A specialist energy consultancy

Appendix 17.1

Operational Noise Report

Cloiche Wind Farm

SSE Renewables

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27 March 2020

tneigroup.com

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Executive Summary

TNEI Services was commissioned by SSE Renewables Development (UK) Limited (the 'Developer') on behalf of SSE Generation Limited (the 'Applicant') to undertake predictions of the wind turbine noise that would be emitted by the operation of the proposed Cloiche Wind Farm (hereinafter referred to as the Proposed Development). The noise predictions were used to assess the potential impact of operational noise from the Proposed Development on the nearest noise sensitive receptors.

The Scottish Government's web based renewables advice on *'Onshore Wind Turbines'* states: *'The Report, "The Assessment and Rating of Noise from Wind Farms" (Final Report, Sept 1996, DTI), (ETSU-R-97), describes a framework for the measurement of wind farm noise, which should be followed by applicants and consultees, and used by planning authorities to assess and rate noise from wind energy developments, until such time as an update is available. This gives indicative noise levels thought to offer a reasonable degree of protection to wind farm neighbours, without placing unreasonable burdens on wind farm developers, and suggests appropriate noise conditions.'* Whilst the advice then goes on to state: *'The Institute of Acoustics (IOA) has since published Good Practice Guide to the Application of ETSU-R-97 for the Assessment and Rating of Wind Turbine Noise* [IOA GPG]*. The document provides significant support on technical issues to all users of the ETSU-R-97 method for rating and assessing wind turbine noise, and should be used by all IOA members and those undertaking assessments to ETSU-R-97. The Scottish Government accepts that the guide represents current industry good practice.'* The guidance contained within ETSU-R-97 and current good practice has been used to assess the potential operational noise impact of the Proposed Development.

The noise assessment has been undertaken in three stages:

1) setting the Total ETSU-R-97 Noise Limits (which are applicable to noise from all wind turbines in the area operating concurrently) at noise sensitive receptors;
2) predicting the likely effects (undertaking a cumulative noise assessment where required) to determine whether noise immissions at noise sensitive receptors will meet the Total ETSU-R-97 Noise Limits; and
3) setting Site Specific Noise Limits for the Proposed Development.

A total of four noise sensitive receptors were chosen as noise assessment locations. The assessment locations were chosen to represent the noise sensitive receptors located closest to the Proposed Development and other nearby schemes in order to consider the cumulative noise impacts. Due to the large separation distances between the Proposed Development and the closest receptors, background noise monitoring was not undertaken and instead the assessment relies on a simplified assessment approach, as detailed within ETSU-R-97.

Predictions of wind turbine noise for the Proposed Development were made based upon the sound power level data for a representative candidate wind turbine under consideration for the site, the GE 3.8-130, 3.8 MW. This wind turbine model has been chosen in order to allow a representative assessment of the noise impacts. Whatever the final turbine choice is, the Proposed Development would have to meet the noise limits determined and contained within any condition applied as part of consent.

Modelling was undertaken using the ISO 9613: 1996 'Acoustics – Attenuation of sound during propagation outdoors Part 2: General method of calculation' noise prediction model which accords with current good practice and is considered to provide a realistic impact assessment. For the other schemes, predictions have been undertaken using sound power level data for the installed turbines or a suitable candidate. The model of turbine was either identified through an online search, or through the use of Highland Council's Planning Application Portal.

The cumulative assessment shows that the Proposed Development can operate concurrently with the proposed, consented and operational wind farms, whilst still meeting the Total ETSU-R-97 Noise limits at all receptors.

Site Specific Noise Limits have also been derived that take account (where required) of the other wind farm developments. Apportionment of the Total ETSU-R-97 Noise Limits was undertaken in accordance with current good practice.

Predicted noise levels indicate that at all noise assessment locations' wind turbine noise immissions were below the Site Specific Noise Limits when considering the GE 3.8-130 as a candidate turbine. The use of Site Specific Noise Limits would ensure that the Proposed Development could operate concurrently with other proposed, consented or operational turbines in the area and would also ensure that the Proposed Development's individual contribution could be measured and enforced if required.

Should consent be granted for the Proposed Development it would be appropriate to include a set of noise related planning conditions, which detail the noise limits applicable to the Proposed Development. A proposed draft condition has been included within this report.

There are a number of wind turbine makes and models that may be suitable for the Proposed Development. Should the Proposed Development receive consent the final choice of turbine would be subject to a competitive tendering process. As such, predictions of wind turbine noise are for information only. The final choice of turbine would, however, have to meet the noise limits determined and contained within any condition imposed.

