turbines on the proposed Development will cover an area extending approximately eight kilometres north to south and four kilometres west to east, located in Dumfries and Galloway and East Ayrshire in an area of relatively low population density. The noise environment in the surrounding area is generally characterised by 'natural' sources, such as wind disturbed vegetation, birds, farm animals, water flow sounds as well as existing wind energy developments. A number of nearby receptor locations are closer to the A76 road running approximately east to west to the north of the proposed Development, with these nearby receptors also likely to experience some road traffic noise. Other sources of noise are likely to include agricultural vehicle movements in the area, commercial forestry, occasional road traffic (for receptors further from the A76) and distant aircraft.

4.1.2 There are a number of other wind energy developments in the area around the proposed Development, some of which are operational and some consented but not yet operational. 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. In addition, the existing wind turbines present on the proposed Development are controlled by noise limits which also relate to existing baseline background noise levels. A review of these adjacent sites and the existing turbines on the proposed Development has confirmed that suitable baseline background noise levels for all relevant noise sensitive receptors around the proposed Development have already been sufficiently defined for the purposes of an assessment in accordance with ETSU-R-97, accordingly additional baseline surveys were not undertaken for the proposed Development. The resulting data remains representative of the noise environment. This approach also provides consistency when considering cumulative effects of the proposed Development and the appropriate noise limits which may apply to the proposed Development, whilst also considering the noise limits which apply to the existing turbines on the proposed Development.

22 Hare Hill Repowering and Extension – Noise Assessment Methodology, letter from James Lightbody, Consenting and EIA Manager, Natural Power Consultants Limited to Dumfries & Galloway Council and East Ayrshire Council, 3rd December 2024.

4.2 Details of the Baseline and Assessment Approach

4.2.1 A number of noise sensitive receptor locations were considered during the consultation stage with the local councils (discussed above) at which assessment of noise from the proposed Development may be required. For each of these locations, the consultation letter set out the source of baseline data and background noise related noise assessment criteria/limits which were proposed to be used. This list of locations has been revised to only include those locations which are closest to the proposed Development and are those which require noise impacts of the proposed Development to be assessed.

4.2.2 The fifteen assessment locations are shown on the plan in Annex B and listed in Table 2. This list is not intended to be exhaustive but sufficient to be representative of noise levels typical of those receptors closest to the proposed Development. Those locations which are further from the proposed Development would be less exposed to noise from the proposed Development, with consequently reduced impacts, and are not considered further. This approach is consistent with the guidance provided by ETSU-R-97 and current good practice as set out in the IOA GPG. Table 2 also indicates which wind turbine on the proposed Development is closest to each of the assessment locations, once phase two is completed, with the wind turbine names prefixed with 'HHER1' and 'HHER2' for phase one and phase two respectively.

Table 2 - Assessment locations in the vicinity of the proposed Development (approximate Easting / Northing), the source of the assessment criteria and approach to the assessment (see main text).

Property	Easting	Northing	Approximate distance to closest turbine (m)	Closest turbine	Source of assessment criteria (Annex C)	Assessment approach (see para 4.3.10)
Blackcraig	263350	608200	1760	HHER1-T09	Blackcraig (Table C2)	SSNL1
Burtonhill	264115	612373	1979	HHER1-T06	Lochingerroch & Lochbrowan (Tables C3 & C4)	TNL
Craig	263442	606454	2305	HHER1-T11	Craigdarroch & Craig (Table C5)	SSNL3
Craigdarroch	263308	606510	2449	HHER1-T11	Craigdarroch & Craig (Table C5)	SSNL3
Dalhannah	261907	610700	2696	HHER1-T07	Lochingerroch & Lochbrowan (Tables C3 & C4)	TNL
Euchanbank Cottage	270530	606420	2838	HHER1-T15	Euchanbank Cottage (Table C12)	SSNL2
High Cairn Cottage	268609	612167	2032	HHER1-T01	High Cairn (Table C9)	SSNL2
High Park Farm	262637	611992	2722	HHER1-T06	Lochingerroch & Lochbrowan (Tables C3 & C4)	TNL
Hillend*	268201	608890	1025	HHER2-T21	Hillend (Table C2)	SSNL1
Laigh Cairn	268100	612870	2243	HHER1-T01	Laigh Cairn (Table C9)	SSNL2
Lochingerroch	262292	609447	2268	HHER1-T07	Lochingerroch & Lochbrowan (Table C3 & C4)	TNL
Nether Cairn	269679	612348	3029	HHER1-T01	Nether Cairn (Table C9)	SSNL2
Over Cairn	266600	613000	2134	HHER1-T01	Laigh Cairn (Table C9)	SSNL2
Polshill	265100	613120	2536	HHER1-T06	Laigh Cairn (Table C9)	SSNL2
Waistland	266000	613120	2435	HHER1-T01	Laigh Cairn (Table C9)	SSNL2

* *This receptor location is financially involved with the existing turbines operating on HH and HHE and will be financially involved with the proposed Development.*

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 assessment location in Table 2 are detailed in Annex C.

4.3.2 The general approach to the assessment is to use site-specific noise limits ('SSNL') to assess noise from operation of the proposed Development alone, where these are relevant, or for some assessment locations (where it is relevant to assess cumulative levels of noise), these are assessed against total ETSU-R-97 noise limits ('TNL'). Specifically, where extant SSNL apply to control noise from the existing wind turbines on HH and HHE at nearer assessment locations, these SSNL would continue to be available and are used to assess the proposed Development. For more distant assessment locations, stringent SSNL are derived and set 10 dB below the TNL, which when met result in the proposed Development not having an acoustically relevant contribution to cumulative noise levels. For some of these more distant assessment locations, SSNL have been derived which make an allowance to account for the present levels of noise arising from operation of the existing wind turbines on HH and HHE. For the remaining assessment locations, TNL are derived for assessment of total cumulative noise levels, which arise when operating the proposed Development together with relevant adjacent windfarms.

4.3.3 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.

4.3.4 The effect of site-specific wind shear can be appropriately addressed by implementing the ETSU-R-97 option of considering ten metre height wind speed reference data derived from measurements made at taller heights. It is this method that has generally been referenced in the noise assessment for the proposed Development to account for the potential effect of site-specific wind shear, by utilising wind speeds representative of those at the turbine hub heights 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.

4.3.5 The IOA GPG suggests that potential effects of wind shear be accounted for where there could be large differences in hub heights (between the proposed turbines and those used for baseline surveys and derivation of noise limits) and where wind shear is likely to differ significantly from those of 'standardised' conditions[23]. The effects of wind shear can potentially make a difference to the noise limit for those elements related to a margin above background noise levels. The fixed threshold elements of the noise limits would be unaffected by wind shear.

4.3.6 For the proposed Development, some of the turbine hub heights are marginally higher than those consented or existing on adjacent developments (see Annex B). In most cases, these height differences are not considered to be sufficiently different to result in changes to standardised wind speeds which could result in acoustically relevant differences in noise immission levels. Accordingly, total ETSUR97 noise limits derived for these other windfarms have been utilised directly.

4.3.7 An exception is the existing turbines on HH and HHE which are smaller than those on adjacent sites and those on the proposed Development (once phase two is completed), consequently there may in theory be small effects due to wind shear associated with these differences. However, it is unlikely that

23 Standardised ten metre wind speeds are calculated from wind speeds at the hub height of the wind turbines using a roughness length of 0.05 m.

the wind shear on the proposed Development differs substantially from standardised conditions, given the hilly terrain and high elevations which will introduce mixing in the atmosphere. On a precautionary basis, an allowance has been made for wind shear effects for the site-specific noise limits which currently apply to the existing HH and HHE wind turbines (at the two named locations of Blackcraig and Hillend), and which will be utilised for the proposed Development. Those which apply at Blackcraig are fixed at 35 dB(A), therefore no potential correction would need to be made. For the site-specific noise limits which apply at Hillend, a precautionary shift of 1 m/s has been applied to the wind speed reference (i.e. the limit value at 9 m/s is applied at 10 m/s and so on, leading to a reduction in the limit at some of the higher wind speeds).

4.3.8 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. The general approach to the assessment for each of the assessment locations is described above and indicated in Table 2 in the final column are applied to assess the proposed development, as detailed in Table 3. For assessment locations where a cumulative assessment is relevant, these are assessed by reference to a TNL, with a relevant description of the source of the TNL set out in more detail in Table 3. For these assessment locations, contributions from other more distant windfarms not specifically named in Table 3 would not make an acoustically relevant contribution to total noise levels and are not included within the cumulative assessment. The relevance of noise from other adjacent windfarms at all assessment locations is discussed further in Annex C when developing the assessment criteria discussed above.

4.3.9 All wind turbines currently operating on HH and HHE which are on the site of the proposed Development are owned and operated by ScottishPower Renewables (SPR) as a single windfarm within the current consent noise limits. All wind turbines on both phases of the proposed Development would continue to be owned and operated by SPR as a single windfarm during the life of the proposed Development.

4.3.10 For locations where the assessment uses site-specific noise limits (labelled 'SSNL1', 'SSNL2 or 'SSNL3'), the site-specific assessment criteria are shown in Table 4 (day-time) and Table 5 (night-time) for relevant assessment locations. For locations where the assessment uses TNL, the cumulative assessment criteria are shown in Table 6 (day-time) and Table 7 (night-time) for relevant assessment locations.

4.3.11 This assessment is based on a choice of 40 dB(A) for the fixed part of the day-time limit, consistent with the choice, and directly adopting for this assessment, the cumulative noise limits already defined in the consents for the adjacent Pencloe Windfarm, Sandy Knowe Windfarm and Sanqhuar II Windfarm. This choice is also consistent with the choice of the fixed part of the day-time limits in the consent for the Afton Windfarm. The choice of 40 dB(A) for these other schemes was relevant on the premise of their significant energy generating capacity, combined with the relatively low number of dwellings in the surrounding area.

4.3.12 It would be illogical to adopt a lower choice within this range when assessing the proposed Development, considering the choice of 40 dB(A) has already been made when consenting adjacent schemes at many of the receptor locations relevant to assessment of the proposed Development.

4.3.13 In terms of the three factors given in ETSU-R-97 it is relevant to consider that the proposed Development represents a substantial increase in the energy generating capacity compared with the existing wind turbines on the proposed Development (approximately three times once both phases are completed) and adding substantially to the generating capacity of the adjacent windfarms. At the majority of nearby receptors, exposure to noise is sufficiently low that noise is below stringent criteria set 10 dB(A) below the total ETSU-R-97 noise limits, or compliant with the noise limits applying to the wind turbines already operating on the proposed Development.

4.3.14 It is therefore considered wholly appropriate to adopt the same choice for the fixed part of the total ETSU-R-97 noise limits for consistency of control of cumulative noise levels and as the basis for assessment of the proposed Development.

Table 3 - Assessment approach (see main text).

Approach	Description	Assessment of phase one	Assessment of phase two
SSNL1	For the two assessment locations of Blackcraig and Hillend, site-specific assessment criteria are equal to the noise limits that apply to the wind turbines of HH and HHE which are currently operating on the site of the proposed Development (corrected for wind shear as discussed above)	Assessment of noise which is predicted from operating phase one of the proposed Development (turbines prefixed 'HHER1') with the existing wind turbines on HHE.	Assessment of noise which is predicted from operating phase two of the proposed Development, once all existing wind turbines on HH and HHE have been repowered and extended (turbines prefixed 'HHER1' + 'HHER2').
SSNL2	These assessment locations are further from the proposed Development, accordingly site-specific assessment criteria have been derived which are 10 dB below the total ETSU-R-97 noise limits[24] and where it is possible that existing cumulative levels of wind turbine noise may already be similar to these total noise limits. These stringent criteria are used to demonstrate that levels of noise from the proposed Development are not acoustically important when considering cumulative noise levels and accordingly a cumulative assessment against the full ETSU-R-97 noise limits is not necessary, in accordance with the IOA GPG		
SSNL3	These assessment locations are also further from the proposed Development with similar considerations as those discussed above and where site-specific assessment criteria are derived as stringent criteria, which are 10 dB below the total ETSUR97 noise limits. However, an allowance has also been made to account for the contribution within cumulative total noise levels due to the operation of the existing HH and HHE wind turbines on the site of the proposed Development. Where noise levels due to the operation of the existing HH and HHE wind turbines are predicted to be higher than the stringent criteria, the assessment criteria have been increased to take account of existing predicted noise levels (see 'Pencloe and Afton' in Annex C). Levels of noise from these existing wind turbines were accounted for within the assessment and consent noise limits for adjacent windfarms, therefore the contribution to cumulative noise levels from these existing HH and HHE wind turbines remains available to the proposed Development. Consequently, cumulative total noise levels would be maintained within total ETSU-R-97 noise limits by application of these site-specific noise assessment criteria for the proposed Development.		
TNL	These assessment locations are closer to the proposed Development, or the proposed Development may have a contribution to total cumulative noise levels which is comparable to levels of noise from other windfarms. At these locations a full ETSU-R-97 assessment is appropriate. The assessment criteria derived for these locations are total ETSU-R-97 cumulative assessment criteria.	Assessment of noise which is predicted from operating phase one of the proposed Development (turbines prefixed 'HHER1') with the existing wind turbines on HHE and those on Pencloe Windfarm, Afton Windfarm and the wind turbine at High Park Farm.	Assessment of noise which is predicted from operating phase two of the proposed Development (turbines prefixed 'HHER1' + 'HHER2') and those on Pencloe Windfarm, Afton Windfarm and the wind turbine at High Park Farm.

Table 4 - Day-time L_{A90} dB site-specific criteria derived from baseline noise data according to ETSU-R-97.

Property	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Blackcraig	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0
Craig	30.0	30.0	30.0	30.0	30.0	30.0	30.0	31.1	31.3	32.0	35.0	39.0
Craigdarroch	30.0	30.0	30.0	30.0	30.0	30.0	30.0	31.1	31.3	32.0	35.0	39.0
Euchanbank Cottage	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	31.0	32.0	34.0
High Cairn Cottage	30.0	30.0	30.0	31.6	33.8	35.5	36.3	36.3	37.1	38.9	40.7	42.3
Hillend	41.2	41.2	41.2	41.2	41.2	41.2	41.2	41.2	41.2	41.2	44.8	47.0
Laigh Cairn	30.0	30.0	30.0	30.7	31.1	31.4	32.1	33.6	33.3	34.9	36.7	38.6
Nether Cairn	30.0	30.0	30.0	30.0	30.0	30.0	30.7	31.4	31.8	33.3	35.1	37.0
Over Cairn	30.0	30.0	30.0	30.7	31.1	31.4	32.1	33.6	33.3	34.9	36.7	38.6
Polshill	30.0	30.0	30.0	30.7	31.1	31.4	32.1	33.6	33.3	34.9	36.7	38.6
Waistland	30.0	30.0	30.0	30.7	31.1	31.4	32.1	33.6	33.3	34.9	36.7	38.6

Table 5 - Night-time L_{A90} dB site-specific criteria derived from baseline noise data according to ETSU-R-97.

Property	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Blackcraig	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0
Craig	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	34.0	37.0	40.0
Craigdarroch	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	34.0	37.0	40.0
Euchanbank Cottage	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0
High Cairn Cottage	33.0	33.0	33.0	33.0	33.0	33.0	33.5	35.3	37.1	38.9	40.7	42.3
Hillend	41.2	41.2	41.2	41.2	41.2	41.2	41.2	41.2	41.2	41.2	42.6	45.2
Laigh Cairn	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.3	34.9	36.7	38.6
Nether Cairn	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.3	35.1	37.0
Over Cairn	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.3	34.9	36.7	38.6
Polshill	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.3	34.9	36.7	38.6
Waistland	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.3	34.9	36.7	38.6

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

Table 6 - Day-time L_{A90} dB noise limits / criteria (TNL) derived from baseline noise data according to ETSU-R-97 and used for assessment of cumulative noise levels.

Property	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Burtonhill	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	42.0	45.0	47.0	50.0
Dalhannah	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	42.0	45.0	47.0	50.0
High Park Farm	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	42.0	45.0	47.0	50.0
Lochingerroch	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	42.0	45.0	47.0	50.0

Table 7 - Night-time L_{A90} dB noise limits / criteria (TNL) derived from baseline data according to ETSU-R-97 and used for assessment of cumulative noise levels.

Property	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Burtonhill	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0
Dalhannah	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0
High Park Farm	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0
Lochingerroch	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0

5. Noise Impact Assessment

5.1 Predicted Construction Noise Levels

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

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

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

5.1.4 Table 8 lists the key construction activities, the associated types of plant normally involved, the expected worst-case sound power level over a working day for each activity, the property which would be closest to the activity for a portion of construction, and the predicted noise level. It must be emphasised that these predictions only relate the noise level occurring during the time when the activity is closest to the referenced property. In many cases such as access track construction and turbine erection, the separating distances will be considerably greater for the majority of the construction period and the predictions are therefore the worst-case periods of the construction phase.

Table 8 - 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	Predicted Upper Day-Time L_{Aeq}
Upgrade to main access and existing Access Track	excavator / dump trucks / tippers / dozers / vibrating rollers	120	Over Cairn	320	59
Construct temporary site compounds	excavator / dump truck / tippers / rollers/ delivery trucks	120	Over Cairn	320	59
Construct site tracks	excavators / dump trucks / tippers / dozers / vibrating rollers	120	Over Cairn	400	57
Construct Sub-Station	excavator / concrete truck / delivery truck	110	Lochingarroch	2700	29
Construct crane hardstandings	excavators / dump trucks	115	Hillend	870	45
Construct turbine foundations	Piling Rigs / excavators / tippers / concrete trucks / mobile cranes / water pumps / pneumatic hammers / compressors / vibratory pokers	120	Hillend	1000	48
Excavate and lay site cables	excavators / dump trucks / tractors & cable drum trailers / wacker plates	115	Hillend	1090	43
Erect turbines	cranes / turbine delivery vehicles / artics for crane movement / generators / torque guns	115	Hillend	1000	43
Reinstate crane bases	excavator / dump truck	115	Hillend	870	45
Lay cable to sub-stations	JCB / saws / hydraulic breaker / dump truck/ tipper / wacker plate / tandem roller / tractor & cable drum trailer / delivery truck	120	Hillend	1000	48
Borrow Pit Quarrying	Primary and secondary stone Crushers / excavators / screening systems / pneumatic breakers / conveyors	125	Hillend	1490	50
Concrete Batching	Batching Plant	110	Hillend	1490	35

5.1.5 Comparing the above predicted noise levels to the range of background noise levels that are typical of those around the proposed Development suggests that the noisier construction activities would be audible at various times throughout the construction phase. However, comparing the predicted levels, varying between less than 45 dB L_{Aeq} to 59 dB L_{Aeq}, to the criteria presented previously indicates that the construction activities will have impacts of negligible to minor magnitude.

5.1.6 In addition to onsite activities, construction traffic passing to and from the site will also represent- a potential source of noise to surrounding properties. The traffic statement for the proposal presented in Chapter 11: Access, Traffic and Transport has identified that the most intensive traffic will occur for the turbine foundation reinforcement phase of construction. Specifically, the highest volume of traffic generated by construction is expected to occur in the eighth month of construction in which an average of 496 daily trips (two-way) are predicted, assuming a worst-case, using off-site delivery of concrete during phase one of the proposed Development. Table 11-28 (phase one), Table 11-29 (phase two) and Table 11-37 (phase one cumulatively constructed with The Drum Windfarm) of Chapter 11 have been used to ascertain the projected traffic flows for scenarios with and without the proposed Development.

5.1.7 The above-referenced projected changes in traffic flow are summarised in Table 9 and Table 10 for construction of phase one and phase two respectively, and Table 11 for the cumulative case. On this basis, the methodology set out in CRTN has been used to determine the associated maximum total change in the average day-time traffic noise level at any given location due to construction of the proposed Development. The predicted increases shown in the right-hand column of Table 9 to Table 11 indicate a maximum potential increase of 1.8 dB(A) in the day-time average noise level during particular phases of the construction programme at locations adjoining the A76 at Cumnock. Based on the criteria set out in the DMRB, the predicted short term change in traffic noise level would correspond to an impact of minor magnitude.

5.1.8 The primary construction site construction track which leads from the site entrance of the proposed Development to the wind turbines will pass closest to one location at Over Cairn. Once vehicles are travelling on this haul road this will give rise to a maximum predicted noise level of 51 dB(A) $L_{eq,1hr}$ based on 42 vehicles per hour[25] travelling at 35 km/hr[26]. Comparing this to the criteria presented previously indicates this represents an impact of negligible magnitude.

Table 9 - Projected traffic flows and CRTN predicted increase in day time average traffic noise levels ($L_{A10,18hour}$) - worst-case including off-site concrete deliveries (construction of phase one).

Road	Without Development		With Development		Maximum Change in Traffic Noise Level, dB(A)
	Annual Average Daily Traffic Flow	% Heavy Goods Vehicles	Annual Average Daily Traffic Flow	% Heavy Goods Vehicles	
Link 1 (A76 Hurlford)	11467	5.9%	11793	8.0%	0.5
Link 2 (A76 Crosshands)	10553	6.3%	10879	8.6%	0.5
Link 3 (A76 Mauchline)	11453	5.3%	11949	8.8%	1.1
Link 4 (A76 Between Mauchline and Auchinleck)	10683	5.1%	11179	8.8%	0.9
Link 5 (A76 West of Cumnock)	8381	4.7%	8877	9.4%	1.1
Link 6 (A76 Cumnock)	6069	6.4%	6565	12.7%	1.7
Link 7 (A76 Between Cumnock and New Cumnock)	5777	14.9%	6273	20.8%	1.1
Link 8 (A76 West of Site entrance)	3657	18.6%	4153	27.0%	1.5
Link 9 (A76 East of Site entrance)	3908	17.3%	3914	17.3%	0.0

25 The traffic assessment reports a maximum of 442 HGV plus 60 light vehicle movements per day for the most intense month of construction (assuming off-site concrete deliveries during construction of phase one and by adding flows from site traffic using both east and west directions on the A76). This is a total of 502 vehicles per day or 42 per hour (for a 12 hour construction day). As a worst case these are all assumed to be HGV movements.

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

Table 10 - Projected traffic flows and CRTN predicted increase in day time average traffic noise levels ($L_{A10,18hour}$) - worst-case including off-site concrete deliveries (construction of phase two).

Road	Without Development		With Development		Maximum Change in Traffic Noise Level, dB(A)
	Annual Average Daily Traffic Flow	% Heavy Goods Vehicles	Annual Average Daily Traffic Flow	% Heavy Goods Vehicles	
Link 1 (A76 Hurlford)	11038	5.9%	11374	8.2%	0.5
Link 2 (A76 Crosshands)	10158	6.3%	10494	8.8%	0.6
Link 3 (A76 Mauchline)	11024	5.3%	11406	8.0%	0.9
Link 4 (A76 Between Mauchline and Auchinleck)	10282	5.1%	10664	8.0%	0.7
Link 5 (A76 West of Cumnock)	8067	4.7%	8449	8.3%	0.9
Link 6 (A76 Cumnock)	5841	6.4%	6223	11.3%	1.4
Link 7 (A76 Between Cumnock and New Cumnock)	5560	14.9%	5942	19.4%	0.9
Link 8 (A76 West of Site entrance)	3520	18.6%	3902	25.1%	1.2
Link 9 (A76 East of Site entrance)	3761	17.3%	3767	17.3%	0.0

Table 11 - Projected traffic flows and CRTN predicted increase in day time average traffic noise levels ($L_{A10,18hour}$) - cumulative construction of phase one overlapping with construction of The Drum Windfarm.

Road	Without Development		With Development		Maximum Change in Traffic Noise Level, dB(A)
	Annual Average Daily Traffic Flow	% Heavy Goods Vehicles	Annual Average Daily Traffic Flow	% Heavy Goods Vehicles	
Link 1 (A76 Hurlford)	11467	5.9%	11557	5.9%	0.0
Link 2 (A76 Crosshands)	10553	6.3%	10643	6.4%	0.0
Link 3 (A76 Mauchline)	11453	5.3%	11803	7.4%	0.7
Link 4 (A76 Between Mauchline and Auchinleck)	10683	5.1%	11033	7.4%	0.6
Link 5 (A76 West of Cumnock)	8381	4.7%	8731	7.6%	0.7
Link 6 (A76 Cumnock)	6069	6.4%	6419	10.3%	1.2
Link 7 (A76 Between Cumnock and New Cumnock)	5777	14.9%	6005	17.2%	0.5
Link 8 (A76 West of Site entrance)	3657	18.6%	3885	22.0%	0.7
Link 9 (A76 East of Site entrance)	3908	17.3%	3914	17.3%	0.0

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

5.1.10 This conclusion is based on construction activities generally being limited to the following working hours: from 07:00 to 19:00 on weekdays, and 07:00 to 13:00 on Saturdays. However, activities that are unlikely to give rise to noise audible at the site boundary will continue outside of the stated hours. Furthermore, turbine deliveries may take place outside these times with the prior consent of the relevant authorities. In addition, good practice measures recommended in BS 5228-1 should be used to minimise construction noise levels.

5.2 Construction Noise & Vibration Levels – Blasting

5.2.1 Because of the difficulties in predicting noise and air overpressure resulting from blasting operations at on-site borrow pits, these activities are best controlled following the use of good practice during the setting and detonation of charges, as set out earlier in this report. Given the separation distances between the location of borrow pits and the nearest noise sensitive receptors (approximately 1.5 kilometres as a minimum) it is very unlikely that these activities would cause non-negligible adverse impacts, and therefore no further mitigation is required.

5.3 Decommissioning Noise

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

5.4 Operational Wind Turbine Emissions Data

5.4.1 The proposed Development will be built in two phases to replace and extend the existing turbines on the site of the proposed Development, which are currently part of HH and HHE. Phase one would replace and extend the 20 wind turbines on HH with up to 15 turbines, which would operate together with the 35 wind turbines currently on HHE. Phase two would replace and extend the turbines currently on HHE with up to eight wind turbines.

5.4.2 The exact model of turbines to be used for the proposed Development will be the result of a future tendering process, therefore indicative candidate turbine models have been assumed for this noise assessment. Once both phases are completed, the proposed Development would consist of up to 23 wind turbines, with a mix of three different tip heights of 150 m, 180 m and 200 m. For these tip heights, three candidate turbine models have been chosen, each with a corresponding rotor size and hub height. This operational noise assessment is based upon the noise specification of three Vestas models of turbine: the V136-4.5 MW with a hub height 82 m for turbines with a tip height of 150 m, the V150-6.0 MW with a hub height 105 m for turbines with a tip height of 180 m and the V162-6.8 MW with a hub height 119 m for turbines with a tip height of 200 m.

5.4.3 The candidate turbines are variable speed, pitch regulated machines, which, due to their variable speed operation, the sound power output of these turbine models varies considerably with wind speed, being quieter at the lower wind speeds when the blades are rotating more slowly. The candidate turbine models have (as standard) Serrated Trailing Edges (or STE) to the turbine blades, typically resulting in lower noise emission levels than turbines without this blade technology.

5.4.4 Vestas have supplied specification noise emission data for the three candidate turbine models which are values the manufacturer considers to be typical. In the absence of specific information about uncertainty allowances in the manufacturers' specification a further correction factor of +2 dB was added to these specification data, consistent with advice in the IOA GPG. Sound power data have been made available for a range of wind speeds at hub height, converted to standardised ten metre reference wind speeds for the range from 3 m/s to 12 m/s inclusive for the specific hub heights. In addition to the overall sound power data, reference has been made to additional documentation from the manufacturer to derive a representative sound spectrum for these turbine models. The overall sound power and spectral data are presented in Table B3 and B4 in Annex B.

5.4.5 In addition to the general low noise characteristic at lower wind speeds the candidate turbine models also incorporates noise control technology. This allows the sound power output of the turbines 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.

5.4.6 The existing HH wind turbines are Vestas V47-660 kw with a hub height of 40 m, whilst those on HHE are Gamesa G52-850 kW with a mix of hub heights of 44 m, 55 m and 65 m. The Vestas V47-660 kW wind turbines are pitch-regulated but fixed speed whilst the Gamesa wind turbines are pitch-regulated and variable speed (similar technology to those on the proposed Development). Neither of the existing turbine models have STE blades. The overall sound power and spectral data for the existing wind turbines are presented in Table B7 and B8 in Annex B. These sound power level data have appropriate margins included to allow for uncertainty, consistent with advice in the IOA GPG.

5.4.7 Noise levels from the two phases of the proposed Development have been modelled as well as levels of noise from the existing wind turbines on the site of the proposed Development (HH with HHE), for comparative purposes. The layout of wind turbines for the existing turbines and the two phases are indicated on the maps in Annex B. The HH and HHE existing wind turbines as well as both phases of the proposed Development have been modelled assuming standard operation without use of constrained modes of operation.

5.4.8 A detailed cumulative ETSU-R-97 assessment is required at only four of the assessment locations listed above (see Table 2 and Section 4.3): Burtonhill, Dalhannah, High Park Farm and Lochingerroch. At these locations, noise levels need to be assessed for both phases of the proposed Development when operating with contributions from operation of the Pencloe Windfarm, Afton Windfarm and the single wind turbine at High Park Farm. Assessment of the cumulative noise from operating the proposed Development with other windfarms requires source information for the turbine types similar to that discussed above for the proposed Development for each windfarm to be considered. The data assumed for the assessment for these adjacent windfarms are shown in Annex B.

5.4.9 The data in Annex B for other windfarms include margins for uncertainty as required by the IOA GPG. In addition, consideration is given for each of these schemes of the levels of noise which may arise from these wind turbines whilst remaining compliant with their respective consent noise limits. Appropriate margins for consideration of these windfarms within a cumulative assessment have also been included where relevant, also required by the IOA GPG (see discussion for each windfarm in Annex B).

5.5 Choice of Wind Farm Operational Noise Propagation Model

5.5.1 The ISO 9613-2 model[27] has been used to calculate the noise immission levels at the selected nearest residential neighbours as advised in the IOA GPG. The model accounts for the attenuation due to geometric spreading, atmospheric absorption, and barrier and ground effects. All attenuation calculations have been made on an octave band basis and therefore account for the sound frequency characteristics of the turbines.

5.5.2 For the purposes of the present assessment, all noise level predictions have been undertaken using mixed ground (G=0.5), together with a receiver height of four metres above local ground level, and an air absorption based on a temperature of 10°C and 70% relative humidity. 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. These propagation factors are shown in Annex B for each of the separate windfarms.

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

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

5.6 Predicted Wind Turbine Operational Noise Immission Levels

5.6.1 Table 12 and Table 13 show predicted noise immission levels at each of the selected assessment locations for each wind speed from 3 m/s to 12 m/s inclusive for the two phases of the proposed Development. All wind turbine noise immission levels in this report are presented in terms of the L_{A90} noise indicator in accordance with the recommendations of the ETSU-R-97 report, obtained by subtracting 2 dB(A) from the calculated L_{Aeq} noise levels, based on the turbine sound power levels presented in Annex B.

Table 12 - Predicted L_{A90}(dB) windfarm noise immission levels at each of the noise assessment locations as a function of standardised wind speed for phase one of the proposed Development (HHX + HHER1).

Property	Standardised Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Blackcraig	-	-	-	24.6	29.1	32.8	34.0	34.5	34.5	34.5	34.5	34.6
Burtonhill	-	-	-	21.9	26.4	30.2	31.3	31.7	31.7	31.7	31.7	31.7
Craig	-	-	-	22.4	26.8	30.6	31.7	32.2	32.2	32.2	32.2	32.2
Craigdarroch	-	-	-	22.1	26.5	30.3	31.4	31.9	32.0	32.0	32.0	32.0
Dalhannah	-	-	-	19.0	23.5	27.3	28.4	28.9	28.9	28.9	28.9	28.9
Euchanbank Cottage	-	-	-	19.7	24.1	27.8	29.0	29.5	29.5	29.5	29.5	29.5
High Cairn Cottage	-	-	-	22.4	26.8	30.5	31.6	32.0	32.1	32.1	32.1	32.1
High Park Farm	-	-	-	20.5	25.2	28.9	29.9	30.3	30.3	30.3	30.3	30.3
Hillend	-	-	-	31.9	36.3	40.0	41.2	41.8	41.8	41.8	41.8	41.8
Laigh Cairn	-	-	-	21.1	25.6	29.3	30.3	30.8	30.8	30.8	30.8	30.8
Lochingerroch	-	-	-	21.7	26.2	30.0	31.1	31.5	31.6	31.6	31.6	31.6
Nether Cairn	-	-	-	19.5	23.9	27.6	28.7	29.1	29.2	29.2	29.2	29.2
Over Cairn	-	-	-	21.9	26.4	30.1	31.2	31.6	31.6	31.6	31.6	31.6
Polshill	-	-	-	20.8	25.3	29.1	30.1	30.5	30.6	30.6	30.6	30.6
Waistland	-	-	-	21.4	25.9	29.6	30.7	31.1	31.1	31.2	31.2	31.2

Table 13 - Predicted L_{A90}(dB) windfarm noise immission levels at each of the noise assessment locations as a function of standardised wind speed for **phase two of the proposed Development alone (HHER1 + HHER2)**.

Property	Standardised Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Blackcraig	-	-	20.3	23.2	27.7	31.3	32.0	32.1	32.1	32.2	32.2	32.2
Burtonhill	-	-	17.5	20.5	25.2	28.8	29.5	29.6	29.6	29.6	29.6	29.7
Craig	-	-	17.9	20.6	25.1	28.7	29.4	29.5	29.6	29.7	29.7	29.7
Craigdarroch	-	-	17.6	20.3	24.9	28.4	29.1	29.2	29.3	29.4	29.4	29.4
Dalhannah	-	-	14.3	17.1	21.8	25.4	26.1	26.1	26.2	26.2	26.2	26.3
Euchanbank Cottage	-	-	15.2	17.8	22.2	25.7	26.4	26.6	26.7	26.8	26.8	26.8
High Cairn Cottage	-	-	18.3	21.0	25.5	29.0	29.7	29.9	29.9	30.0	30.0	30.0
High Park Farm	-	-	16.4	19.4	24.2	27.8	28.5	28.6	28.6	28.6	28.6	28.6
Hillend	-	-	27.7	29.7	34.2	37.7	38.3	38.5	38.7	38.9	38.9	38.9
Laigh Cairn	-	-	17.1	19.8	24.3	27.9	28.6	28.7	28.8	28.9	28.9	28.9
Lochingerroch	-	-	17.5	20.4	25.0	28.6	29.3	29.4	29.5	29.5	29.5	29.5
Nether Cairn	-	-	15.6	18.2	22.7	26.2	26.9	27.1	27.2	27.2	27.2	27.3
Over Cairn	-	-	17.6	20.5	25.1	28.6	29.3	29.4	29.5	29.6	29.6	29.6
Polshill	-	-	16.4	19.3	23.9	27.5	28.2	28.3	28.3	28.4	28.4	28.4
Waistland	-	-	17.1	20.0	24.6	28.2	28.9	29.0	29.0	29.1	29.1	29.1

5.6.2 Table D1 in Annex D shows predicted noise immission levels at each the noise assessment locations for each standardised wind speed due to operation of the existing wind turbines on the proposed Development. These are provided for comparative purposes when considering levels of noise from repowering and extending these turbines for the proposed Development. A comparison between predicted noise levels from the existing turbines and proposed Development is discussed further below.

5.6.3 Tables D2 to D4 in Annex D show predicted noise immission levels at each the noise assessment locations for each standardised wind speed due to operation of the adjacent windfarms which are considered in the cumulative assessment for Afton Windfarm, Pencloe Windfarm and the single High Park Farm turbine. These predicted noise immission levels are provided for the four receptor locations of Table 2 where a cumulative assessment is required, as discussed in Section 4.3.

5.6.4 Table 14 (phase one) and Table 15 (phase two) show predicted cumulative noise immission levels at each of the selected assessment locations. These predictions are cumulative assuming all other wind farms are operating as set out in Annex B and that all receptors are downwind of all wind turbines at the same time. These cumulative noise levels are unlikely to occur in practice.

5.6.5 Figures E1 to E4 (Annex E) show the calculated windfarm noise immission levels at the assessment location of High Park Farm which in the assessment location with higher noise levels from the turbine at High Park Farm, compared with the other cumulative assessment locations (Burtonhill, Dalhannah, and Lochingerroch) which are further from this wind turbine. Charts shown for High Park Farm assessment location would therefore be representation of a worst case for these other locations, which are not therefore shown in chart form in addition to tabular form.

Table 14 - Cumulative predicted L_{A90} (dB) windfarm noise immission levels at relevant noise assessment locations as a function of standardised wind speed for **phase one of the proposed Development (HHX + HHER1) operating together with the other windfarms considered cumulatively (Table 3)**.

Property	Standardised Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Burtonhill	-	-	-	23.2	27.8	31.5	32.6	33.1	33.2	33.2	33.2	33.2
Dalhannah	-	-	-	23.1	28.0	31.6	32.6	32.8	32.9	32.9	32.9	32.9
High Park Farm	-	-	-	26.0	30.4	34.3	35.7	36.4	36.5	36.5	36.5	36.5
Lochingerroch	-	-	-	24.4	29.2	32.8	33.7	33.9	34.0	34.0	34.0	34.0

Table 15 - Cumulative predicted L_{A90} (dB) windfarm noise immission levels at relevant noise assessment locations as a function of standardised wind speed for **phase two of the proposed Development (HHER1 + HHER2) operating together with the other windfarms considered cumulatively (Table 3)**.

Property	Standardised Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Burtonhill	-	-	-	22.2	26.9	30.5	31.4	31.7	31.8	31.8	31.8	31.8
Dalhannah	-	-	-	22.5	27.5	31.0	31.8	31.9	32.0	32.0	32.0	32.0
High Park Farm	-	-	-	25.7	30.2	34.0	35.4	36.0	36.1	36.1	36.1	36.1
Lochingerroch	-	-	-	23.7	28.6	32.1	32.8	32.8	32.9	32.9	32.9	32.9

5.7 Comparison with Existing Noise Levels

5.7.1 Table D1 in Annex D provides predicted noise immission levels for the existing wind turbines on the proposed Development. As discussed in Annex C, the noise limits which apply to control these noise levels are defined at the two receptors, the financially involved assessment location of Hillend and the assessment location of Blackcraig. At all other locations not named, the consents for the existing wind turbines on the proposed Development stipulates the limits be derived for these properties from the geographically nearest property which is listed, which in practice would likely be the fixed noise limit of 35 dB(A) at all wind speeds applying at Blackcraig. This fixed limit is also consistent with the ETSU-R-97 simplified assessment methodology discussed in paragraph 3.2.7. At all assessment locations, the levels of noise from the existing wind turbines on the proposed Development are below the consent noise limits, based upon a limit of 35 dB(A) applying at those not named directly in the consents.

5.7.2 Tables D5 and Table D6 in Annex D provide a comparison of predicted noise levels from the HH and HHE wind turbines (which are currently operating on the site of the proposed Development) with phase one (operating with HHE turbines) and phase two of the proposed Development respectively. These tables indicate that noise levels from operating phase one of the proposed Development with the turbines on HHE are marginally higher (maximum increase approximately 2 dB) than the existing wind turbines (HH & HHE) at most assessment locations and wind speeds. Once phase two is completed, levels of noise are similar or lower than those from the existing wind turbines (HH & HHE) at most locations with a few exceptions where there is a small increase (maximum increase approximately 1 dB at wind speeds of 6 m/s and 7 m/s). These comparisons assume unconstrained operation of all wind turbines and no mitigation applied to either phase of the proposed Development (mitigation is discussed further below).

5.8 ETSU-R-97 Assessment

5.8.1 Table 16 to Table 19 show the differences between predicted noise immission levels, due to the two phases of the proposed Development, and the applicable site-specific noise limits shown in Table 4 and

Table 5 for both day-time and night-time periods at the eleven assessment locations. These are assessment locations where it is appropriate to compare levels of noise from the proposed Development against site-specific assessment criteria, which are derived either from the site-specific noise limits (which apply to the existing wind turbines on the proposed Development) or stringent criteria set to existing total noise limits minus 10 dB(A)[28] (see discussion in Section 4.3).

5.8.2 Table 16 (day-time) and Table 17 (night-time) show that the predicted wind turbine noise immission levels from phase one of the proposed Development operating with HHE meet these criteria at most of the assessment locations, except during the day-time at the financially involved location of Hillend (to the east) with a maximum excess of approximately 0.6 dB(A) and at Craig and Craigdarroch to the south west, with a maximum excess of approximately 1.7 dB(A). During the night-time the criteria are met at all wind speeds at all assessment locations except again at Hillend, where there is similarly a 0.6 dB(A) maximum excess (the day-time and night-time criteria are the same during both periods at Hillend at relevant wind speeds). Accordingly, it is concluded that these criteria are not complied with at all of these locations and all wind speeds for phase one and that some noise mitigation would be required during operation of phase one based on the assumptions made.

5.8.3 Table 18 (day-time) and Table 19 (night-time) show that the predicted wind turbine noise immission levels from phase two of the proposed Development (HHER1 and HHER2 turbines) meet these criteria under all wind speeds and at all relevant locations, accordingly it is concluded that these criteria are complied with at all of these locations and all wind speeds once phase two is completed.

Table 16 Difference between the derived **day-time SSNL assessment criteria** and the predicted L_{A90} dB wind turbine noise immission levels at relevant noise assessment locations for **phase one of the proposed Development alone**. Negative values indicate the noise immission level is below the criterion. Only those assessment locations to be compared with the site-specific criteria are shown.

Property	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Blackcraig	-	-	-	-10.4	-5.9	-2.2	-1.0	-0.5	-0.5	-0.5	-0.5	-0.5
Craig	-	-	-	-7.6	-3.2	**0.6**	**1.7**	**1.1**	**0.9**	**0.2**	-2.8	-6.8
Craigdarroch	-	-	-	-7.9	-3.5	**0.3**	**1.4**	**0.8**	**0.7**	0.0	-3.0	-7.0
Euchanbank Cottage	-	-	-	-10.3	-5.9	-2.2	-1.1	-0.6	-0.5	-1.5	-2.5	-4.5
High Cairn Cottage	-	-	-	-9.2	-7.0	-5.0	-4.7	-4.3	-5.1	-6.8	-8.6	-10.2
Hillend	-	-	-	-9.3	-4.9	-1.2	0.0	**0.6**	**0.6**	**0.6**	-3.0	-5.2
Laigh Cairn	-	-	-	-9.6	-5.6	-2.1	-1.8	-2.8	-2.5	-4.1	-5.9	-7.8
Nether Cairn	-	-	-	-10.6	-6.1	-2.4	-2.0	-2.3	-2.6	-4.1	-5.9	-7.8
Over Cairn	-	-	-	-8.8	-4.7	-1.3	-0.9	-2.0	-1.7	-3.3	-5.1	-7.0
Polshill	-	-	-	-9.9	-5.8	-2.4	-2.0	-3.1	-2.7	-4.3	-6.1	-8.0
Waistland	-	-	-	-9.3	-5.3	-1.8	-1.4	-2.5	-2.2	-3.8	-5.6	-7.5

28 For assessment locations Craig and Craigdarroch, an allowance was made for the contribution to cumulative noise levels based on predicted noise levels from operating HH and HHE for the day-time assessment criteria. Where an existing predicted contribution was higher than the stringent criteria set 10 dB(A) below the total ETSU-R-97 noise limit, the assessment criteria was set equal to the existing predicted noise levels.

Table 17 - Difference between the derived **night-time SSNL assessment criteria** and the predicted L_{A90} dB wind turbine noise immission levels at relevant noise assessment locations for **phase one of the proposed Development alone**. Negative values indicate the noise immission level is below the criterion. Only those assessment locations to be compared with the site-specific criteria are shown.