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1 Introduction

1.1 Brief

1.1.1 TNEI was commissioned by SSE Renewables Development (UK) Limited (the 'Developer') on behalf of SSE Generation Limited (the 'Applicant') to undertake an operational noise assessment for the proposed Cloiche Wind Farm (hereinafter referred to as the Proposed Development). The following steps summarise the noise assessment process:

- Determine the Total ETSU-R-97 Noise Limits applicable to all wind turbines in the area with reference to existing Government Guidance and the recommendations of the Department of Trade and Industry Noise Working Group on Noise from Wind Turbines which are contained within ETSU-R-97 *'The Assessment and Rating of Noise from Wind Farms'* [1] and *'A Good Practice Guide to the Application of ETSU-R-97 for the Assessment and Rating of Wind Turbine Noise'* [2] (IOA GPG) which represents current good practice;
- Assess and undertake a cumulative noise assessment, where required, to take account of other proposed, consented or operational schemes near to the Proposed Development;
- Suggest Site Specific Noise Limits for the Proposed Development, suitable for inclusion in the noise related planning condition should Scottish Ministers be minded to grant consent for the Proposed Development;
- Undertake predictions of the operational wind turbine noise immissions from the Proposed Development that will be incident at neighbouring noise sensitive receptors;
- Compare predictions of the operational wind turbine noise immissions from the Proposed Development against the Site Specific ETSU-R-97 Noise Limits that will be incident at neighbouring noise sensitive receptors; and
- Assess the impact of noise from the Proposed Development with reference to existing Government Guidance and the recommendations of the Department of Trade and Industry Noise Working Group on Noise from Wind Turbines, which are contained within ETSU-R-97 and the IOA GPG (current good practice).

1.2 Background

1.2.1 The Proposed Development is located approximately 11 km to the south east of Fort Augustus on land adjacent to the operational Stronelairg Wind Farm. The site comprises two clusters; an eastern and western cluster. The approximate OS Grid References are 256665, 802745 (eastern cluster) and 247780, 802578 (western cluster) and the proposed layout can be seen in Figure A1.1 in Annex A.

1.2.2 In the absence of a confirmed turbine model, this noise assessment models a candidate turbine, the GE 3.8-130 3.8 MW. This turbine has been selected as it is representative of the turbine type which could be installed at the site.

1.2.3 There are a number of proposed, consented and operational wind farm developments in proximity to the Proposed Development, which include the following:

- Stronelairg Wind Farm 66 turbines (operational) (Ref: 12/02560/S36)
- Corriegarth Wind Farm 23 turbines (operational) (Ref: 13/02456/S36)
- Dell Wind Farm 14 turbines (consented) (Ref: 14/02879/FUL)
- Glenshero Wind Farm 39 turbines (proposed) (Ref: 18/04733/S36)

1.2.4 Figure A1.1b in Annex A details the location of the above developments and the Proposed Development.

1.2.5 For the consented schemes noise related planning conditions have been set within the relevant Decision Notices, as detailed in Annex 2. As such the noise limits derived for the Proposed Development have taken account the noise limits already allocated to, or could potentially be used by, the other schemes in the area.

1.2.6 For the purposes of assessing the above schemes in conjunction with the Proposed Development the following terms have been referred to throughout the assessment;

- 'Total ETSU-R-97 Noise Limits'; defined as being the limit that should not be exceeded from the cumulative operation of all wind farm developments, including the Proposed Development; and
- 'Site Specific Noise Limits'; defined as being the limit that is specific to the Proposed Development only, and derived through the apportionment (where required), of the 'Total ETSU-R-97 Noise Limits' in accordance with current good practice.

1.2.7 Note that in this report, the term 'noise emission' relates to the sound power level actually radiated from each wind turbine, whereas the term 'noise immission' relates to the sound pressure level (the received noise) at any receptor location due to the operation of the wind turbines.

2 Noise Planning Policy and Guidance

2.1 Overview of Noise Planning Policy and Guidance

2.1.1 In assessing the potential noise impacts of the Proposed Development the following guidance and policy documents have been considered:

- Local Policy;
- National Planning Policy [3];
- Web Based Renewables Advice: *'Onshore Wind Turbines'* [4];
- Planning Advice Note PAN 1/2011: *'Planning and Noise'* [5];
- ETSU-R-97 *'The Assessment and Rating of Noise from Wind Farms'*; and
- Institute of Acoustics *'A Good Practice Guide to the Application of ETSU-R-97 for the Assessment and Rating of Wind Turbine Noise'* (IOA GPG) May 2013.

2.2 Local Policy

2.2.1 In determining an application for planning permission the 'starting point' for decision makers is to consider the compliance of a proposal against the Proposed Development Plan taken as a whole. Plans often have policies tailored specifically to control certain kinds of Proposed Development and such policies should carry more weight and be more dominant in the minds of decision makers.