Property	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Blackcraig	-	-	-	-10.4	-5.9	-2.2	-1.0	-0.5	-0.5	-0.5	-0.5	-0.5
Craig	-	-	-	-10.6	-6.2	-2.5	-1.3	-0.8	-0.8	-1.8	-4.8	-7.8
Craigdarroch	-	-	-	-10.9	-6.5	-2.7	-1.6	-1.1	-1.0	-2.0	-5.0	-8.0
Euchanbank Cottage	-	-	-	-13.3	-8.9	-5.2	-4.1	-3.6	-3.5	-3.5	-3.5	-3.5
High Cairn Cottage	-	-	-	-10.6	-6.2	-2.5	-1.9	-3.3	-5.1	-6.8	-8.6	-10.2
Hillend	-	-	-	-9.3	-4.9	-1.2	0.0	0.6	0.6	0.6	-0.8	-3.4
Laigh Cairn	-	-	-	-11.9	-7.5	-3.7	-2.7	-2.2	-2.5	-4.1	-5.9	-7.8
Nether Cairn	-	-	-	-13.6	-9.1	-5.4	-4.3	-3.9	-3.8	-4.1	-5.9	-7.8
Over Cairn	-	-	-	-11.1	-6.6	-2.9	-1.8	-1.4	-1.7	-3.3	-5.1	-7.0
Polshill	-	-	-	-12.2	-7.7	-4.0	-2.9	-2.5	-2.7	-4.3	-6.1	-8.0
Waistland	-	-	-	-11.6	-7.2	-3.4	-2.3	-1.9	-2.2	-3.8	-5.6	-7.5

Table 18 - Difference between the derived **day-time SSNL assessment criteria** and the predicted L_{A90} dB wind turbine noise immission levels at relevant noise assessment locations for **phase two of the proposed Development alone**. Negative values indicate the noise immission level is below the criterion. Only those assessment locations to be compared with the site-specific criteria are shown.

Property	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Blackcraig	-	-	-14.7	-11.8	-7.3	-3.7	-3.0	-2.9	-2.9	-2.8	-2.8	-2.8
Craig	-	-	-12.1	-9.4	-4.9	-1.3	-0.6	-1.6	-1.7	-2.3	-5.3	-9.3
Craigdarroch	-	-	-12.4	-9.7	-5.2	-1.6	-0.9	-1.9	-2.0	-2.6	-5.6	-9.6
Euchanbank Cottage	-	-	-14.9	-12.2	-7.8	-4.3	-3.6	-3.4	-3.3	-4.3	-5.3	-7.2
High Cairn Cottage	-	-	-11.7	-10.6	-8.3	-6.5	-6.6	-6.5	-7.2	-8.9	-10.7	-12.3
Hillend	-	-	-13.6	-11.5	-7.0	-3.5	-2.9	-2.7	-2.5	-2.4	-6.0	-8.1
Laigh Cairn	-	-	-12.9	-10.9	-6.8	-3.5	-3.5	-4.9	-4.5	-6.1	-7.9	-9.7
Nether Cairn	-	-	-14.4	-11.8	-7.3	-3.8	-3.8	-4.4	-4.6	-6.1	-7.9	-9.7
Over Cairn	-	-	-12.4	-10.2	-6.1	-2.8	-2.8	-4.2	-3.8	-5.4	-7.2	-9.0
Polshill	-	-	-13.6	-11.4	-7.2	-3.9	-3.9	-5.3	-5.0	-6.5	-8.3	-10.2
Waistland	-	-	-12.9	-10.7	-6.5	-3.2	-3.2	-4.6	-4.3	-5.8	-7.6	-9.5

Table 19 - Difference between the derived **night-time SSNL assessment criteria** and the predicted $L_{A90,t}$ dB wind turbine noise immission levels at relevant noise assessment locations for **phase two of the proposed Development alone**. Negative values indicate the noise immission level is below the criterion. Only those assessment locations to be compared with the site-specific criteria are shown.

Property	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Blackcraig	-	-	-14.7	-11.8	-7.3	-3.7	-3.0	-2.9	-2.9	-2.8	-2.8	-2.8
Craig	-	-	-15.1	-12.4	-7.9	-4.3	-3.6	-3.5	-3.4	-4.3	-7.3	-10.3
Craigdarroch	-	-	-15.4	-12.7	-8.2	-4.6	-3.9	-3.8	-3.7	-4.6	-7.6	-10.6
Euchanbank Cottage	-	-	-17.9	-15.2	-10.8	-7.3	-6.6	-6.4	-6.3	-6.3	-6.3	-6.2
High Cairn Cottage	-	-	-14.7	-12.0	-7.5	-4.0	-3.8	-5.5	-7.2	-8.9	-10.7	-12.3
Hillend	-	-	-13.6	-11.5	-7.0	-3.5	-2.9	-2.7	-2.5	-2.4	-3.8	-6.3
Laigh Cairn	-	-	-15.9	-13.2	-8.7	-5.1	-4.4	-4.3	-4.5	-6.1	-7.9	-9.7
Nether Cairn	-	-	-17.4	-14.8	-10.3	-6.8	-6.1	-6.0	-5.8	-6.1	-7.9	-9.7
Over Cairn	-	-	-15.4	-12.5	-8.0	-4.4	-3.7	-3.6	-3.8	-5.4	-7.2	-9.0
Polshill	-	-	-16.6	-13.7	-9.1	-5.5	-4.8	-4.7	-5.0	-6.5	-8.3	-10.2
Waistland	-	-	-15.9	-13.0	-8.4	-4.8	-4.1	-4.0	-4.3	-5.8	-7.6	-9.5

5.8.4 Table 20 to Table 21 show the differences between the ETSU-R-97 total noise limits shown in Table 6 (day-time) and Table 7 (night-time) and predicted noise immission levels (Table 14) due to the cumulative total of operating phase one of the proposed Development with Pencloe Windfarm, Afton Windfarm and the turbine at High Park Farm. Similarly, Table 21 and Table 22 show these differences for phase two of the proposed Development (predicted noise immission levels shown in Table 15). These four tables show that both phases of the proposed Development would result in cumulative noise levels which are compliant with the total ETSU-R-97 noise limits at the four assessment locations where a cumulative assessment is relevant. For the other eleven assessment locations, these are assessed against site-specific criteria which already account for cumulative effects, as discussed above.

Table 20 - Difference between the ETSU-R-97 derived **day-time** noise limits and the cumulative predicted L_{A90} (dB) windfarm noise immission levels at relevant noise assessment locations for **phase one of the proposed Development**. Negative values indicate the noise immission level is below the limit and only those assessment locations for which a cumulative assessment is relevant are shown.

Property	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Burtonhill	-	-	-	-16.8	-12.2	-8.5	-7.4	-6.9	-8.8	-11.8	-13.8	-16.8
Dalhannah	-	-	-	-16.9	-12.0	-8.4	-7.4	-7.2	-9.1	-12.1	-14.1	-17.1
High Park Farm	-	-	-	-14.0	-9.6	-5.7	-4.3	-3.6	-5.5	-8.5	-10.5	-13.5
Lochingerroch	-	-	-	-15.6	-10.8	-7.2	-6.3	-6.1	-8.0	-11.0	-13.0	-16.0

Table 21 - Difference between the ETSU-R-97 derived **night-time** noise limits and the cumulative predicted L_{A90} (dB) windfarm noise immission levels at relevant noise assessment locations for **phase one of the proposed Development**. Negative values indicate the noise immission level is below the limit and only those assessment locations for which a cumulative assessment is relevant are shown.

Property	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Burtonhill	-	-	-	-19.8	-15.2	-11.5	-10.4	-9.9	-9.8	-9.8	-9.8	-9.8
Dalhannah	-	-	-	-19.9	-15.0	-11.4	-10.4	-10.2	-10.1	-10.1	-10.1	-10.1
High Park Farm	-	-	-	-17.0	-12.6	-8.7	-7.3	-6.6	-6.5	-6.5	-6.5	-6.5
Lochingerroch	-	-	-	-18.6	-13.8	-10.2	-9.3	-9.1	-9.0	-9.0	-9.0	-9.0

Table 22 - Difference between the ETSU-R-97 derived **day-time** noise limits and the cumulative predicted L_{A90} (dB) windfarm noise immission levels at relevant noise assessment locations for **phase two of the proposed Development**. Negative values indicate the noise immission level is below the limit and only those assessment locations for which a cumulative assessment is relevant are shown.

Property	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Burtonhill	-	-	-	-17.8	-13.1	-9.5	-8.6	-8.3	-10.2	-13.2	-15.2	-18.2
Dalhannah	-	-	-	-17.5	-12.5	-9.0	-8.2	-8.1	-10.0	-13.0	-15.0	-18.0
High Park Farm	-	-	-	-14.3	-9.8	-6.0	-4.6	-4.0	-5.9	-8.9	-10.9	-13.9
Lochingerroch	-	-	-	-16.3	-11.4	-7.9	-7.2	-7.2	-9.1	-12.1	-14.1	-17.1

Table 23 - Difference between the ETSU-R-97 derived **night-time** noise limits and the cumulative predicted L_{A90} (dB) windfarm noise immission levels at relevant noise assessment locations for **phase two of the proposed Development**. Negative values indicate the noise immission level is below the limit and only those assessment locations for which a cumulative assessment is relevant are shown.

Property	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Burtonhill	-	-	-	-20.8	-16.1	-12.5	-11.6	-11.3	-11.2	-11.2	-11.2	-11.2
Dalhannah	-	-	-	-20.5	-15.5	-12.0	-11.2	-11.1	-11.0	-11.0	-11.0	-11.0
High Park Farm	-	-	-	-17.3	-12.8	-9.0	-7.6	-7.0	-6.9	-6.9	-6.9	-6.9
Lochingerroch	-	-	-	-19.3	-14.4	-10.9	-10.2	-10.2	-10.1	-10.1	-10.1	-10.1

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

5.9 Mitigation – Proposed Development

5.9.1 As discussed above, during operation of phase one of the proposed Development, noise immission levels from the proposed Development (operating with HHE) could be above the site-specific criteria defined for the assessment at the two locations of Craig and Craigdarroch to the south west during only the day-time, and marginally above the site-specific criteria at the involved location of Hillend to the east during day-time and night-time. Once phase two of the proposed Development is completed, noise immission levels meet all criteria.

5.9.2 Some constraints could be applied to the wind turbines during operation of phase one of the proposed Development with HHE in order to reduce noise levels and result in operational noise levels then being compliant with the site-specific assessment criteria. Such constraints could entail stopping certain HHE wind turbines (those closest to the assessment locations being considered) in relevant wind speeds and wind directions to result in lower noise levels. Table 24 provides an example pattern of constraints that could be applied, focussing on applying constraints to the turbines on HHE, given their lower energy generating capacity compared with the phase one turbines. Other potential constraint patterns could be used to achieve the same outcome, such as constrained modes of operation or alternate turbines stopped or constrained using noise control modes.

Table 24 – Example constraints which could be applied during operation of phase one of the proposed Development with HHE so that predicted noise levels are compliant with the assessment criteria at the three relevant assessment locations where an excess has been identified.

Conditions	Standardised 10 m Wind Speed (m/s)				
	6	7	8	9	10
North east winds (~325° to ~125°) day-time. Turbines closest to Craig/ Craigdarroch	Stop four HHE turbines	Stop fourteen HHE turbines	Stop seven HHE turbines	Stop six HHE turbines	-
South west winds (~160° to ~320°) day-time and night-time. Turbines closest to Hillend	-	-	Stop one HHE turbine	Stop one HHE turbine	Stop one HHE turbine

Table 25 - Predicted L_{A90} (dB) windfarm noise immission levels as a function of standardised wind speed for phase one of the proposed Development (HHX + HHER1) with turbine constraints applied (Table 24). Predicted noise levels are shown only for the three relevant assessment locations where an excess has been identified.

Property	Standardised Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Craig	-	-	-	22.4	26.8	30.3	30.3	31.4	31.6	32.2	32.2	32.2
Craigdarroch	-	-	-	22.1	26.5	30.0	30.0	31.1	31.3	32.0	32.0	32.0
Hillend	-	-	-	31.9	36.3	40.0	41.2	41.1	41.1	41.1	41.8	41.8

Table 26 - Difference between the derived day-time SSNL assessment criteria and the predicted L_{A90} dB wind turbine noise immission levels at relevant assessment locations for phase one of the proposed Development alone including constraints (Table 25). Negative values indicate the noise immission level is below the criterion. Only the three assessment locations are shown where a predicted excess has been identified above.

Property	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Craig	-	-	-	-7.6	-3.2	0.3	0.3	0.3	0.3	0.2	-2.8	-6.8
Craigdarroch	-	-	-	-7.9	-3.5	0.0	0.0	0.0	0.0	0.0	-3.0	-7.0
Hillend	-	-	-	-9.3	-5.0	-1.2	0.0	-0.2	-0.1	-0.1	-3.0	-5.2

5.9.3 Table 25 shows revised predicted noise immission levels at the three assessment locations where an excess has been identified for phase one of the proposed Development (operating with HHE) and which incorporate the example constraints detailed in Table 24. Table 26 provides a comparison of these revised predicted noise levels with the day-time site-specific assessment criteria shown in

Table 4[29]. Some small excesses remain but these are 0.3 dB(A) or lower and are not acoustically important, given the conservative nature of the criteria selected, and it is considered that sufficient reduction would be achieved by the example constraints.

5.9.4 It is finally concluded that predicted cumulative noise immission levels from the proposed Development when operating with adjacent windfarms are compliant with the ETSU-R-97 criteria at all locations and all wind speeds. This outcome has been achieved through use of mitigation applied to some of the turbines on HHE during phase one of the proposed Development (operating with HHE), with phase two compliant without mitigation.

5.10 Proposed Development Site-specific Noise Limits

5.10.1 Satisfactory control of cumulative noise immission levels could be achieved through enforcement of individual consent limits for each of the individual windfarms. Site-specific noise limits which could be applied to the proposed Development in isolation are set out in Table 27 for day-time and Table 28 for night-time periods respectively. These site-specific noise limits are consistent with the site-specific assessment criteria defined in Table 4 (day-time) and Table 5 (night-time) for the eleven assessment locations where a cumulative assessment was not required.

5.10.2 The noise limits which apply to the existing turbines operating on the site of the proposed Development (HH and HHE) have consent noise limits defined at two named locations of Blackcraig and Hillend as discussed in Annex C (see section 'Hare Hill and Hare Hill Extension'), with the lowest noise limit which could apply at non-named locations being a fixed value of 35 dB(A) day-time and night-time at all wind speeds[30].

5.10.3 At the four assessment locations where a cumulative assessment has been completed, suitable site-specific noise limits could be derived through a calculation, whereby the total contribution from other relevant wind farms considered in the cumulative assessment (Pencloe Windfarm, Afton Windfarm and the turbine at High Park Farm) are subtracted from the total ETSU-R-97 noise limits. Due to the low noise levels from these other wind turbines, the noise limits resulting from this process would be close to the total ETSU-R-97 noise limits, with a potential lowest value of approximately 38 dB(A). Inspection of predicted noise levels from the proposed Development (Table 12 and Table 13) show that there would be large margins between these noise limits and predicted noise levels[31], indicating such noise limits would be higher than necessary and higher than limits which currently apply to the existing HH and HHE turbines on the site of the proposed Development. It is proposed instead to implement noise limits for these four assessment locations which are consistent with the consent for the existing windfarms of HH and HHE, set to be equal to a fixed value of 35 dB(A) at all times and wind speeds. These site-specific noise limits can be complied with by both phases of the proposed Development at these four assessment locations, with a minimum margin of approximately 3 dB(A).

29 For Hillend an excess was identified both day-time and night-time and example constraints defined for both periods for wind speeds of 8 m/s, 9 m/s and 10 m/s. However the site-specific assessment criteria at Hillend are the same day-time and night-time for these, therefore only a comparison with day-time site-specific criteria are shown as the resulting change would be the same day-time and night-time at these wind speeds.

30 The consent stipulates that at locations not specifically named the noise limits are taken from the geographically nearest named location. The consent names only two locations with the lowest noise limits being those at Blackcraig, which are fixed at 35 dB(A) at all wind speeds during both day-time and night-time.

31 The highest predicted noise levels are from phase one operating with HHE at Burtonhill of 31.7 dB(A). On the assumption the lowest noise limit were to be 38 dB (derived at High Park Farm not at Burtonhill) then the smallest margin would be approximately 6 dB(A). However, if a limit of 35 dB(A) were applied the smallest margin would be approximately 3 dB(A).

Table 27 – Proposed site-specific noise limits to be applied to the proposed Development during day-time periods.

Property	Standardised Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Blackcraig	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0
Burtonhill	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0
Craig	30.0	30.0	30.0	30.0	30.0	30.0	30.0	31.1	31.3	32.0	35.0	39.0
Craigdarroch	30.0	30.0	30.0	30.0	30.0	30.0	30.0	31.1	31.3	32.0	35.0	39.0
Dalhannah	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0
Euchanbank Cottage	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	31.0	32.0	34.0
High Cairn Cottage	30.0	30.0	30.0	31.6	33.8	35.5	36.3	36.3	37.1	38.9	40.7	42.3
High Park Farm	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0
Hillend	41.2	41.2	41.2	41.2	41.2	41.2	41.2	41.2	41.2	41.2	44.8	47.0
Laigh Cairn	30.0	30.0	30.0	30.7	31.1	31.4	32.1	33.6	33.3	34.9	36.7	38.6
Lochingerroch	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0
Nether Cairn	30.0	30.0	30.0	30.0	30.0	30.0	30.7	31.4	31.8	33.3	35.1	37.0
Over Cairn	30.0	30.0	30.0	30.7	31.1	31.4	32.1	33.6	33.3	34.9	36.7	38.6
Polshill	30.0	30.0	30.0	30.7	31.1	31.4	32.1	33.6	33.3	34.9	36.7	38.6
Waistland	30.0	30.0	30.0	30.7	31.1	31.4	32.1	33.6	33.3	34.9	36.7	38.6

Table 28 – Proposed site-specific noise limits to be applied to the proposed Development during night-time periods.

Property	Standardised Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Blackcraig	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0
Burtonhill	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0
Craig	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	34.0	37.0	40.0
Craigdarroch	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	34.0	37.0	40.0
Dalhannah	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0
Euchanbank Cottage	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0
High Cairn Cottage	33.0	33.0	33.0	33.0	33.0	33.0	33.5	35.3	37.1	38.9	40.7	42.3
High Park Farm	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0
Hillend	41.2	41.2	41.2	41.2	41.2	41.2	41.2	41.2	41.2	41.2	42.6	45.2
Laigh Cairn	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.3	34.9	36.7	38.6
Lochingerroch	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0
Nether Cairn	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.3	35.1	37.0
Over Cairn	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.3	34.9	36.7	38.6
Polshill	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.3	34.9	36.7	38.6
Waistland	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.3	34.9	36.7	38.6

5.10.4 The selection of the final turbine to be installed at the site should be made on the basis of enabling the relevant noise limits of Table 27 and Table 28 to be achieved at the surrounding properties.

5.11 Low Frequency Noise, Vibration and Amplitude Modulation

5.11.1 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.

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

6. Summary of Key Findings and Conclusions

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

6.1.2 Several residential properties lying around the windfarm have been selected as being representative of the closest located properties to the windfarm. 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 criteria have been derived from the existing consents and are related to background noise levels considered representative of those at surrounding properties, as derived from existing measurements.

6.1.3 The construction noise assessment has determined that associated levels are expected to be audible at various times throughout the construction programme but remain with acceptable limits, such that their temporary impacts are considered of minor magnitude.

6.1.4 Operational noise from the windfarm has been assessed in accordance with the methodology set out in ETSU-R-97, 'The Assessment and Rating of Noise from Wind Farms'. This document provides a robust basis for assessing the operational noise of a windfarm as recommended by Scottish Government Onshore Wind Policy Statement 2022.

6.1.5 It has been demonstrated that both the day-time and night-time noise criteria can be satisfied at all assessment properties across all wind speeds. This outcome may be achieved through use of turbine constraints applied to some of the existing wind turbines on HHE during operation of phase one of the proposed Development with the existing HHE, and without constraints applied once phase two of the proposed Development is completed. This assessment has been based on the use of the manufacturer's warranted sound power data for the three Vestas models of wind turbine which are typical of the type and size of turbine which may be considered for the proposed Development, and assuming worst case downwind propagation.

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

Annex A - General Approach to Noise Assessment & Glossary

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

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

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

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

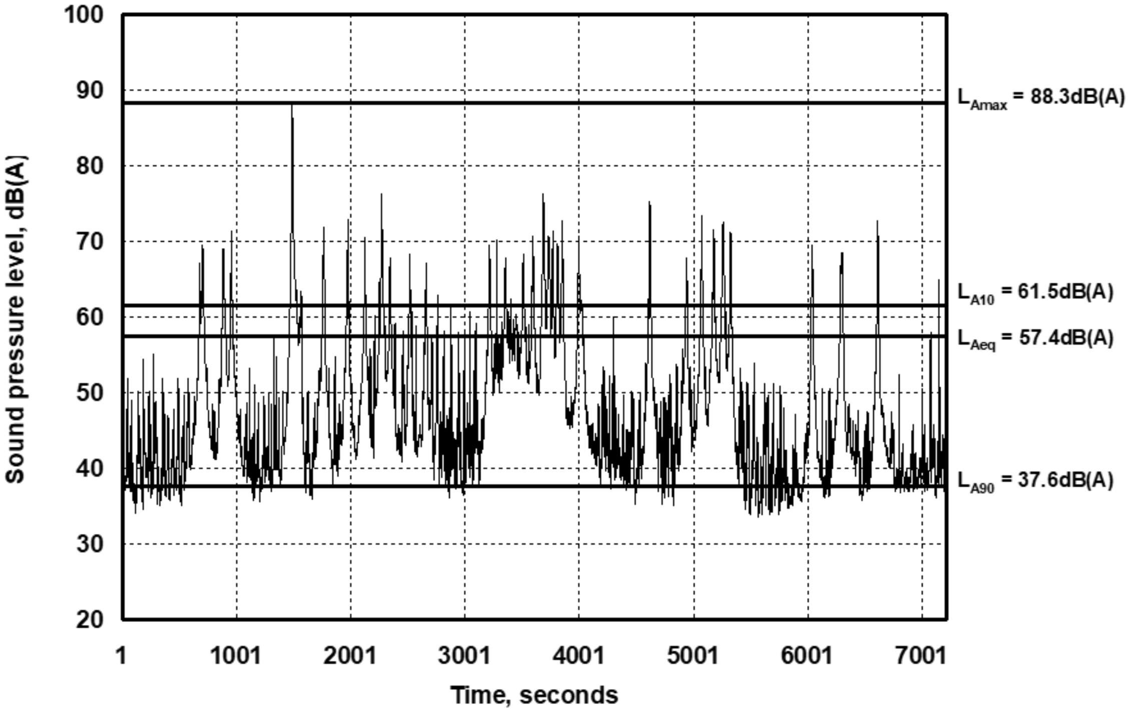
A.5. Before reviewing the potential effects of environmental sound on people, it is useful first to consider the means by which physical sound can be quantified.

Indicators of physical sound levels

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

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

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



Objective measures of noise

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

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

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

Sound levels and decibels

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

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

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

Frequency selectivity of human hearing and A-weighting

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

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

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

Temporal variation of noise and noise indices

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

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

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

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

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

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

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

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

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

Speech interference

A.33. The instantaneous masking effects of unwanted noise on speech communication can be predicted with some accuracy by using specialist methods of calculation, but the overall effect of a small amount of speech interference on everyday life is harder to judge. The significance of speech masking depends on the context in which it occurs. For example, isolated noise events could interfere with telephone conversations by masking out particular words or parts of words but, because of the high redundancy in normal speech, the masking of individual words can often have no significant effect on the intelligibility of the overall message. Notwithstanding the above, noise levels from 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.34. Although sleep seems to be a fundamental requirement for humans, the most significant effect of sleep loss seems to be increased sleepiness the next day. Sleep normally follows a regular cyclic pattern from awake through light sleep to deep sleep and back, this cycle repeating several times during the night at around 90 minute intervals. Most people wake for short periods several times every night as part of the normal sleep cycle without necessarily being aware of this the next day. REM, or rapid eye movement, sleep is associated with dreaming and occurs several times each night during the lighter sleep stages.

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

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

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

Noise annoyance

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

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

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

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

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

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

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

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

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

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

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

A.46. More recently, Environmental Noise Guidelines for the European Region (2018) were published and include general recommendations for wind turbine noise. However, they are designed to inform policy on noise, at the population and strategic level. They are based on the Lden noise indicator, which requires knowledge of the noise levels experienced over the course of a full year. This type of noise index is more suitable for general strategic studies and not appropriate for assessing the acceptability of noise produced by any specific development. Furthermore, these guidelines do not provide recommendations for indoor noise levels and the 2000 WHO Guidelines for Community Noise remain applicable in this regard. For these reasons, the 2018 guidelines will not be referenced any further.

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

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

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

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

Low frequency noise and vibration – windfarms

A.51. 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.52. In this respect, there are three distinct characteristics of sound that should be clearly differentiated between:

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

A.53. Looking at the first two of the three types of sound referred to in the preceding bullet points, a distinction is usually made between low frequency sound and very low frequency sound, otherwise termed infrasound. This distinction is based on the fact that the frequency range of audible noise is generally taken to be from 20 Hz to 20,000 Hz. Therefore, the range of frequencies from about 20 Hz to 200 Hz is usually taken to cover audible low frequency sound, whereas frequencies below 20 Hz are usually described as infrasound. The implication here is that low frequency sound is audible and infrasound is inaudible. However, this relatively arbitrary distinction between low frequency sound and infrasound can introduce some confusion in that frequencies below 20 Hz can still be heard provided they produce a sound pressure level at the ear of the listener that lies above the threshold of audibility of that listener to sound at that particular frequency.

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

A.55. One of the problems inherent in the assessment of both low frequency sound and infrasound is the variability of hearing sensitivity across human subjects with otherwise healthy hearing. This threshold for sound below 200 Hz varies significantly more between different subjects than does the hearing threshold at higher frequencies. However, what is always true is that the perception threshold to lower frequency noise is much higher than the perception threshold for speech frequencies between around 250 Hz to 4,000 Hz. For example, the average person with healthy hearing is some 70 dB less sensitive to sounds at 20 Hz than to sounds that fall within the range of speech frequencies. An additional factor relevant to the perception of infrasound is that, although audibility remains below 20 Hz, tonality is lost below 16 Hz to 18 Hz, thus losing a key element of perception.

A.56. Both low frequency sound and infrasound are generally present all around us in modern life. They may be generated by many natural sources, such as thunder, earthquakes, waves and wind. They may also be produced by machinery including household appliances such as washing machines and air conditioning units, all forms of transport and by turbulence. The presence of low frequency sound and infrasound in our everyday lives is heightened by the fact that the attenuation of sound in air is significantly lower at low frequencies than at the mid to high frequencies. As a result, noise which has travelled over long distances is normally biased towards the low frequencies. However, the fact that human hearing naturally down-weights, or filters out, sounds of such low frequencies means we are generally not aware of its presence. It is only under circumstances when it reaches a sufficiently high level, for example in the 'rumble' of distant thunder or the sound of large waves crashing on a shore, that we become aware of its presence.

A-weighting

A.57. It is because the human ear increasingly filters out sounds of lower frequencies that environmental noise measurements are undertaken as standard using sound level meters that apply the A-weighting curve, as it filters out lower frequency sounds to the same degree as the hearing of a healthy person with unimpaired hearing. The A-weighted sound level is used as a measure of subjective perception of sound unless there exists such a predominance of low frequency sound or infrasound relative to the level of sound at higher frequencies that the use of the A-weighting curve would down-weight the actual source of the problem to such a degree that the resultant objective noise levels do not truly reflect the potential subjective effects of the noise. It is for this reason that a number of alternative weighting curves have been developed, specifically aimed at better accounting for the assessment of low frequency sound and infrasound.

Alternative frequency weightings

A.58. One such curve is denoted C-weighting. Unlike the A weighting curve, which gradually reduces the significance of frequencies below 1000 Hz until at 10 Hz the attenuation is 70 dB, the C-weighting curve is flat to within 1 dB down to about 50 Hz and then drops by 3 dB at 31.5 Hz and 14 dB at 10 Hz. The C weighting curve was originally developed to reflect the fact that, at higher overall noise levels, low frequencies can have a greater subjective effect than at lower overall noise levels.

A.59. One relatively simple measure of undertaking a first-pass assessment as to whether low frequency sound is likely to be an issue is to determine the difference between the overall C weighted noise level and the overall A weighted noise level. The C weighted level includes contributions from low frequency sound, whereas the A weighted level filters it out. It has been suggested in that a level difference of more than 20 dB indicates that low frequency sound may be subjectively significant, but more detailed investigations are in practice required to determine whether or not this is actually the case.

A.60. Another curve, termed the G weighting curve, has been specifically derived to provide a measure of the audibility of infrasound when considered separately from higher frequency noise. The G weighting curve falls off rapidly above 20 Hz and below 20 Hz it follows assumed hearing contours with a slope of 12 dB per octave down to 2 Hz.

Wind-farm infrasound and vibration

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

A.62. As early as 1997 a report by Snow[32] 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 metres from the nearest turbine itself were a factor of 10 lower than those recommended for human exposure in the most critical buildings (i.e. laboratories for precision measurements), and lower again than the limits specified for residential premises. A similar comparison with recognised limits for assessing structural damage showed that the measured vibrations were a factor of 100 below the recommended guidelines at 100 metres from the turbines.

A.63. Noise and vibration levels were found to comply with recommended residential criteria even on the wind turbine site itself. Although low level infrasonic (i.e. below 20 Hz) periodic noise from the 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.64. In 2003, findings on both low frequency sound and infrasound have been compiled into the previously referenced extensive review report commissioned by DEFRA and prepared by Dr G Leventhall[33]. 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.

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

He goes on to describe the low frequency hearing threshold i.e. the lowest levels which are audible to an average person with normal hearing. He notes the threshold at 4 Hz is about 107 dB, at 10 Hz it is about 97 dB and at 20 Hz it is 79 dB. As such, high levels of infrasound are required to exceed the hearing thresholds at such low frequencies. Leventhall therefore concluded that most people can be reassured that there will be no serious consequences to peoples' health from infrasound exposure.

A.65. Indeed, specifically in relation to 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. Typical levels of infrasound produced by a wind turbine at representative separation distances would not exceed 70 dB, and clearly below the perception thresholds discussed above. In the light of this, Leventhall issued an open statement:

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

A.66. In 2004/2005 researchers from Keele University investigated the effects of the extremely low levels of vibration resulting from 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 were initially 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 subsequently explained[34] that:

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

A.67. They then continue:

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

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

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

A.69. In 2006, the results of a study specifically commissioned by the UK Department of Trade and industry (DTI) to look at the effects of infrasound and low frequency noise (LFN) arising from the operation of windfarms have been published in what is commonly referred to as the DTI LFN Report[35]. This Report is quite categorical in its findings: infrasound is not the perceived health threat suggested by some

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

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 windfarm neighbour'.*

A.70. This has been subsequently confirmed by many international studies and reviews. For example, a study for the National Institute for Public Health and the Environment (RIVM) in the Netherlands[36] published in 2020 concluded in this regard that:

> *'Although low frequency sound and infrasound might have other effects than 'normal' sound has, these effects are highly unlikely at sound levels typical for wind turbines. Brain studies show that low frequency and infrasound are processed in the same parts of the brain as 'normal' sound and there is no evidence that infrasound elicits any reaction at sub-audible levels.'*

A.71. In conclusion, whilst is known that infrasound can have an adverse effect on people (potential adverse health impacts are listed by the World Health Organisation as stress, irritation, unease, fatigue, headache, possible nausea and disturbed sleep), these effects can only come into play when the infrasound reaches a sufficiently high level. This is a level above the threshold of audibility. However, all available information from measurements on current wind turbines reveals that the level of infrasound emitted by these wind turbines lies below the threshold of human perception.

Low frequency sound

A.72. A report prepared for DEFRA by Casella Stanger[37] 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.73. 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 windfarm'. 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.74. Based on the findings of the DTI LFN Report, low frequency sound in the greater than 20 Hz frequency range may, under some circumstances, be measured to be of a comparable or higher level than the

36 Health effects related to wind turbine sound: an update, I. van Kamp, G.P. van den Berg, National Institute for Public Health and the Environment (RIVM), RIVM report 2020-0150, October 2020.
37 'Low frequency noise', Report by Casella Stanger for DEFRA, 2001.

threshold of audibility. On such occasions this low frequency sound may become audible to low frequency sensitive persons who may already be awake inside nearby properties, but not to the degree that it will cause awakenings. However, such noise should still be assessed for its potential subjective effects in the conventional manner in which environmental noise is generally assessed. In particular, the subjective effects of this audible low frequency sound should not be confused with the claimed adverse health effect arguments concerning infrasound which, in any event, have now been shown from the results of the DTI LFN Report to be wholly unsubstantiated.

A.75. In November 2006, the UK Government released a statement[38] concerning low frequency sound, reiterating the conclusion of the DTI LFN report that:

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

A.76. The Government statement concluded the position regarding low frequency sound from 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.77. The noise assessment methodology presented in ETSU-R-97, sets out noise limits which already account for typically encountered levels of blade swish. Notwithstanding the conclusions and advice presented in the preceding paragraphs concerning both infrasound and low frequency sound, the DTI LFN Report went on to suggest that, where complaints of noise at night had occurred, these had most likely resulted from an increased amplitude modulation of the blade passing noise, making the 'swish, swish, swish' sound (often referred to as 'blade swish') more prominent than normal. Whilst it was therefore acknowledged that this effect of enhanced amplitude modulation of blade aerodynamic noise may occur, it was also concluded that there were a number of factors that should be borne in mind when considering the importance to be placed on the issue when considering present and proposed 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.78. The Government then commissioned an independent research project to further investigate the prevalence of the impact of enhanced levels of amplitude modulation across UK windfarms. This

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

research work was awarded to the University of Salford who reported on their findings in July 2007[39]. The Salford study concluded that that the occurrence of increased levels of 'blade swish' was infrequent, but suggested it would be useful to undertake further work to understand and assess this feature of wind turbine noise.

A.79. As a consequence of the findings of the report by the University of Salford, the UK Department for Business, Enterprise and Regulatory Reform (BERR formerly the DTI) issued a statement in August 2007[40] 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 windfarm fleet.*
>
> *AM indicates aerodynamic noise from wind turbines that is greater than the normal degree of regular fluctuation of blade swoosh. It is sometimes described as sounding like a distant train or distant piling operation.*
>
> *The Government commissioned work assessed 133 operational wind projects across Britain and found that although the occurrence of AM cannot be fully predicted, the incidence of it from operational turbines is low'.*

A.80. The statement then concludes with the advice:

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

A.81. This represents an aspect of wind turbine noise which has become the subject of considerable research in the UK and abroad in the past years and the state of knowledge on the subject is rapidly evolving. An extensive research programme entitled 'Wind Turbine Amplitude Modulation: Research to Improve Understanding as to its Cause and Effect' was published in 2013[41]. This research, commissioned by RenewableUK (ReUK) was specifically aimed at identifying and explaining some of the key features of wind turbine AM noise.

A.82. Claims have emerged from different researchers that wind turbines were capable of generating noise with characteristics out with that expected of them. This characteristic was an enhanced level of modulated aerodynamic noise that resulted in the blade swish becoming more impulsive in character, such that those exposed to it would describe it more as a 'whoomp' or 'thump' than a 'swish'. It could also become audible at distances from the wind turbines that were considerably greater than the distances at which blade swish could ordinarily be perceived. It has since emerged that this may be similar to the character of the noise identified in the DTI LFN study. Hence for the purposes of the ReUK project, any such AM phenomena with characteristics falling outside those expected of this "normal" AM (NAM) were therefore termed 'Other AM' (OAM).

A.83. The research identified the most likely cause of OAM noise is transient stall on the wind turbine blade (i.e. stall which occurs over a small area of each turbine blade in one part of the blade's rotation only). The occurrence of transient stall will be dependent on a combination of factors, including the air inflow conditions onto the individual blades, how these inflow conditions may vary across the rotor disc, the design of the wind turbine blades and the manner in which the wind turbine is operated. Variable inflow conditions may arise, for example, from any combination of wind shear, wind veer, yaw errors, turbine

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

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

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

wake effects, topographic effects, large scale turbulence, etc. However, the occurrence of OAM on any particular site cannot be predicted at this stage.

A.84. As a consequence of the combined results of the ReUK research, and most notably the development of objective techniques for identifying and quantifying AM noise and the ability to relate such an objective measure to the subjective response to AM noise, ReUK has proposed an AM test[42] for implementation as a planning condition, although this was subject to discussion.

A.85. The Institute of Acoustics (IOA) published in 2016 a standardised methodology[43] for the assessment and rating of AM magnitude. The method provides a decibel level each 10 minute which represents the magnitude of the modulation in the noise, and minimises the influence of sources not related to wind turbines. The proposed method, unlike other methods that have previously been proposed, utilises as the core of its detection capability the fact that AM noise from wind turbines, by definition, exhibits periodicity at a rate that is directly related to the rotational speed of the source wind turbine. The IOA document does not however provide any thresholds or criteria methodology for using the resulting AM values.

A.86. The UK Government (DECC or Department of Energy and Climate Change, now obsolete) commissioned a review focused on the subjective response to AM with a view to recommend how this feature may be controlled. The outcome of this research has been published[44] 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.

A.87. Subsequently, a report commissioned by the UK Department for Business, Energy & Industrial Strategy was published[45] in February 2023 and concludes that the noise limits in ETSU-R-97 should be reviewed and that updated guidance on amplitude modulation should be included but makes no firm recommendations with regards to any update. Therefore, until the UK or Scottish government concludes such a review, the ETSU-R-97 methodology continues to be applicable. The UK Government has also confirmed[46] that ETSU-R-97 should continue to apply until the review recommendations are considered in further detail.

42 Template Planning Condition on Amplitude Modulation (guidance notes), RenewableUK, December 2013.
43 Institute of Acoustics (IOA) Amplitude Modulation Working Group, Final Report, A Method for Rating Amplitude Modulation in Wind Turbine Noise, June 2016.
44 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
45 WSP, A Review of Noise Guidance for Onshore Wind Turbines, report for the UK Department for Business, Energy & Industrial Strategy, October 2022 (published 10 February 2023).
46 Government Response to the House of Lords Science and Technology Committee Report: The neglected pollutants: the effects of artificial light and noise on human health, December 2023. https://committees.parliament.uk/publications/42401/documents/210714/default/ [accessed September 2024]

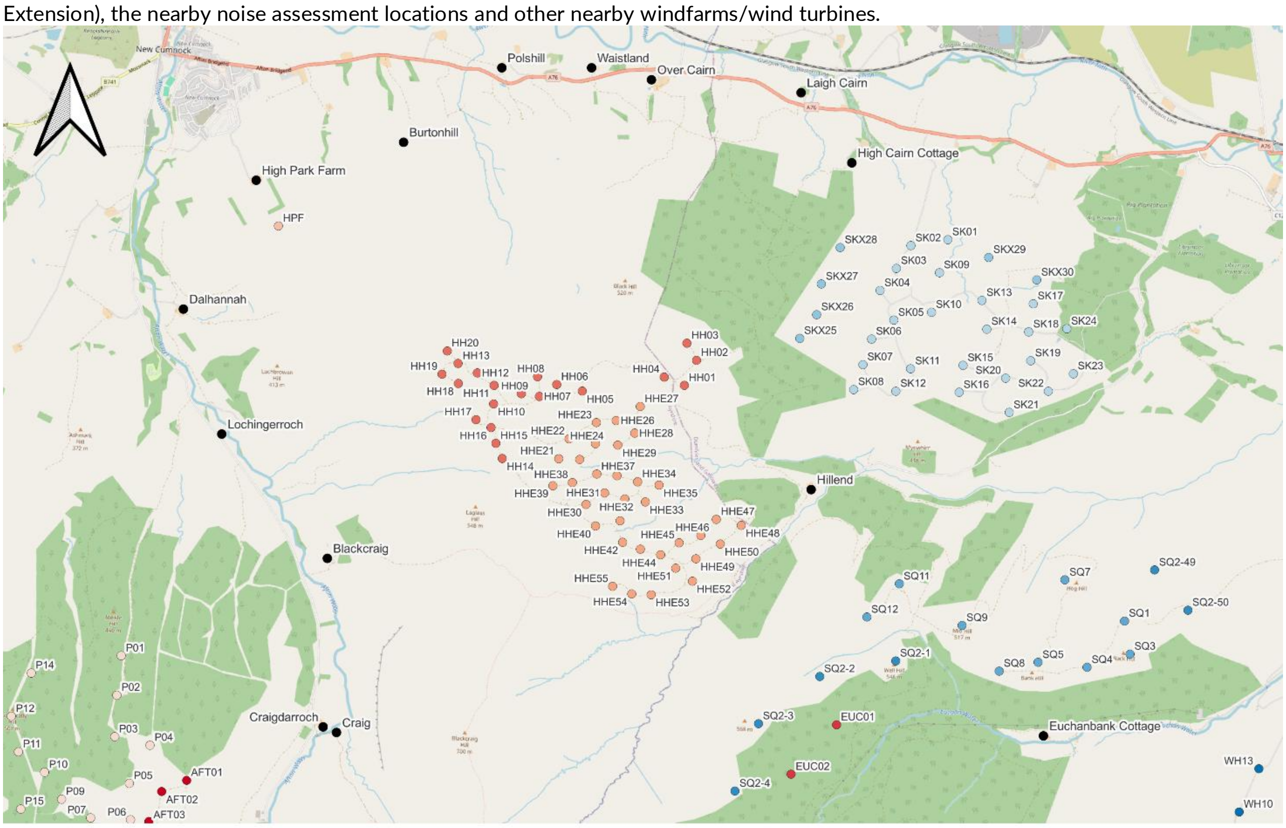
Glossary of Acoustics Terminology

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

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

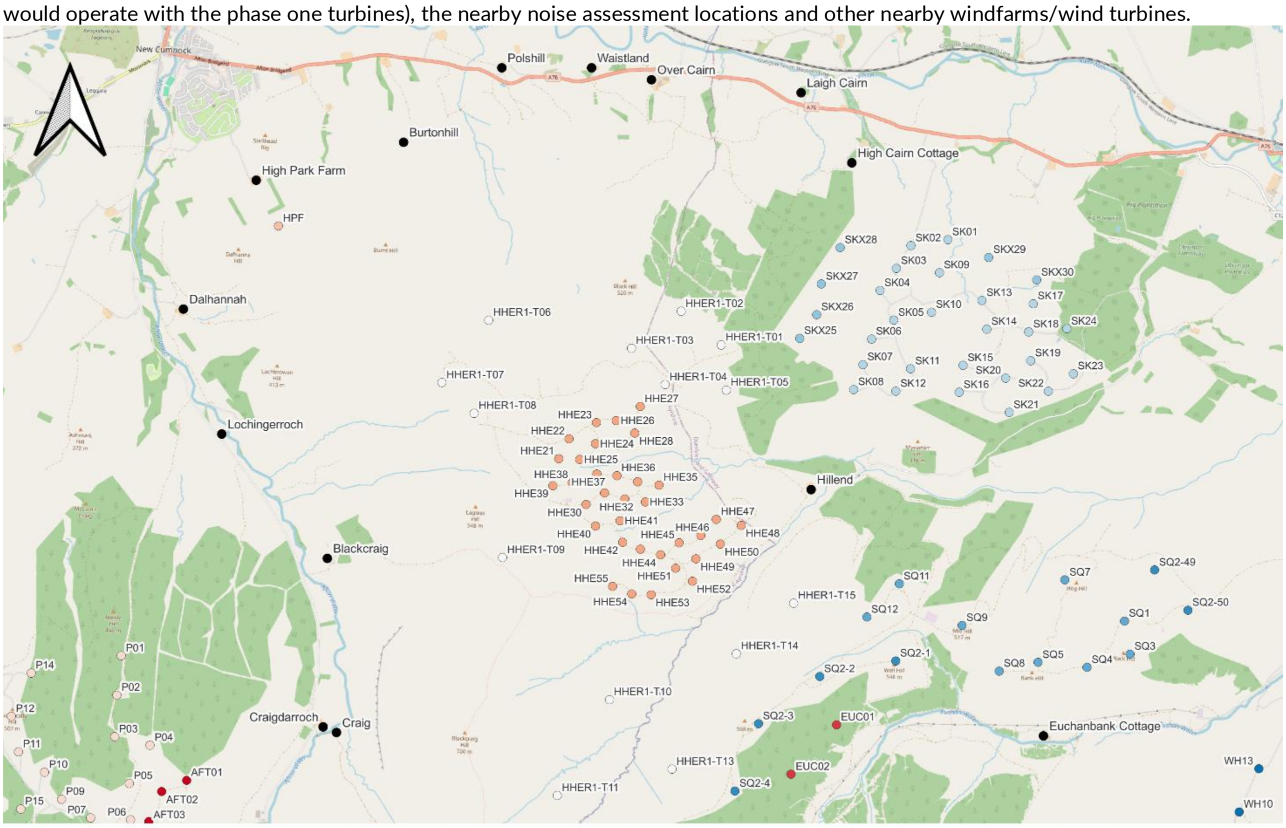
Annex B – Location Maps and Turbine Coordinates

Figure B1 - Map showing the layout of the existing wind turbines on the site of the proposed Development (Hare Hill and Hare Hill Extension), the nearby noise assessment locations and other nearby windfarms/wind turbines.



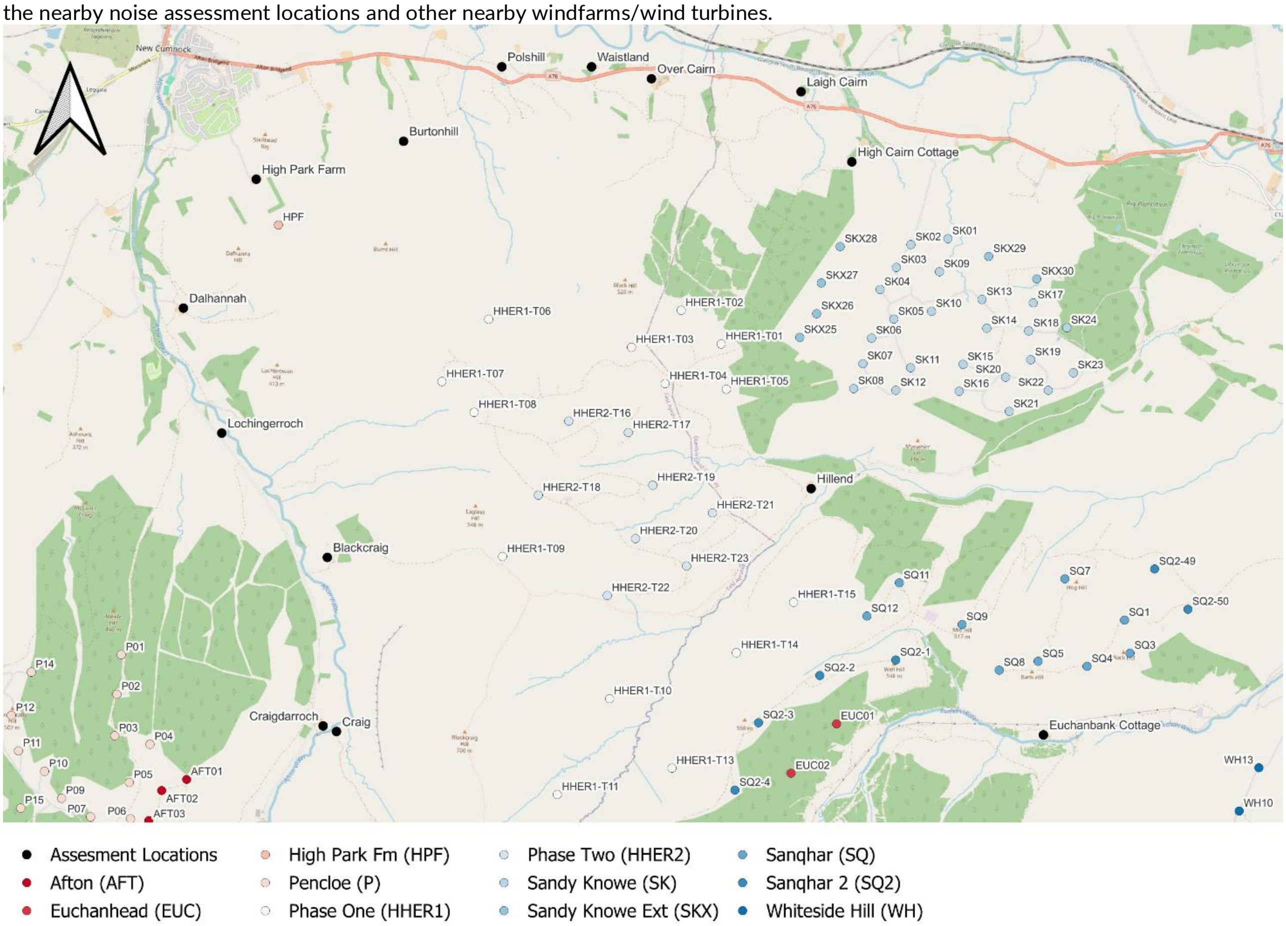
- Assesment Locations
- Afton (AFT)
- Euchanhead (EUC)
- Hare Hill (HH)
- Hare Hill Ext (HHE)
- High Park Fm (HPF)
- Pencloe (P)
- Sandy Knowe (SK)
- Sandy Knowe Ext (SKX)
- Sanqhar (SQ)
- Sanqhar 2 (SQ2)
- Whiteside Hill (WH)

Figure B2 - Map showing the layout of the wind turbines for phase one of the proposed Development, those on Hare Hill Extension (which would operate with the phase one turbines), the nearby noise assessment locations and other nearby windfarms/wind turbines.



- Assesment Locations
- Afton (AFT)
- Euchanhead (EUC)
- Hare Hill Ext (HHE)
- High Park Fm (HPF)
- Pencloe (P)
- Phase One (HHER1)
- Sandy Knowe (SK)
- Sandy Knowe Ext (SKX)
- Sanqhar (SQ)
- Sanqhar 2 (SQ2)
- Whiteside Hill (WH)

Figure B3 - Map showing the layout of the wind turbines for phase two of the proposed Development (turbines from phase one and two), the nearby noise assessment locations and other nearby windfarms/wind turbines.



Turbine & Propagation Details: the proposed Development

B.1. The proposed Development will have turbines with three different tip heights of 150 m, 180 m and 200 m. For these tip heights, three candidate turbine models have been chosen, each with a corresponding rotor size and hub height. These three Vestas models of wind turbine are typical of the type and size which would be installed and are suitable as candidates wind turbines for the assessment. Data are provided by Vestas for the V136-4.5 MW (hub height 82 m), the V150-6.0 MW (hub height 105 m) and the V162-6.8 MW (hub height 119 m). All of these turbine models are fitted with serrated trailing edge blades as standard. Turbine coordinates are shown in Table B1, propagation correction factors in Table B2 and relevant noise emission data shown in Tables B3 and B4. The sound power levels data include appropriate allowances for uncertainty in accordance with the IOA GPG (see notes below Table B3).

Table B1 – Turbine coordinates – the proposed Development

Turbine	Easting	Northing	Hub Height (m)	Type	Turbine	Easting	Northing	Hub Height (m)	Type
HHER1-T01	267299	610340	105	V150	HHER1-T13	266806	606087	105	V150
HHER1-T02	266898	610678	105	V150	HHER1-T14	267451	607244	105	V150
HHER1-T03	266400	610307	82	V136	HHER1-T15	268025	607750	105	V150
HHER1-T04	266737	609943	82	V136	HHER2-T16	265771	609567	82	V136
HHER1-T05	267351	609887	119	V162	HHER2-T17	266368	609452	105	V150
HHER1-T06	264968	610589	82	V136	HHER2-T18	265466	608824	105	V150
HHER1-T07	264499	609964	82	V136	HHER2-T19	266613	608924	119	V162
HHER1-T08	264822	609655	82	V136	HHER2-T20	266440	608389	119	V162
HHER1-T09	265107	608209	105	V150	HHER2-T21	267212	608646	119	V162
HHER1-T10	266180	606783	119	V162	HHER2-T22	266157	607818	119	V162
HHER1-T11	265656	605822	105	V150	HHER2-T23	266952	608114	119	V162
HHER1-T12	266503	605539	82	V136					

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

Turbine	Property														
	Blackcraig	Burtonhill	Craig	Craigdarroch	Dalhannah	Euchanbank Cottage	High Cairn Cottage	High Park Farm	Hillend	Laigh Cairn	Lochingerroch	Nether Cairn	Over Cairn	Polshill	Waistland
HHER1-T01	2	0	2	2	2	2	0	2	0	0	2	0	0	0	0
HHER1-T02	2	0	2	2	2	2	0	0	0	0	2	0	0	0	0
HHER1-T03	2	0	2	2	2	2	0	0	0	0	2	0	0	0	0
HHER1-T04	2	2	2	2	2	2	0	2	0	0	2	0	0	0	0
HHER1-T05	2	2	2	2	2	2	0	2	0	0	2	0	0	0	0
HHER1-T06	2	0	0	0	2	2	0	-3	2	0	2	0	0	0	0
HHER1-T07	0	0	-3	-3	0	2	2	-3	2	2	0	2	0	0	0

Turbine	Property														
	Blackcraig	Burtonhill	Craig	Craigdarroch	Dalhannah	Euchanbank Cottage	High Cairn Cottage	High Park Farm	Hillend	Laigh Cairn	Lochingerroch	Nether Cairn	Over Cairn	Polshill	Waistland
HHER1-T08	0	0	-3	-3	2	2	2	0	2	2	-3	2	2	2	2
HHER1-T09	0	2	2	2	2	2	2	0	2	2	0	2	2	2	2
HHER1-T10	2	2	2	2	2	0	2	2	0	2	2	2	2	2	2
HHER1-T11	2	2	2	2	2	2	2	2	-3	2	2	2	2	2	2
HHER1-T12	2	2	2	2	2	2	2	2	0	2	2	2	2	2	2
HHER1-T13	2	2	2	2	2	2	2	2	0	2	2	2	2	2	2
HHER1-T14	2	2	2	2	2	0	2	2	0	2	2	2	2	2	2
HHER1-T15	2	2	2	2	2	0	2	2	0	2	2	0	2	2	2
HHER2-T16	2	2	2	2	2	2	2	2	2	2	2	0	2	2	0
HHER2-T17	2	2	2	2	2	2	2	2	-3	0	2	0	2	2	2
HHER2-T18	0	2	2	2	2	2	2	0	2	2	0	2	2	2	2
HHER2-T19	2	2	2	2	2	2	2	2	0	2	0	0	2	2	2
HHER2-T20	2	2	2	2	2	2	2	2	0	2	2	0	2	2	2
HHER2-T21	2	2	2	2	2	2	2	2	0	0	2	0	2	2	2
HHER2-T22	2	2	2	2	2	2	2	2	2	2	0	2	2	2	2
HHER2-T23	2	2	2	2	2	2	2	2	0	2	2	0	2	2	2

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

Turbine make / model	Standardised Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
V136-4.5 MW	-	-	93.4	96.6	101.5	105.2	105.9	105.9	105.9	105.9	105.9	105.9
V150-6.0 MW	-	-	94.8	98.2	102.5	106.0	106.8	106.9	106.9	106.9	106.9	106.9
V162-6.8 MW	-	-	96.0	96.9	101.4	104.9	105.3	105.7	106.1	106.4	106.4	106.5

Derived from:-

- V136-4.5 MW – Vestas document Performance Specification V136-4.5 MW 50/60 Hz (Low HH) 0067-7056.V02 2021-09-03. Data for the version with STE blades for the operating mode with the highest noise levels described as 'Mode PO4'. These are given at hub height and converted to a standardised ten metre height of 82 metres. The values presented above include 2 dB added to allow for uncertainty.
- V150-6.0 MW – Vestas document Performance Specification V150-6.0 MW 0098-0749.V01 2020-10-13. Data for the version with STE blades for the operating mode with the highest noise levels described as 'Mode PO6000'. These are given at hub height and converted to a standardised ten metre height of 105 metres. The values presented above include 2 dB added to allow for uncertainty.
- V162-6.8 MW - Vestas document Performance Specification 0114-3788 V01 2022-01-18. Data for the version with STE blades for the operating mode with the highest noise levels described as 'Mode PO6800'. These are given at hub height and converted to a standardised ten metre height of 119 metres. The values presented above include 2 dB added to allow for uncertainty

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
V136-4.5 MW	87.0	94.6	99.2	101.0	99.9	95.8	89.0	79.1	105.8
V150-6.0 MW	81.1	88.7	93.4	95.1	94.0	89.9	82.9	72.9	99.9
V162-6.8 MW	88.1	95.6	100.1	101.9	100.8	96.8	90.1	80.4	106.8

Derived from:-

- V136-4.5 MW – Vestas Document DMS 00067-4732 V02, 20/03/2018 for V136 4/4.2MW variant. Values at 11 m/s (hub height) used as reference, reducing 1/3 data to octaves.
- V150-6.0 MW – Vestas Document V150-6.0MW Third Octaves, 0095-3747.V01 2020-11-03. Values at 12 m/s (hub height) used as reference, reducing 1/3 data to octaves.
- V162-6.8 MW – Vestas Document: V162-6.2MV Third Octaves, 0105-5200_00, 21/04/2022. Values at 11 m/s (hub height) used as reference, reducing 1/3 data to octaves.

Turbine & Propagation Details: existing turbines on the site of the proposed Development

B.2. The existing wind turbines on the site of the proposed Development are those on HH and HHE, which consist of two different turbine models and differing hub heights. Turbines on HH are Vestas V47-660 kW turbines (hub height 40 m) and those on HHE are Gamesa G52-850 kW (hub heights 44 m, 55 m and 65 m).

B.3. Condition 30 of the consent for HHE[47] provided noise limits which apply to the combined operation of HH together with HHE and required information to be submitted which demonstrated how HH and HHE would be operated so that these noise limits would be complied with. An assessment by Arcus was submitted[48] to satisfy this requirement which provided details of the turbines, their sound power levels, as well as predicted noise levels, which demonstrated that combined operation of HH and HHE was compliant with the noise limits at two named locations: Hillend (268201, 608890) and Blackcraig (263350, 608200). This report identified a small excess of a maximum of 0.3 dB at the nearest receptor Hillend and proposed a minimal constraint be applied to one turbine on HHE, however this excess is not acoustically important and could in practice be ignored. Predicted noise levels completed for this assessment indicate this constraint would not be required (see Annex C).

B.4. Data used in this assessment are shown below, with turbine coordinates shown in Table B5, propagation correction factors in Table B6 and relevant noise emission data in Tables B7 and B8. Noise emission data in Tables B7 and B8 are taken directly from the Arcus assessment (see above), which confirmed these included appropriate allowances for uncertainty in accordance with the IOA GPG. Turbine coordinates and hub heights are those ‘as-built’. The propagation attenuation factors shown in Table B6 are calculated for this assessment.

Table B5 – Turbine coordinates – existing turbines on the site of the proposed Development (Hare Hill prefixed ‘HH’ and Hare Hill Extension prefixed ‘HHE’).

Turbine	Easting	Northing	Hub Height (m)	Type	Turbine	Easting	Northing	Hub Height (m)	Type
HH01	266930	609935	40	V47-660 kW	HHE29	266262	609336	65	G52-850 kW
HH02	267052	610186	40	V47-660 kW	HHE30	265945	608741	44	G52-850 kW
HH03	266955	610358	40	V47-660 kW	HHE31	266130	608856	55	G52-850 kW
HH04	266728	610018	40	V47-660 kW	HHE32	266333	608796	65	G52-850 kW
HH05	265906	609878	40	V47-660 kW	HHE33	266539	608766	65	G52-850 kW
HH06	265650	609944	40	V47-660 kW	HHE34	266461	608968	65	G52-850 kW
HH07	265476	609824	40	V47-660 kW	HHE35	266676	608935	65	G52-850 kW
HH08	265458	610022	40	V47-660 kW	HHE36	266254	609029	55	G52-850 kW
HH09	265296	609851	40	V47-660 kW	HHE37	266052	609046	55	G52-850 kW
HH10	265017	609749	40	V47-660 kW	HHE38	265807	608960	55	G52-850 kW
HH11	265022	609935	40	V47-660 kW	HHE39	265612	608929	44	G52-850 kW
HH12	264854	610060	40	V47-660 kW	HHE40	266039	608525	44	G52-850 kW
HH13	264661	610155	40	V47-660 kW	HHE41	266285	608577	65	G52-850 kW
HH14	265104	609202	40	V47-660 kW	HHE42	266311	608361	44	G52-850 kW
HH15	265040	609354	40	V47-660 kW	HHE43	266489	608292	44	G52-850 kW
HH16	264992	609512	40	V47-660 kW	HHE44	266692	608236	44	G52-850 kW

47 Grant of Planning Permission, East Ayrshire Council (Ref 07/0809/FL), 18th June 2015.
48 The Construction and Operation of Hare Hill Extension Windfarm, Noise, Planning Consent Response by ScottishPower Renewables (UK) Limited to East Ayrshire Council, Version 01, March 2016. This submission included Appendix A which provided a report from Arcus, ScottishPower Renewables, Hare Hill Extension Wind Farm, Condition 30(g) - Turbine Details, January 2016.

Turbine	Easting	Northing	Hub Height (m)	Type	Turbine	Easting	Northing	Hub Height (m)	Type
HH17	264841	609591	40	V47-660 kW	HHE45	266877	608356	65	G52-850 kW
HH18	264663	609954	40	V47-660 kW	HHE46	267095	608430	65	G52-850 kW
HH19	264500	610047	40	V47-660 kW	HHE47	267250	608591	65	G52-850 kW
HH20	264553	610280	40	V47-660 kW	HHE48	267500	608531	65	G52-850 kW
HHE21	265671	609199	44	G52-850 kW	HHE49	267046	608196	65	G52-850 kW
HHE22	265774	609399	44	G52-850 kW	HHE50	267290	608344	65	G52-850 kW
HHE23	266048	609562	55	G52-850 kW	HHE51	266843	608102	44	G52-850 kW
HHE24	266039	609350	65	G52-850 kW	HHE52	267011	607971	65	G52-850 kW
HHE25	265880	609192	55	G52-850 kW	HHE53	266597	607835	65	G52-850 kW
HHE26	266246	609582	44	G52-850 kW	HHE54	266402	607844	65	G52-850 kW
HHE27	266488	609723	44	G52-850 kW	HHE55	266211	607920	55	G52-850 kW
HHE28	266432	609456	65	G52-850 kW					

Table B6 - Propagation attenuation effects due to terrain (dB) – existing turbines on the proposed Development – Positive numbers are due to terrain shielding barrier effects (e.g. 2), representing a decrease in noise levels, and negative numbers (e.g. -3) represent an increase in predicted noise levels due to concave ground effects. Where there is a zero shown, neither terrain shielding nor concave ground were found.

Turbine	Property														
	Blackcraig	Burtonhill	Craig	Craigdarroch	Dalhannah	Euchanbank Cottage	High Cairn Cottage	High Park Farm	Hillend	Laigh Cairn	Lochingerroch	Nether Cairn	Over Cairn	Polshill	Waistland
HH01	2	2	2	2	2	2	2	2	-3	0	2	-3	0	2	2
HH02	2	2	2	2	2	2	0	2	0	0	2	-3	0	2	2
HH03	2	2	2	2	2	2	0	2	0	-3	2	-3	0	2	2
HH04	2	2	2	2	2	2	2	2	-3	0	2	0	2	2	2
HH05	2	2	2	2	2	2	2	2	2	2	2	0	2	2	2
HH06	2	2	2	2	2	2	2	2	2	2	2	2	2	2	0
HH07	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
HH08	2	2	2	2	2	2	2	2	2	2	2	2	0	2	2
HH09	2	2	2	-3	2	2	2	2	2	2	0	2	2	2	2
HH10	2	2	2	-3	2	2	2	0	2	2	-3	2	2	2	2
HH11	2	2	2	-3	2	2	2	-3	2	2	2	2	2	2	2
HH12	2	2	-3	-3	2	2	2	-3	2	2	2	2	2	2	2
HH13	2	0	-3	-3	2	2	2	-3	2	2	2	2	2	0	0
HH14	2	2	2	2	2	2	2	2	2	2	-3	2	2	2	2
HH15	2	2	2	-3	2	2	2	2	2	2	-3	2	2	2	2
HH16	2	2	2	-3	2	2	2	0	2	2	-3	2	2	2	2
HH17	2	2	-3	-3	2	2	2	-3	2	2	-3	2	2	2	2
HH18	2	2	-3	-3	2	2	2	-3	2	2	2	2	2	2	2
HH19	2	0	-3	-3	2	2	2	-3	2	2	2	2	2	2	2
HH20	2	0	-3	-3	2	2	2	-3	2	2	2	2	0	0	2

Turbine	Property														
	Blackcraig	Burtonhill	Craig	Craigdarroch	Dalhannah	Euchanbank Cottage	High Cairn Cottage	High Park Farm	Hillend	Laigh Cairn	Lochingerroch	Nether Cairn	Over Cairn	Polshill	Waistland
HXA21	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
HXA22	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
HXA23	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
HXA24	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
HXA25	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
HXA26	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
HXA27	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
HXA28	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
HXA29	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
HXB30	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
HXB31	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
HXB32	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
HXB33	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
HXB34	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
HXB35	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
HXB36	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
HXB37	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
HXB38	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
HXB39	2	2	2	2	2	2	2	2	2	2	0	2	2	2	2
HXC40	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
HXC41	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
HXC42	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
HXC43	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
HXC44	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
HXC45	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
HXC46	2	2	2	2	2	2	2	2	0	2	2	2	2	2	2
HXC47	2	2	2	2	2	2	2	2	0	2	2	2	2	2	2
HXC48	2	2	2	2	2	2	2	2	0	2	2	2	2	2	2
HXC49	2	2	2	2	2	2	2	2	0	2	2	2	2	2	2
HXC50	2	2	2	2	2	2	2	2	0	2	2	2	2	2	2
HXD51	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
HXD52	2	2	2	2	2	2	2	2	0	2	2	2	2	2	2
HXD53	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
HXD54	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
HXD55	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2

Table B7 - Wind turbine sound power levels (dB L_{Aeq}) used in the noise assessment – existing turbines on the proposed Development.

Turbine make / model	Standardised Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
V47-660 kW (40 m)	-	-	-	101.0	101.5	101.9	102.4	102.8	103.3	103.7	104.2	104.6
G52-850 kW (44 m)	-	-	-	94.7	98.8	102.9	104.7	105.6	105.8	105.8	105.8	105.8
G52-850 kW (55 m)	-	-	-	95.2	99.5	103.5	105.0	105.8	105.8	105.8	105.8	105.8
G52-850 kW (65 m)	-	-	-	95.6	100.0	103.8	105.1	105.8	105.8	105.8	105.8	105.8
Derived from: data for the V47 from Table 4, data for the G52 from Table 6 (three different hub heights) of the Arcus Consultancy Services report: ScottishPower Renewables, Hare Hill Extension Wind Farm, Discharge of Condition 30(g) - Turbine Details, January 2016. 2 dB were added to the values shown in the tables in the Arcus report, consistent with the text of that report which stated a further 2 dB was added for uncertainty to yield warranted values, in accordance with the IOA GPG.												

Table B8 - Octave band sound power spectrum (dB L_{Aeq}) for reference wind speed conditions (v_{10} = 8 m/s) - existing turbines on the proposed Development.

Turbine make / model	Octave Band Centre Frequency (Hz)								
	63	125	250	500	1000	2000	4000	8000	A
V47-660 kW	78.2	86.1	89.8	95.2	97.0	92.9	87.9	69.2	100.0
G52-850 kW	82.4	88.9	93.3	94.7	93.8	90.9	85.2	72.8	100.0
Derived from: data for the V47 from Table 5, data for the G52 from Table 7 of the Arcus Consultancy Services report: ScottishPower Renewables, Hare Hill Extension Wind Farm, Discharge of Condition 30(g) - Turbine Details, January 2016.									

Turbine & Propagation Details: High Park Farm Turbine

B.5. The single wind turbine at High Park Farm is bult and operating. The application for this turbine was supported by a noise assessment[49] which used the Vestas V52-850 kW (50 m hub height) wind turbine as the candidate and provided predicted noise levels for nearby receptor locations for this turbine operating alone, with the highest of these predicted at the applicant's property High Park Farm (262644, 612017) of 34.55 dB(A). The sound power levels supplied with that noise assessment were for the Vestas V52-850 kW and reached a maximum sound power level of 101 dB(A)[50]. Permission was granted[51] for the turbine by East Ayrshire Council (EAC) but did not contain noise limits. A non-material variation application[52] was made to change the wind turbine to a Gamesa G52.

B.6. A subsequent application for two further turbines by the same applicant was refused on appeal with the supporting noise assessment[53] confirming the consent for the existing turbine did not contain noise limits and adopted a Gamesa G52-800 kW as the turbine model (restricted to 500 kW) for the High Park Farm Turbine in the noise assessment, with sound power levels which reached a maximum of 100 dB(A) for wind speeds from 8 m/s upwards.

B.7. The coordinates of the High Park Farm Turbine are shown in Table B9, propagation correction factors in Table B10 and relevant noise emission data in Tables B11 and B12. Sound power levels used for this noise assessment are those available to ourselves for the Gamesa G52-850 kW. These include an uncertainty margin in accordance with the IOA GPG and reach a maximum noise levels of 105.8 dB(A) from a wind speed of approximately 8 m/s upwards. For the purpose of modelling the noise from the High Park Farm turbine, these sound power levels have been reduced by 3 dB(A) at all wind speeds so that resulting predicted noise levels at the receptor location of High Park Farm do not exceed 35 dB(A) (at wind speeds of 8 m/s upwards). This approach results in predicted noise levels which are consistent with the original noise assessment for the High Park Farm Turbine. Such sound power levels are therefore comparable with those assumed for the original High Park Farm Turbine application, higher than those used in the assessment of the refused application for the two additional wind turbines and considered to include sufficient margins for the purposes of a cumulative noise assessment for the proposed Development, in accordance with the IOA GPG.

Table B9 - Turbine coordinates – High Park Farm Turbine.

Turbine	Easting	Northing
HPF	262860	611534
Turbine is assumed to be 49 metres in height to the hub.		

49 11/0893/PP – East Ayrshire Council, Proposed erection of one 49m high wind turbine (75m to blade tip), associated meter housing and access track. High Park Farm Afton Road Mossmark New Cumnock East Ayrshire KA18 4BG. Application Received Thu 10 Nov 2011 (https://eplanning.east-ayrshire.gov.uk/online/applicationDetails.do?activeTab=summary&keyVal=LUGEVBGF02N00). The application was refused by East Ayrshire Council but granted on appeal, with details of the appeal not found.
High Park Farm, Environmental Noise Report, VG Energy. The document is undated but stamped as received by East Ayrshire Council 10th Nov 2011. This document provided Appendix B which was a test report for a Vestas V52-850 kW wind turbine.

50 WINDTEST, Report of Acoustical Emissions of a Wind Turbine Generator System of the Type V52-850 kW Report WT 2422/02, October 2002. Measured sound power levels for a 49 m hub height turbine reach a maximum of 99.7 dB(A) at a wind speed of 10 m/s with a stated uncertainty of 0.9 dB(A). The sound power level with an appropriate allowance for uncertainty in accordance with the IOA GPG would be 101 dB(A), based upon the measured uncertainty being 'expanded' (multiplied by 1.5) and adding the result to the measured sound power level.

51 Review Decision Notice, Decision by East Ayrshire Review Body 3rd October 2012.

52 Proposed change of turbine from a V52 to a Gamesa G52 (same hub height and height to blade tip), East Ayrshire Council, Application for Non-material Variation, Town and Country Planning (Scotland) Act 1997, Section 64. Young Brothers, High Park Farm, 11th Dec 2012.

53 Improving New Cumnock Wind Turbines, Volume I: Environmental Impact Assessment Report, Chapter 8 Noise. Greencat Renewables, July 2017.

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

Turbine	Property														
	Blackcraig	Burtonhill	Craig	Craigdarroch	Dalhannah	Euchanbank Cottage	High Cairn Cottage	High Park Farm	Hillend	Laigh Cairn	Lochingerroch	Nether Cairn	Over Cairn	Polshill	Waistland
HPF	2	-3	2	2	2	2	2	0	2	2	2	2	2	2	2

Table B11 - Wind turbine sound power levels (dB L_{Aeq}) used in the noise assessment – High Park Farm Turbine.

Turbine make / model	Standardised Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
G52-850 kW (49 m)	-	-	-	94.9	99.2	103.2	104.8	105.7	105.8	105.8	105.8	105.8
Derived from: Gamesa document 'GD027758-en Rev: 5 G52 850kW 50/60 Hz Wind Turbine Power and Noise Emission Curves', dated 15/08/2012 for 'Level 1' which are the highest sound power levels. 2 dB was added for uncertainty to yield declared values as shown above. A reduction of 3 dB was applied to the shown values so that predicted noise levels are similar those in the original assessment for High Park Farm, which shows predicted noise levels being approximately 35 dB(A) at the nearest receptor location of High Park Farm.												

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

Turbine make / model	Octave Band Centre Frequency (Hz)								
	63	125	250	500	1000	2000	4000	8000	A
G52-850 kW	81.0	87.9	92.9	94.5	94.1	91.6	86.1	75.3	99.9
Derived from: Gamesa document GD037369-en 'Spectral Analysis of Noise Emissions in G5X Wind Turbines', dated 20/01/2009, reducing 1/3 data to octaves.									

Turbine and Propagation Details: Pencloe Windfarm & Afton Windfarm

B.8. Afton Windfarm is built and operating whilst Pencloe is consented but not yet built. The consent[54] for Afton Windfarm is based on day-time noise limits of the greater of 40 dB(A) or 5 dB(A) above background day-time and the greater of 43 dB(A) or 5 dB(A) above background night-time. These noise limits would represent the total ETSU-R-97 noise limits at nearby receptor locations; however the background noise levels were not referenced to a previous assessment, consequently the numerical limits values cannot be derived.

B.9. Background noise surveys were completed for the original noise assessment[55] for Pencloe Windfarm at two locations Craig An Dhu (262706, 605689) and Craigdarroch Farm (263316, 606543) and also used data measured at Pencloe Farm Cottage (261858, 609486) for the noise assessment for the refused Ashmark Windfarm[56]. The consent for Pencloe Windfarm[57] defines noise limits derived from these background noise survey results and provides two sets of tabular value noise limits: those which apply to Pencloe and those which apply cumulatively when operating with other windfarms.

B.10. For the present assessment the turbine coordinates for Afton and Pencloe are shown in Tables B9 and B10, propagation correction factors in Tables B11 and B12 and relevant noise emission data in Tables B13 and B14. The noise assessment[58] supporting the variation to the consent for Pencloe used sound power levels for a Siemens SWT-DD-130 in Mode 1 as the candidate turbine, with the same candidate used for this noise assessment based on similar sound power level data available to ourselves. It is probable Pencloe may be built using the Vestas V136-4.5 MW[59] turbine, which would typically have lower noise emission levels (by around 3 dB at maximum noise levels) than the Siemens SWT-DD-130 in Mode 1, but this was not the basis for the assessment undertaken. For Afton Windfarm, a Gamesa G80-2000 has been used as the candidate for this assessment, consistent with the assessment for the now consented Sanquhar II Windfarm[60].

B.11. These noise emission data already include suitable margins for uncertainty as required by the IOA GPG. The sound power levels values presented in Tables B13 and B14 have been increased to allow appropriate margins to complete the cumulative noise assessment, in accordance with the IOA GPG. An uplift of 1 dB(A) was applied to data at all wind speeds for both Afton and Pencloe. Predicted noise levels at the controlling location of Craig An Dhu / Lynn View (262729, 605695) due to the combination of Pencloe and Afton (when applying these uplifts) are just compliant with the cumulative noise limits. Accordingly sound power levels shown below, with a further 1 dB(A) uplift, include sufficient margins for the purpose of a cumulative assessment in accordance with the IOA GPG.

54 Application under Section 36C of the Electricity Act 1989 to vary the consent granted under Section 36 of the Electricity Act 1989 on 17 October 2014 to construct and operate Afton Wind Farm, located in the planning authority area of East Ayrshire, Energy Consents Unit, Energy Division, Energy and Climate Change Directorate, 9th October 2015.

55 Pencloe Windfarm, Environmental Statement, Volume 2 (of 4), Chapter 12 Noise and Vibration, Jacobs, July 2015.

56 East Ayrshire Council Reference 18/0354/PP. Erection and operation of seven wind turbines of up to 135 m to blade tip height with associated infrastructure, Land At Ashmark Hill C90 Afton Road From Leggate To Craigdarroch New Cumnock East Ayrshire. Refused 28 Sep 2018.

57 Application under Section 36C of the Electricity Act 1989 to vary the consent granted under Section 36 of the Electricity Act 1989 on 6 December 2018 to construct and operate Pencloe Wind Farm located in East Ayrshire Council planning area, Energy Consents Unit, Energy and Climate Change Directorate, 31st August 2021.

58 Pencloe Wind Farm Variation, EIA Report, Volume II (of IV), Chapter 12 Noise and Vibration, June 2019.

59 Vestas wins 81 MW order in the UK, News release from Vestas Northern and Central Europe, Hamburg, 28 June 2024. *"Vestas has secured an 81 MW order from Invenergy for the wind energy project Pencloe in Dumfries and Galloway in Scotland, UK. Vestas will deliver 18 V136-4.5 MW wind turbines…..".* Accessed 30 Oct 2024 (https://www.vestas.com/en/media/company-news/2024/vestas-wins-81-mw-order-in-the-uk-c4008697).

60 Sanquhar II Community Wind Farm – Additional Information Report, Section 11 Noise, Hayes McKenzie Partnership, August 2020.

Table B13 - Turbine coordinates – Afton Windfarm

Turbine	Easting	Northing	Turbine	Easting	Northing	Turbine	Easting	Northing
AFT-01	261940	605974	AFT-10	261849	604325	AFT-19	262807	603100
AFT-02	261689	605862	AFT-11	262272	604470	AFT-20	263250	602950
AFT-03	261561	605561	AFT-12	262139	604178	AFT-21	263018	602789
AFT-04	261875	605480	AFT-13	262675	604385	AFT-22	263346	602691
AFT-05	261551	605239	AFT-14	262341	603952	AFT-23	263120	602530
AFT-06	261865	605055	AFT-15	262608	604063	AFT-24	263380	602291
AFT-07	261615	604919	AFT-16	262559	603661	AFT-25	263070	602210
AFT-08	261673	604593	AFT-17	262885	603710			
AFT-09	261992	604635	AFT-18	262743	603417			
All turbines modelled assuming a hub height of 80 m								

Table B14 - Turbine coordinates – Pencloe Windfarm

Turbine	Easting	Northing	Turbine	Easting	Northing	Turbine	Easting	Northing
P01	261284	607224	P08	261100	605193	P15	260276	605686
P02	261240	606828	P09	260686	605784	P16	259717	605357
P03	261219	606412	P10	260515	606055	P17	259215	605384
P04	261572	606326	P11	260253	606260	P18	259090	605686
P05	261365	605944	P12	260182	606617	P19	259134	606033
P06	261377	605579	P13	260008	606898	P20	259463	605922
P07	260977	605598	P14	260382	607050	P21	259740	605785
All turbines modelled assuming a hub height of 85 m								

Table B15 - Propagation attenuation effects due to terrain (dB) – Afton 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	Property														
	Blackcraig	Burtonhill	Craig	Craigdarroch	Dalhannah	Euchanbank Cottage	High Cairn Cottage	High Park Farm	Hillend	Laigh Cairn	Lochingerroch	Nether Cairn	Over Cairn	Polshill	Waistland
AFT01	2	2	0	0	2	2	2	2	2	2	2	2	2	2	2
AFT02	2	2	0	0	-3	2	2	2	2	2	2	2	2	2	2
AFT03	2	2	0	0	-3	2	2	2	2	2	2	2	2	2	2
AFT04	2	2	0	0	2	2	2	2	2	2	2	2	2	2	2
AFT05	2	2	0	0	2	2	2	2	2	2	2	2	2	2	2
AFT06	2	2	-3	0	2	2	2	2	2	2	2	2	2	2	2
AFT07	2	2	0	0	2	2	2	2	2	2	2	2	2	2	2
AFT08	2	2	0	0	2	2	2	2	2	2	2	2	2	2	2
AFT09	2	2	0	0	2	2	2	2	2	2	2	2	2	2	2
AFT10	2	2	0	-3	2	2	2	2	2	2	2	2	2	2	2

	Property														
Turbine	Blackcraig	Burtonhill	Craig	Craigdarroch	Dalhannah	Euchanbank Cottage	High Cairn Cottage	High Park Farm	Hillend	Laigh Cairn	Lochingerroch	Nether Cairn	Over Cairn	Polshill	Waistland
AFT11	2	2	0	0	2	2	2	2	2	2	2	2	2	2	2
AFT12	2	2	0	-3	2	2	2	2	2	2	2	2	2	2	2
AFT13	-3	2	2	2	2	2	2	2	2	2	2	2	2	2	2
AFT14	-3	2	2	0	2	2	2	2	2	2	2	2	2	2	2
AFT15	-3	2	2	2	2	2	2	2	2	2	2	2	2	2	2
AFT16	-3	2	2	2	2	2	2	2	2	2	2	2	2	2	2
AFT17	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
AFT18	-3	2	2	2	2	2	2	2	2	2	2	2	2	2	2
AFT19	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
AFT20	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
AFT21	2	2	2	2	2	2	2	2	0	2	2	2	2	2	2
AFT22	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
AFT23	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
AFT24	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
AFT25	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2

Table B16 - Propagation attenuation effects due to terrain (dB) – Pencloe 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.

	Property														
Turbine	Blackcraig	Burtonhill	Craig	Craigdarroch	Dalhannah	Euchanbank Cottage	High Cairn Cottage	High Park Farm	Hillend	Laigh Cairn	Lochingerroch	Nether Cairn	Over Cairn	Polshill	Waistland
P01	0	2	2	2	0	2	2	2	2	2	2	2	2	2	2
P02	2	2	2	2	0	2	2	2	2	2	2	2	2	2	2
P03	2	2	2	2	0	2	2	2	2	2	2	2	2	2	2
P04	2	2	0	2	-3	2	2	2	2	2	2	2	2	2	2
P05	2	2	0	0	-3	2	2	2	2	2	2	2	2	2	2
P06	2	2	0	0	0	2	2	2	2	2	2	2	2	2	2
P07	2	2	0	2	0	2	2	2	2	2	2	2	2	2	2
P08	2	2	0	2	0	2	2	2	2	2	2	2	2	2	2
P09	2	2	2	2	0	2	2	2	2	2	2	2	2	2	2
P10	2	2	2	2	-3	2	2	2	2	2	2	2	2	2	2
P11	2	2	2	2	-3	2	2	2	2	2	2	2	2	2	2
P12	2	2	2	2	-3	2	2	2	2	2	2	2	2	2	2
P13	0	2	2	2	-3	2	2	2	2	2	2	2	2	2	2

Turbine	Property														
	Blackcraig	Burtonhill	Craig	Craigdarroch	Dalhannah	Euchanbank Cottage	High Cairn Cottage	High Park Farm	Hillend	Laigh Cairn	Lochingerroch	Nether Cairn	Over Cairn	Polshill	Waistland
P14	0	2	2	2	-3	2	2	2	2	2	2	2	2	2	2
P15	2	2	2	2	0	2	2	2	2	2	2	2	2	2	2
P16	2	2	2	2	0	2	2	2	2	2	2	2	2	2	2
P17	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
P18	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
P19	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
P20	2	2	2	2	-3	2	2	2	2	2	2	2	2	2	2
P21	2	2	2	2	0	2	2	2	2	2	2	2	2	2	2

Table B17 - Wind turbine sound power levels (dB L_{Aeq}) used in the noise assessment – Afton and Pencloe Windfarms.

Turbine make / model	Standardised Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Siemens SWT-DD-130 (85 m)	-	-	-	99.1	104.4	108.2	109.0	109.0	109.0	109.0	109.0	109.0
Gamesa G80 (80 m)				97.9	102.7	105.0	105.1	105.1	105.1	105.1	105.1	105.1

Derived from:-

- SWT-DD-130. Specification document from Siemens/Gamesa document reference WP ON PLM&EN EN GS-40-0000-031AA19-00, dated 04/01/2018, for 'Mode 1' which are the highest sound power levels. 2 dB was added for uncertainty to yield declared values as shown above.
- Table 11.5 from Sanquhar II Community Wind Farm – Additional Information Report, Section 11 Noise, Hayes McKenzie Partnership, August 2020.

Table B18 - Octave band sound power spectrum (dB L_{Aeq}) for reference wind speed conditions (v_{10} = 8 m/s) – Afton and Pencloe Windfarms.

Turbine make / model	Octave Band Centre Frequency (Hz)								
	63	125	250	500	1000	2000	4000	8000	A
Siemens SWT-DD-130	89.2	94.6	97.9	100.7	103.5	103.9	100.0	86.9	108.9
Gamesa G80	87.7	94.5	98.5	100.3	98.9	94.5	87.7	77.4	

Derived from:-

- SWT-DD-130. Specification document from Siemens/Gamesa document reference WP ON PLM&EN EN GS-40-0000-031AA19-00, dated 04/01/2018, spectrum given at 8 m/s.
- Gamesa G80. Derived from test report DEWI S AM 133 / 04 – of 2004/01/15, Hub Height 60 m at 8 m/s.

Annex C – Baseline Information & Derived Noise Limits/Criteria

Hare Hill and Hare Hill Extension Windfarm

C.1 The existing turbines operating on the site of the proposed Development are on HH and HHE, with consents which allow operation until 2041[61]. All of the wind turbines on HH and HHE will be replaced as part of the proposed Development. This replacement would take place in two phases, with the first phase replacing the turbines on HH and operating these together replacement turbines (those turbines in Annex B named starting with 'HHER1-') with those already operating on HHE. The second phase would replace all wind turbines on HH and HHE (those turbines in Annex B named starting with 'HHER1-' and 'HHER2-').

C.2 Site-specific noise limits control noise from the combined operation of both HH and HHE apply at two named locations: Hillend (268201, 608890) and Blackcraig (263350, 608200). These site-specific noise limits were demonstrated via a planning submission[62] to be capable of being complied with. This outcome is confirmed in Table C1, which shows that predicted noise levels are within the noise limits, with the smallest margins being 0.2 dB(A) at Hillend and 0.8 dB(A) at Blackcraig.

Table C1 – Comparison of predicted noise immission levels for the existing turbines on the proposed Development on Hare Hill and Hare Hill Extension, at the two locations named in the consent for Hare Hill Extension at which noise limits apply, related to standardised wind speeds (negative values indicate the noise immission level is below the limit). The smallest margin between predicted noise levels and the site-specific noise limits are indicated (bold typeface).

	Standardised Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Hillend												
Predicted noise levels (HH+HHE)	-	-	-	32.4	35.6	38.9	40.2	40.9	41.0	41.0	41.1	41.1
Noise limit (day-time)	41.2	41.2	41.2	41.2	41.2	41.2	41.2	41.2	41.2	44.8	47.0	48.7
Noise limit (night-time)	41.2	41.2	41.2	41.2	41.2	41.2	41.2	41.2	41.2	42.6	45.2	47.4
Excess above noise limit (day)	-	-	-	-8.9	-5.6	-2.3	-1.0	-0.3	**-0.2**	-3.8	-6.0	-7.6
Excess above noise limit (night)	-	-	-	-8.9	-5.6	-2.3	-1.0	-0.3	**-0.2**	-1.6	-4.2	-6.3
Blackcraig												
Predicted noise levels (HH+HHE)	-	-	-	27.5	29.4	31.7	33.0	33.6	33.8	34.0	34.1	34.3
Noise limit (day-time)	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0
Noise limit (night-time)	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0
Excess above noise limit (day)	-	-	-	-7.5	-5.7	-3.3	-2.1	-1.4	-1.2	-1.1	-0.9	**-0.8**
Excess above noise limit (night)	-	-	-	-7.5	-5.7	-3.3	-2.1	-1.4	-1.2	-1.1	-0.9	**-0.8**

C.3 For locations not specifically named, the consent[63] for HHE stipulates that noise limits shall be derived for these properties from the geographically nearest property which is listed. In practice this would result in a noise limit fixed at 35 dB(A) at all wind speeds applying to most receptor locations to the west of the existing HH and HHE turbines, based on the limit specified for Blackcraig, which is geographically closest to receptors to the west. For all assessment locations near to the proposed Development, predicted noise immission levels for the existing wind turbines on the proposed Development are provided in

61 Hare Hill was granted consent by Dumfries & Galloway Council (3 turbines, ref: 18/1907/FUL) and East Ayrshire Council (ref: 18/0934/PP) for extension until 2041 to align with the consent for Hare Hill Extension.

62 The Construction and Operation of Hare Hill Extension Windfarm, Noise, Planning Consent Response by ScottishPower Renewables (UK) Limited to East Ayrshire Council, Version 01, March 2016. This submission included Appendix A which provided a report from Arcus, ScottishPower Renewables, Hare Hill Extension Wind Farm, Condition 30(g) - Turbine Details, January 2016.

63 Grant of Planning Permission, East Ayrshire Council (Ref 07/0809/FL), 18th June 2015.

Table D1. These are all compliant with a noise limit of 35 dB(A) at all wind speeds, the same as the limits applied at Blackcraig.

C.4 The existing turbines operating on the site of the proposed Development were accounted for within the noise assessments for subsequent adjacent windfarm schemes when these were assessed and granted consent (with relevant apportionment of noise limits). Accordingly, the site-specific noise limits which apply to HH and HHE remain relevant and available to the proposed Development which will replace the HH and HHE turbines.

C.5 Similarly, predicted noise levels due to the combined operation of the existing turbines on the site of the proposed Development, particularly at receptor locations not specifically named in the consent for HH & HHE, would represent an existing share of the total ETSU-R-97 noise limit, with this share effectively assigned to HH & HHE and which would remain available to the proposed Development.

C.6 The wind turbines on the proposed Development are significantly taller than those on HH or HHE, it is therefore appropriate to consider the potential effects of wind shear when determining how these site-specific noise limits should apply to the proposed Development, as required by the IOA GPG. Potentially wind shear effects could alter the relationship between background noise levels and wind speed, which for a taller hub height could result in background noise levels which may not increase with wind speed in the same way as for shorter hub heights, potentially remaining at lower levels until higher wind speeds. This effect may be most relevant where there are larger relative differences in the hub height between those used for a background noise survey and those for a potential turbine hub height. Where relative hub height differences are less then wind shear effects are also likely to be correspondingly smaller. Consequently, where a limit contains a proportion which is related to the ETSU-R-97 increment of 5 dB(A) above background noise levels, this aspect could be affected by a change in the hub height of the wind turbines.

C.7 The turbines on HH have a hub height of 40 m and those on HHE a mix of heights (44 m, 55 m & 65 m), whereas the turbines on the proposed Development have a mix of turbine heights of 82 m, 105 m & 119 m. This relative height difference is sufficient to require consideration of wind shear effects. However, it is unlikely that the wind shear on the proposed Development differs substantially from standardised conditions, given the hilly terrain and high elevations which will introduce mixing in the atmosphere.

C.8 On a precautionary basis, an allowance has been made for wind shear effects for the site-specific noise limits which are relevant to assessment of the proposed Development. Those which apply at Blackcraig are fixed at 35 dB(A), therefore no potential correction would need to be made. For the site-specific noise limits which apply at Hillend, a precautionary shift of 1 m/s to the wind speed reference has been applied (i.e. the limit value at 9 m/s would be applied at 10 m/s and so on, leading to a reduction in the limit at some wind speeds). These assessment criteria are shown in Table C2.

Table C2 – Site-specific noise limits / assessment criteria used to assess noise from the proposed Development only at the named receptor locations during both day-time and night-time periods, related to standardised wind speeds.

Property	Standardised Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Hillend (day-time)	41.2	41.2	41.2	41.2	41.2	41.2	41.2	41.2	41.2	41.2	44.8	47.0
Hillend (night-time)	41.2	41.2	41.2	41.2	41.2	41.2	41.2	41.2	41.2	41.2	42.6	45.2
Blackcraig (all times)	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0

Pencloe Windfarm and Afton Windfarm

C.9 As discussed in Annex B, the consent for Pencloe Windfarm[64] defines noise limits as two sets of tabular values: those which apply to Pencloe and those which apply cumulatively when operating with other windfarms. The cumulative noise limits apply when operating Pencloe with other windfarms[65] and are the total ETSU-R-97 noise limits, derived from the baseline background noise levels, and against which total noise levels are to be assessed. These cumulative total noise limits shown in the consent for Pencloe Windfarm are included here for relevant receptor as Table C3 and Table C4 for the day-time and night-time respectively.

Table C3 – Cumulative noise limits derived from the Pencloe Windfarm consent at the named receptor locations during day-time periods, related to standardised wind speeds.

Property	Standardised Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Craig An Dhu / Lynn View	40.0	40.0	40.0	40.0	40.0	42.0	43.0	44.0	45.0	47.0	48.0	50.0
Craigbraneoch / Corbyhill	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	42.0	45.0	49.0
Craigdarroch & Craig	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	41.0	42.0	45.0	49.0
Lochingerroch & Lochbrowan	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	42.0	45.0	47.0	50.0

Table C4 – Cumulative noise limits derived from the Pencloe Windfarm consent at the named receptor locations during night-time periods, related to standardised wind speeds.

Property	Standardised Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Craig An Dhu / Lynn View	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	44.0	45.0	47.0	48.0
Craigbraneoch / Corbyhill	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	44.0	47.0	50.0
Craigdarroch & Craig	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	44.0	47.0	50.0
Lochingerroch & Lochbrowan	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0

C.10 As discussed above in Annex B, cumulative noise levels from operating Afton with Pencloe may already be close to the cumulative noise limits at receptors Craig, Craig An Dhu / Lynn View (262729, 605695), Craigbraneoch / Corbie Hill (263158, 606402), Craigdarroch (263308, 606510) and Craig (263442, 606454). In addition, the consented Sanquhar Windfarm may also contribute to cumulative noise levels. The closest of these receptor locations to the proposed Development are Craig and Craigdarroch, accordingly this assessment focuses on those receptors. Should the assessment criteria be met at these receptors then the criteria would also be met at more distant receptors.

C.11 Robust noise assessment criteria have been derived which are used to assess noise from only the proposed Development. Assessment criteria are derived from the cumulative limits shown in Table C3 and Table C4, set 10 dB(A) below the values shown, on the basis these total ETSU-R-97 noise limits could already be fully utilised. However, as discussed above, the contribution to cumulative noise levels from the existing turbines operating on the site of the proposed Development represents an existing share of the total ETSU-R-97 noise limit, with this share effectively assigned to HH & HHE and which

64 Application under Section 36C of the Electricity Act 1989 to vary the consent granted under Section 36 of the Electricity Act 1989 on 6 December 2018 to construct and operate Pencloe Wind Farm located in East Ayrshire Council planning area, Energy Consents Unit, Energy and Climate Change Directorate, 31st August 2021.

65 Strictly the consent lists the other sites defined within the noise assessment as Afton, Hare Hill Extension, Hare Hill, Windy Standard, Windy Standard Extension, Windy Standard 3, South Kyle, Enoch Hill, Overhill, Lorg and Sanquhar II. However, the derived noise limits are the total ETSU-R-97 noise limits and as such apply to control all wind turbine noise, regardless of whether a wind farm was included in the noise assessment or not.

would remain available to the proposed Development. An allowance has therefore been made for the contribution to cumulative levels of noise due to operation of the existing wind turbines on the site of the proposed Development (HH and HHE).

C.12 Table D1 in Annex D indicates predicted noise levels at Craigdarroch are marginally higher than those at Craig, accordingly at each wind speed predicted noise level for Craigdarroch are used for this allowance. Predicted noise levels at Craigdarroch have been corrected for possible wind shear effects, on a precautionary basis[66], due to the difference in hub height between the existing wind turbines and those which would be added for the proposed Development. The wind shear correction uses values from the IOA GPG[67] which are considered likely to be representative those of the Site. Where the assessment criteria (set 10 dB below the cumulative limits) are lower than these wind shear corrected values, the wind shear corrected values are used instead[68]. This allowance was applied to the assessment criteria for the day-time only, given the night-time criteria are already higher than predicted noise levels. The assessment criteria for Craig and Craigdarroch are shown in Table C5.

Table C5 – Site-specific assessment criteria used to assess noise from the proposed Development only at the named receptor locations during both day-time and night-time periods, related to standardised wind speeds (adjusted values based on predictions from the existing turbines highlighted in bold).

Property	Standardised Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Craigdarroch & Craig (day-time)	30.0	30.0	30.0	30.0	30.0	30.0	30.0	**31.1**	**31.3**	32.0	35.0	39.0
Craigdarroch & Craig (night-time)	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	34.0	37.0	40.0

C.13 For receptor locations further to the north west of the proposed Development at Dalhannah (261907, 610700), High Park Farm (262637, 611992), Burtonhill (264115, 612373), Lochingerroch (262292, 609447) and Lochbrowan (262212, 609754), two of these locations were specified in the Pencloe consent (Lochingerroch and Lochbrowan). Total cumulative noise limits at Lochingerroch and Lochbrowan have been used to provide total ETSU-R-97 noise limits at the other locations further north (Dalhannah, High Park Farm and Burtonhill) for this assessment, on the basis that background noise levels from which these limits derive are likely to be reasonably representative of these additional receptors. For these receptor locations, total ETSU-R-97 noise limits are shown in the final row in both Table C5 and Table C6, which represent the cumulative assessment criteria to be used to assess the proposed Development, when operating with other acoustically relevant windfarms/turbines.

66 The wind turbines on Hare Hill are 40 m hub height, those on Hare Hill Extension a mix of 44 m, 55 m & 65 m, whilst those on the proposed Development (once both phases are completed) would be a mix of 82 m), 105 m & 119 m (for the candidate wind turbines based on the proposed tip heights). The wind shear correction has been applied from a height of 40 m to a height of 119 m as this is the worst-case correction, effectively shifting predicted noise levels to the right relative to wind speed.

67 Values are given of wind shear in Table 2 of the IOA GPG 'Supplementary Guidance Note 4: Wind Shear' Issue 1 July 2014 for 'Amenity' and a 'High Ridgeline/Tall Hill Location' at each standardised wind speed. These values were used to provide a corrective 'shift' to the right at each wind speed. Values were then re-plotted at integer whole-value standardised wind speeds, and which included the wind shear corrections. Generally, the shift in wind speed due to the shear values provided have a maximum 'shift' of approximately 0.4 m/s at 6 m/s reducing to 0.1 m/s at 9 m/s. Values of predicted noise levels when corrected for wind shear were maintained at the value reached at 8 m/s at higher wind speed as a worst-case, rather than continuing to increase.

68 The assessment criteria are the same as those derived from 10 dB(A) below the total cumulative ETSU-R-97 noise limit except at wind speeds of 8 m/s and 9 m/s where the criteria were increased marginally by 1.1 dB(A) and 0.3 dB(A) respectively.

Sandy Knowe and Sandy Knowe Extension Windfarm

C.14 The noise limits which apply to Sandy Knowe Windfarm (SK) are specified as a number of receptor locations, mainly to the north of SK as well as the receptor location Hillend, which is between SK, Sandy Knowe Extension (SKX) and the proposed Development. These noise limits differed based on specific wind direction sectors and were derived from background noise survey results, accounting for acoustical contributions from other adjacent schemes (including the existing turbines operating on the proposed Development) and were therefore site-specific noise limits applying just to noise from SK, based on apportionment of the total ETSU-R-97 noise limits.

C.15 A subsequent application[69] to Dumfries & Galloway Council (D&GC) proposed operating SK against revised noise limits, based on more recent background noise measurements completed at some of the named receptors. Noise limits applying at the receptor Hillend remain the same as the previous consent. The revised total ETSU-R-97 noise limits and the updated baseline survey results were presented in a noise report[70] and the application was granted consent by D&GC in 2021[71]. The revised SK baseline was used again when assessing the proposed SKX[72], with an additional baseline measurement location included and some further receptors considered financially involved with SKX (with corresponding higher limits applying to SK+SKX), again with site-specific limits derived from total ETSU-R-97 noise limits.

C.16 Baseline measurements were detailed for four locations of High Cairn (268741, 612330), Nether Cairn (269679, 612348), A proxy for Nether Glenmuckloch (270334, 613240) and Laigh Cairn (268100, 612870). Relevant to this assessment are baseline data from High Cairn, Nether Cairn and Laigh Cairn as Nether Glenmuckloch is further from the proposed Development. Total ETSU-R-97 noise limits have been derived from these baseline surveys, on the assumption of no financial involvement and are shown in Table C6 and Table C7.

C.17 From the total ETSU-R-97 noise limits (Table C6 and Table C7), robust noise assessment criteria have been derived to be used to assess noise from only the proposed Development, set 10 dB(A) below the total cumulative ETSU-R-97 (non-financially involved) noise limits, on the basis these total ETSU-R-97 noise limits may already be fully utilised. These robust noise assessment criteria are shown in Table C8 and Table C9 and are used at relevant nearest receptors closest to the proposed Development and which are the focus of this assessment. Should the assessment criteria be met at these receptors then the criteria would also be met at more distant receptors.

C.18 For receptor locations to the north east of the proposed Development at Polshill (265100, 613120), Waistland (266000, 613120) and Over Cairn (266600, 613000), assessment criteria derived from Laigh Cairn will be used on the basis that background noise levels from which these limits derive are likely to be reasonably representative of these additional receptors along the A76. At High Cairn Cottage (268609, 612167), criteria derived at High Cairn will be used, due to the close proximity to High Cairn.

69 Sandy Knowe Wind Farm, Application to develop land without compliance with Condition 43 (condition relating to noise) of deemed planning permission of Section 36 Consent ECU00000660 (Construction and Operation of Sandy Knowe Wind Powered Electricity Generating Station) seeking revised noise limits, 20/1798/S42, 20 Oct 2020,

70 Sandy Knowe Wind Farm, Revised Limits from B/G Noise Measurements, Report HM: 3454_R01_EXT6, 19 October 2020, Hayes McKenzie Partnership Ltd.

71 Dumfries & Galloway Council, Grant of Planning Permission, Town and Country Planning (Scotland) Act 1997, Town and Country Planning (Development Management Procedure) (Scotland) Regulations 2013, Application for Planning Permission, Reference 20/1798/S42, 19 April 2021.

72 Sandy Knowe Wind Farm Extension, Environmental impact Assessment, Chapter 11: Noise, July 2022, Atmos Consulting / Hayes McKenzie Partnership Ltd.

Table C6 – Cumulative noise limits derived from the Sandy Knowe Windfarm Extension EIAR at the named receptor locations during day-time periods, related to standardised wind speeds.

Property	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
High Cairn	40.0	40.0	40.0	41.6	43.8	45.5	46.3	46.3	47.1	48.9	50.7	52.3
Laigh Cairn	40.0	40.0	40.0	40.7	41.1	41.4	42.1	43.6	43.3	44.9	46.7	48.6
Nether Cairn	40.0	40.0	40.0	40.0	40.0	40.0	40.7	41.4	41.8	43.3	45.1	47.0

Table C7 – Cumulative noise limits derived from the Sandy Knowe Windfarm Extension EIAR consent at the named receptor locations during night-time periods, related to standardised wind speeds.

Property	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
High Cairn	43.0	43.0	43.0	43.0	43.0	43.0	43.5	45.3	47.1	48.9	50.7	52.3
Laigh Cairn	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.3	44.9	46.7	48.6
Nether Cairn	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.3	45.1	47.0

Table C8 – Site-specific noise limits / assessment criteria used to assess noise from the proposed Development only at the named receptor locations during day-time periods, related to standardised wind speeds.

Property	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
High Cairn	30.0	30.0	30.0	31.6	33.8	35.5	36.3	36.3	37.1	38.9	40.7	42.3
Laigh Cairn	30.0	30.0	30.0	30.7	31.1	31.4	32.1	33.6	33.3	34.9	36.7	38.6
Nether Cairn	30.0	30.0	30.0	30.0	30.0	30.0	30.7	31.4	31.8	33.3	35.1	37.0

Table C9 – Site-specific noise limits / assessment criteria used to assess noise from the proposed Development only at the named receptor locations during night-time periods, related to standardised wind speeds

Property	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
High Cairn	33.0	33.0	33.0	33.0	33.0	33.0	33.5	35.3	37.1	38.9	40.7	42.3
Laigh Cairn	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.3	34.9	36.7	38.6
Nether Cairn	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.3	35.1	37.0

Sanqhuar II Windfarm

C.19 The nearest receptor to the south west of the proposed Development is Euchanbank Cottage (270530, 606420). This receptor location is also close to the turbines on the operational Sanquhar Windfarm, the operational Whiteside Hill Windfarm and consented Sanquhar II Windfarm. Similar to Pencloe Windfarm discussed above, the consent for the Sanqhuar II Windfarm[73] defines noise limits as two sets of tabular values: those which apply to Sanquhar II and those which apply cumulatively when operating with other windfarms. The day-time cumulative noise limits defined in the Sanquhar II consent are based on a choice

73 Consent under Section 36 of the Electricity Act 1989 and deemed planning permission under Section 57(2) of the Town and Country Planning (Scotland) Act 1997 for the construction and operation of Sanquhar II Community Wind Farm in the planning authority areas of Dumfries and Galloway Council and East Ayrshire Council, Energy Consents Unit, Energy and Climate Change Directorate, Scottish Government, 31st August 2023.

of 40 dB(A) for the fixed element of the noise limit. The day-time and night-time cumulative total ETSU-R-97 noise limits in the Sanquhar II consent are shown in Tables C10 and C12.

C.20 Robust noise assessment criteria have been derived to be used to assess noise from only the proposed Development, set 10 dB(A) below the lowest value at each wind speed[74] from the cumulative total ETSU-R-97 noise limits, on the basis the noise limits defined in the Sanquhar II consent could already be fully utilised. These robust noise assessment criteria are shown in Table C12 and are used at the Euchanhead Cottage receptor, which is the focus of this assessment. Should the assessment criteria be met at this receptor then the criteria would also be met at more distant receptors in the same general direction from the proposed Development.

Table C10 – Cumulative noise limits derived from the Sanquhar II Windfarm consent at the named receptor locations during day-time periods, related to standardised wind speeds.

Property	Standardised Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Craig An Dhu / Lynn View	40	40	40	40	40	42	43	44	45	47	48	50
Craig	40	40	40	40	40	40	40	40	41	42	45	49
Hillend	45	45	45	45	45	45	45	45	45	47	48	50
Polskeoch	40	40	40	40	40	40	40	40	41	43	46	48
Polgown	40	40	40	40	40	40	41	43	45	47	48	50
Shiel	40	40	40	40	40	40	40	41	43	44	45	46
Dalgonar	40	40	40	40	40	40	40	40	40	41	42	44
Shinnelhead	40	40	40	40	40	40	40	40	40	42	45	47
Craigdarroch	45	45	45	45	45	45	45	45	45	45	45	49
Craigbraneoch / Corbie Hill	40	40	40	40	40	40	40	40	41	42	45	49

Table C11 – Cumulative noise limits derived from the Sanquhar II Windfarm consent at the named receptor locations during night-time periods, related to standardised wind speeds.

Property	Standardised Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Craig An Dhu / Lynn View	43	43	43	43	43	43	43	43	44	45	47	48
Craig	43	43	43	43	43	43	43	43	43	44	47	50
Hillend	45	45	45	45	45	45	45	45	45	45	47	48
Polskeoch	43	43	43	43	43	43	43	43	43	43	45	48
Polgown	43	43	43	43	43	43	43	43	43	44	46	47
Shiel	43	43	43	43	43	43	43	43	43	45	46	48
Dalgonar	43	43	43	43	43	43	43	43	43	43	43	43
Shinnelhead	43	43	43	43	43	43	43	43	43	43	43	46
Craigdarroch	45	45	45	45	45	45	45	45	45	45	47	50
Craigbraneoch / Corbie Hill	43	43	43	43	43	43	43	43	43	44	47	50

74 Whilst this process was used to derive these noise limits, the lowest values are those shown for the named receptor Dalgonar.

Table C12 – Site-specific noise limits / assessment criteria used to assess noise from the proposed Development only at the named receptor locations during both day-time and night-time periods, related to standardised wind speeds.

Property	Standardised Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Euchanbank Cottage (day)	30	30	30	30	30	30	30	30	30	31	32	34
Euchanbank Cottage (night)	33	33	33	33	33	33	33	33	33	33	33	33

Annex D – Predicted Noise Levels

Table D1 - Predicted L_{A90} (dB) windfarm noise immission levels at each of the noise assessment locations as a function of standardised wind speed for the **existing turbines on the site of the proposed Development alone (HH + HHX)**.

Property	Standardised Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Blackcraig	-	-	-	27.5	29.4	31.7	33.0	33.6	33.8	34.0	34.1	34.3
Burtonhill	-	-	-	26.1	27.4	29.3	30.3	30.9	31.2	31.4	31.6	31.8
Craig	-	-	-	24.2	26.3	29.0	30.2	30.9	31.1	31.2	31.3	31.4
Craigdarroch	-	-	-	25.2	26.9	29.3	30.4	31.1	31.3	31.4	31.6	31.8
Dalhannah	-	-	-	23.1	24.7	26.7	27.9	28.5	28.7	28.9	29.1	29.3
Euchanbank Cottage	-	-	-	18.5	21.9	25.4	26.8	27.5	27.6	27.6	27.7	27.7
High Cairn Cottage	-	-	-	23.5	25.6	28.1	29.4	30.0	30.2	30.3	30.5	30.6
High Park Farm	-	-	-	26.3	27.3	28.7	29.6	30.2	30.5	30.7	31.0	31.3
Hillend	-	-	-	32.4	35.6	38.9	40.2	40.9	41.0	41.0	41.1	41.1
Laigh Cairn	-	-	-	23.3	25.1	27.4	28.6	29.2	29.4	29.6	29.7	29.9
Lochingerroch	-	-	-	27.0	28.3	29.9	30.9	31.6	31.8	32.0	32.3	32.5
Nether Cairn	-	-	-	21.8	23.7	26.1	27.3	27.9	28.1	28.2	28.4	28.5
Over Cairn	-	-	-	24.2	26.0	28.2	29.4	30.1	30.3	30.4	30.6	30.7
Polshill	-	-	-	23.7	25.4	27.6	28.7	29.4	29.6	29.7	29.9	30.1
Waistland	-	-	-	23.7	25.5	27.8	29.0	29.6	29.8	30.0	30.1	30.3

Table D2 - Predicted L_{A90} (dB) windfarm noise immission levels at each of the noise assessment locations at which a cumulative assessment is required as a function of standardised wind speed for the **Afton Windfarm alone**.

Property	Standardised Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Burtonhill	-	-	-	9.3	14.1	16.4	16.5	16.5	16.5	16.5	16.5	16.5
Dalhannah	-	-	-	14.6	19.4	21.7	21.8	21.8	21.8	21.8	21.8	21.8
High Park Farm	-	-	-	10.5	15.3	17.6	17.7	17.7	17.7	17.7	17.7	17.7
Lochingerroch	-	-	-	16.4	21.2	23.5	23.6	23.6	23.6	23.6	23.6	23.6

Table D3 - Predicted L_{A90} (dB) windfarm noise immission levels at each of the noise assessment locations as a function of standardised wind speed for the **Pencloe Windfarm alone**.

Property	Standardised Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Burtonhill	-	-	-	10.1	15.4	19.2	20.0	20.0	20.0	20.0	20.0	20.0
Dalhannah	-	-	-	19.1	24.4	28.2	29.0	29.0	29.0	29.0	29.0	29.0
High Park Farm	-	-	-	12.0	17.3	21.1	21.9	21.9	21.9	21.9	21.9	21.9
Lochingerroch	-	-	-	18.9	24.2	28.0	28.8	28.8	28.8	28.8	28.8	28.8

Table D4 - Predicted L_{A90} (dB) windfarm noise immission levels at each of the noise assessment locations as a function of standardised wind speed for the **High Park Farm turbine alone**.

Property	Standardised Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Burtonhill	-	-	-	15.6	19.9	23.9	25.5	26.4	26.5	26.5	26.5	26.5
Dalhannah	-	-	-	12.5	16.8	20.8	22.4	23.3	23.4	23.4	23.4	23.4
High Park Farm	-	-	-	24.1	28.4	32.4	34.0	34.9	35.0	35.0	35.0	35.0
Lochingerroch	-	-	-	6.7	11.0	15.0	16.6	17.5	17.6	17.6	17.6	17.6

Table D5 – Difference between predicted L_{A90} (dB) windfarm noise immission levels at each of the noise assessment locations as a function of standardised wind speed for the **existing turbines on the proposed Development compared with those from phase one of the proposed Development (operating with HHE)**. Negative values indicate the noise immission level for phase one of the proposed Development is below the level from the existing turbines on the proposed Development.

Property	Standardised Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Blackcraig	-	-	-	-2.9	-0.3	1.1	1.0	0.8	0.7	0.6	0.4	0.3
Burtonhill	-	-	-	-4.2	-1.0	0.9	1.0	0.7	0.5	0.3	0.1	-0.1
Craig	-	-	-	-1.8	0.5	1.6	1.5	1.2	1.1	1.1	0.9	0.8
Craigdarroch	-	-	-	-3.1	-0.4	1.0	1.0	0.8	0.7	0.5	0.4	0.2
Dalhannah	-	-	-	-4.1	-1.2	0.5	0.5	0.4	0.2	0.0	-0.2	-0.3
Euchanbank Cottage	-	-	-	1.3	2.2	2.4	2.2	1.9	1.9	1.9	1.8	1.8
High Cairn Cottage	-	-	-	-1.1	1.2	2.4	2.2	2.0	1.8	1.8	1.6	1.5
High Park Farm	-	-	-	-5.8	-2.2	0.2	0.3	0.1	-0.2	-0.4	-0.7	-1.0
Hillend	-	-	-	-0.5	0.7	1.1	1.0	0.9	0.9	0.8	0.8	0.7
Laigh Cairn	-	-	-	-2.1	0.5	1.9	1.8	1.5	1.4	1.3	1.1	1.0
Lochingerroch	-	-	-	-5.3	-2.0	0.1	0.2	0.0	-0.2	-0.4	-0.7	-0.9
Nether Cairn	-	-	-	-2.3	0.2	1.5	1.4	1.2	1.1	1.0	0.8	0.7
Over Cairn	-	-	-	-2.3	0.4	1.9	1.8	1.5	1.4	1.3	1.1	0.9
Polshill	-	-	-	-3.0	-0.1	1.5	1.4	1.2	1.0	0.9	0.7	0.5
Waistland	-	-	-	-2.3	0.4	1.8	1.7	1.5	1.3	1.2	1.0	0.9

Table D6 – Difference between predicted L_{A90} (dB) windfarm noise immission levels at each of the noise assessment locations as a function of standardised wind speed for the **existing turbines compared with those from phase two of the proposed Development**. Negative values indicate the noise immission level for phase two of the proposed Development is below the level from the existing turbines on the proposed Development.

Property	Standardised Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Blackcraig	-	-	-	-4.3	-1.7	-0.5	-1.0	-1.5	-1.7	-1.8	-1.9	-2.1
Burtonhill	-	-	-	-5.6	-2.3	-0.5	-0.8	-1.4	-1.6	-1.7	-2.0	-2.2
Craig	-	-	-	-3.6	-1.2	-0.3	-0.8	-1.4	-1.5	-1.5	-1.6	-1.7
Craigdarroch	-	-	-	-4.8	-2.1	-0.8	-1.3	-1.9	-2.0	-2.1	-2.2	-2.4
Dalhannah	-	-	-	-6.0	-2.9	-1.4	-1.8	-2.4	-2.5	-2.7	-2.9	-3.0
Euchanbank Cottage	-	-	-	-0.7	0.3	0.3	-0.4	-1.0	-0.9	-0.9	-0.9	-0.9
High Cairn Cottage	-	-	-	-2.6	-0.1	0.9	0.4	-0.2	-0.3	-0.3	-0.5	-0.6
High Park Farm	-	-	-	-6.9	-3.2	-0.9	-1.1	-1.6	-1.9	-2.1	-2.4	-2.7
Hillend	-	-	-	-2.6	-1.4	-1.2	-1.9	-2.4	-2.3	-2.2	-2.2	-2.2
Laigh Cairn	-	-	-	-3.5	-0.8	0.5	0.0	-0.5	-0.6	-0.7	-0.9	-1.0
Lochingerroch	-	-	-	-6.7	-3.2	-1.3	-1.6	-2.1	-2.4	-2.5	-2.8	-3.0
Nether Cairn	-	-	-	-3.6	-1.0	0.2	-0.4	-0.9	-0.9	-1.0	-1.2	-1.3
Over Cairn	-	-	-	-3.7	-0.9	0.4	0.0	-0.6	-0.8	-0.8	-1.0	-1.2
Polshill	-	-	-	-4.5	-1.5	-0.1	-0.5	-1.1	-1.3	-1.4	-1.5	-1.7
Waistland	-	-	-	-3.7	-0.9	0.4	-0.1	-0.7	-0.8	-0.9	-1.1	-1.2

Annex E – Cumulative Assessment

Figure E1 - Chart of the total ETSU-R-97 noise limit curve appropriate for the assessment location of High Park Farm, during day-time periods. Predicted immission noise levels are also shown for phase one of the proposed Development (operating together with Hare Hill Extension) as well as the other sites considered in the cumulative assessment of Pencloe Windfarm, Afton Windfarm, the High Park Farm wind turbine and the total of these developments for the cumulative assessment.

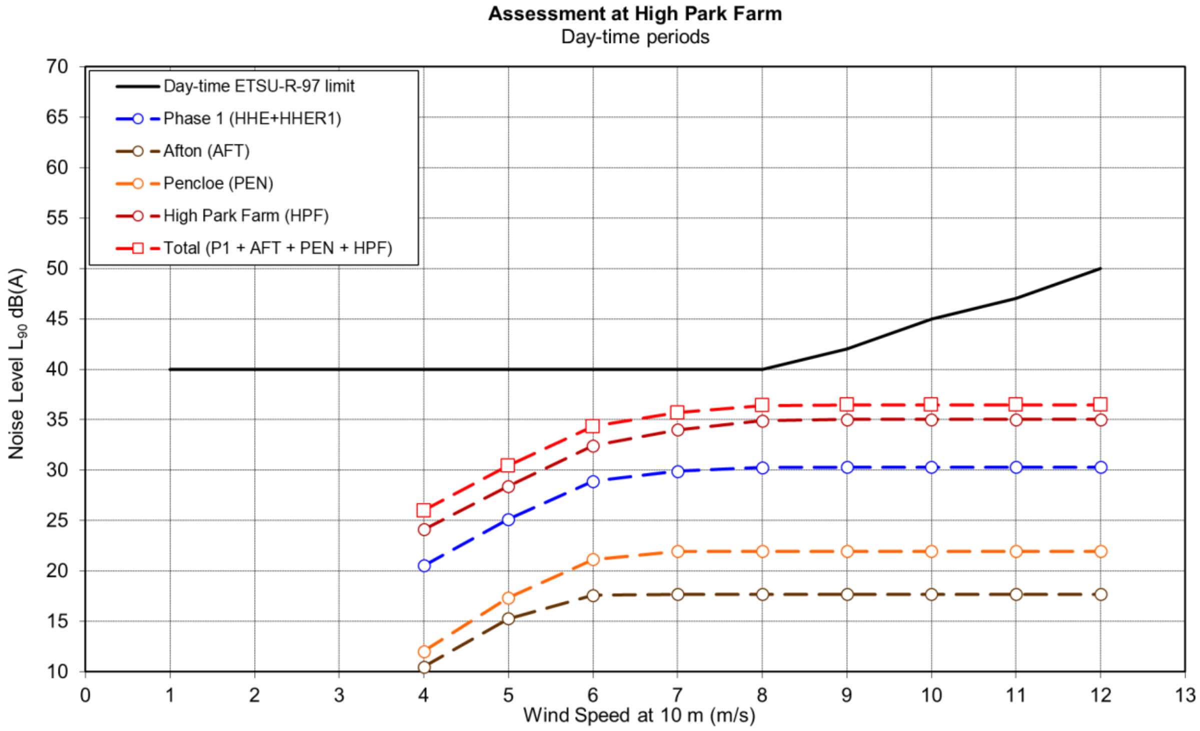


Figure E2 - Chart of the total ETSU-R-97 noise limit curve appropriate for the assessment location of High Park Farm, during day-time periods. Predicted immission noise levels are also shown for phase two of the proposed Development as well as the other sites considered in the cumulative assessment of Pencloe Windfarm, Afton Windfarm, the High Park Farm wind turbine and the total of these developments for the cumulative assessment.

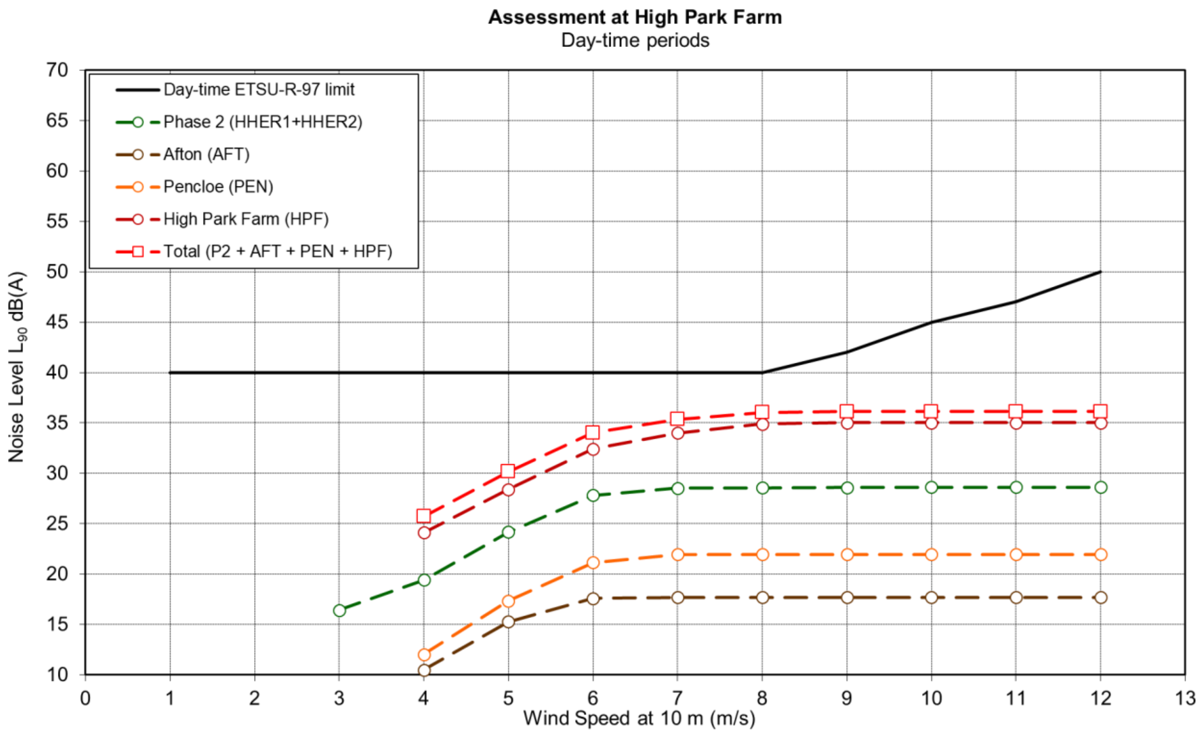


Figure E3 - Chart of the total ETSU-R-97 noise limit curve appropriate for the assessment location of High Park Farm, during night-time periods. Predicted immission noise levels are also shown for phase one of the proposed Development (operating together with Hare Hill Extension) as well as the other sites considered in the cumulative assessment of Pencloe Windfarm, Afton Windfarm, the High Park Farm wind turbine and the total of these developments for the cumulative assessment.

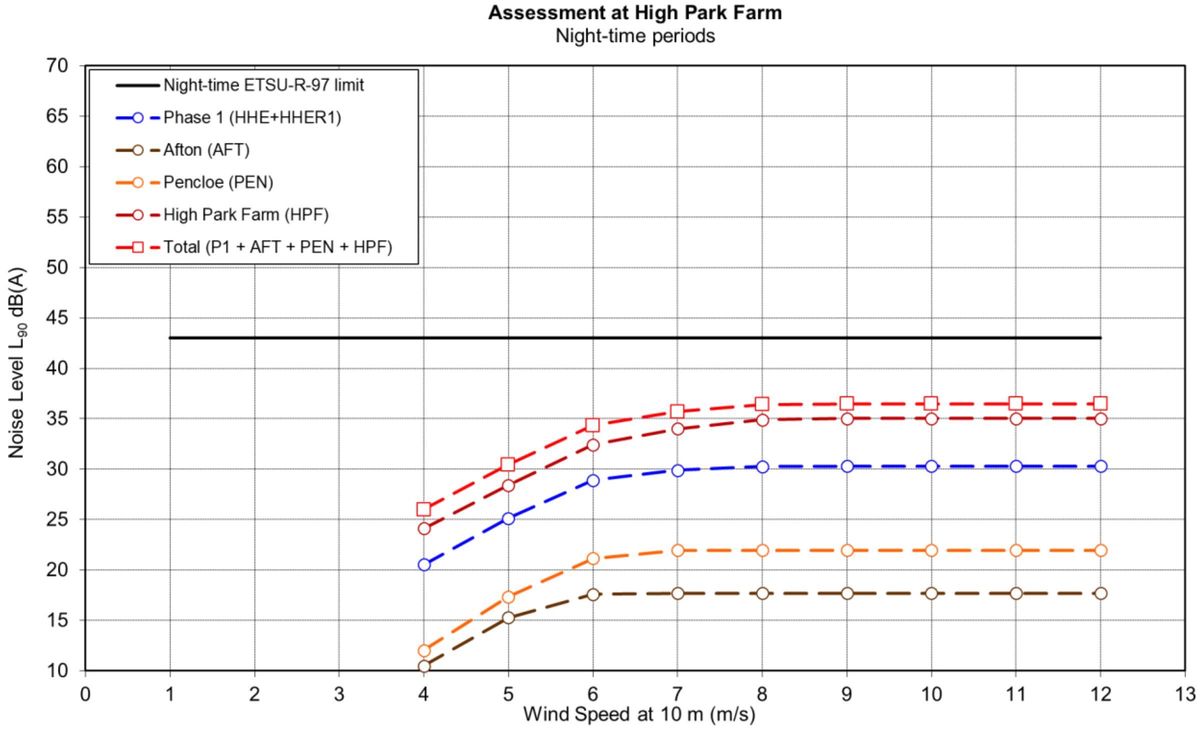
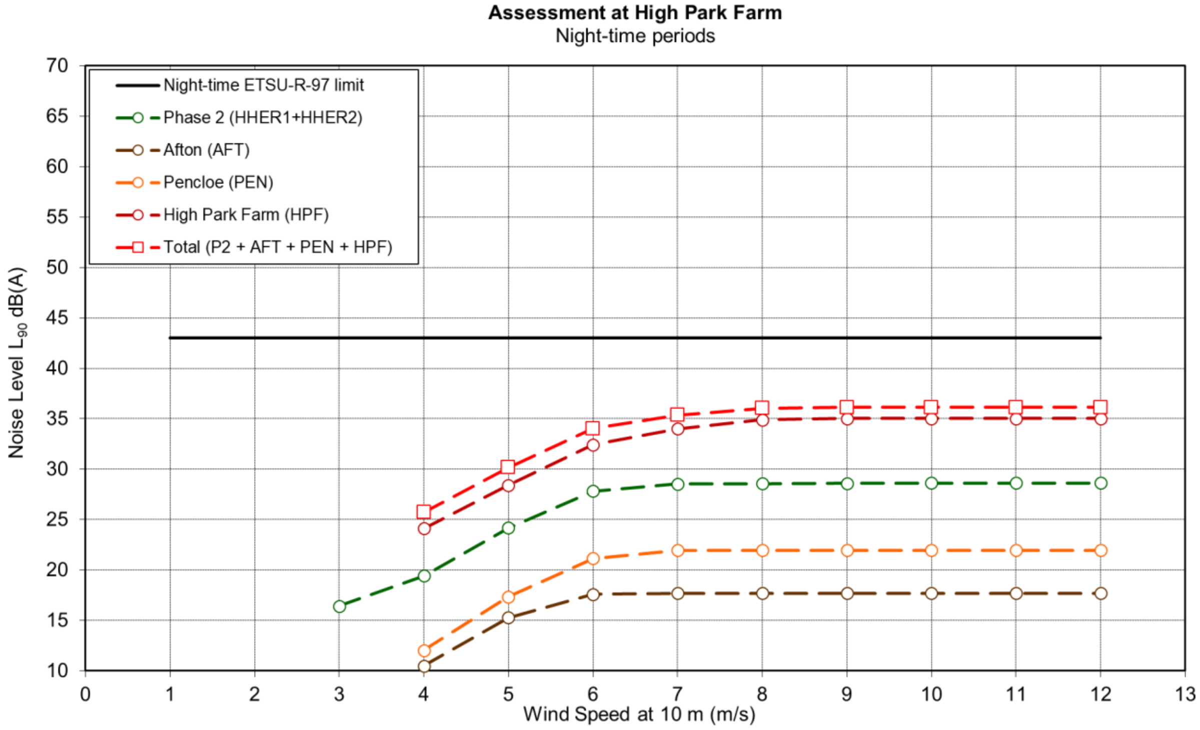


Figure E4 - Chart of the total ETSU-R-97 noise limit curve appropriate for the assessment location of High Park Farm, during night-time periods. Predicted immission noise levels are also shown for phase two of the proposed Development as well as the other sites considered in the cumulative assessment of Pencloe Windfarm, Afton Windfarm, the High Park Farm wind turbine and the total of these developments for the cumulative assessment.



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