2.2.2 When considering planning applications, decision makers should have regard to any adopted Structure Plan Policies, Local Plan (or Local Development Plan) Policies and any accompanying Supplementary Planning Guidance. In determining planning applications due regard should be had to all other material considerations, including National Planning Policy.

The Highland-wide Local Development Plan

2.2.3 The Highland-wide Local Development Plan (HwLDP) was adopted by Highland Council (THC) on 5 April 2012. The HwLDP sets out the overarching vision statement, spatial strategy and general planning policies for the whole of the Highland Council area (with the exception of the area covered by the Cairngorms National Park Local Plan, which is subject to a separate Development Plan).

2.2.4 Preparation of the second HwLDP is underway, with preparatory stages such as the Main Issues Report complete and published. However, there is no anticipated date that the HwLDP 2 is to be adopted as HC has indicated that further review of the current HwLDP will be postponed until after the implications of the Scottish Planning Bill (2017) are better understood. The HwLDP is therefore considered to be a relevant Local Development Plan, but that the overall weight to be attached to it is decreased as it is over 5 years old.

2.2.5 Policy 67 of the HwLDP relates to Renewable Energy Development. The policy is supportive of such schemes where the Council is satisfied that they are located, sited and designed such that they will not be significantly detrimental overall, having regard to a number of effects including the safety and amenity of any regularly occupied buildings and the grounds that they occupy having regard to, amongst other things, the likely effect of noise generation.

2.3 The Highland Council's 'Onshore Wind Energy Supplementary Guidance (2016)

2.3.1 The Highland Council's 'Onshore Wind Energy Supplementary Guidance' (2016) details how onshore wind energy development proposals would be managed. The guidance has a section that sets out the assessment methods and key guiding principles that should form the basis of the noise assessment. The guidance states that a noise assessment for proposed large-scale wind turbine development should be undertaken in accordance with ETSU-R-97 and the IOA GPG.

2.3.2 The guidance goes on to state that due to the undeveloped nature of the Highlands, proposals should aim to achieve noise limits at the lower end of ranges given in national guidance at sensitive locations.

2.3.3 With regard to the cumulative effects of noise from wind farms, THC states: *"Where noise from more than one wind turbine development may have a cumulative impact at any noise sensitive location, applicants must ensure this is adequately assessed in accordance with best practice, which includes consideration of both predicted and consented levels".*

2.4 National Planning Policy

2.4.1 Scottish Planning Policy (SPP) was published in 2014. It states (paragraph 169) that proposals for energy infrastructure should take account of spatial frameworks for wind farms (where relevant) and that considerations may include noise impacts on communities and individual dwellings.

Planning Advice Note PAN 1/2011: Planning and Noise

2.4.2 PAN 1/2011 provides advice on the role of the planning system in helping to prevent and limit the adverse effects of noise. Paragraph 29 contains some specific information on noise from wind farms and states the following:

'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.'

2.5 Web Based Planning Advice – Onshore Wind Turbines

2.5.1 The 'Onshore Wind Turbines' web-based document describes the types of noise (mechanical and aerodynamic) that wind turbines generate. Mechanical noise is generated by the gearbox and generator and other parts of the drive train, which can be radiated as noise through the nacelle, gear box, tower and supporting structures, together with the aerodynamic noise generated by the action of the blades rotating through the air. The document states '*there has been significant reduction in the mechanical noise generated by wind turbines through improved turbine* design' and goes on to note:

'The Report, "The Assessment and Rating of Noise from Wind Farms" (Final Report, Sept 1996, DTI), (ETSU-R-97), describes a framework for the measurement of wind farm noise, which should be followed by applicants and consultees, and used by planning authorities to assess and rate noise from wind energy developments, until such time as an update is available. This gives indicative noise levels thought to offer a reasonable degree of protection to wind farm neighbours, without placing unreasonable burdens on wind farm developers, and suggests appropriate noise conditions.'

2.5.2 The web-based document then refers to the IOA GPG as a source, which provides:

'significant support on technical issues to all users of the ETSU-R-97 method for rating and assessing wind turbine noise, and should be used by all IOA members and those undertaking assessments to ETSU-R-97. The Scottish Government accepts that the guide represents current industry good practice.'

2.5.3 The document also refers to the role of PAN1/2011 'Planning and Noise' to:

'provide advice on the role of the planning system in helping to prevent and limit the adverse effects of noise. The associated Technical Advice Note provides guidance which may assist in the technical evaluation of noise assessment.'

2.5.4 Examination of the Technical Advice Note [6] confirms it provides no further advice on wind farms other than referring to ETSU-R-97 and relevant parameters for modelling identified in the Institute of Acoustics Bulletin March 2009, on page 37. This has been superseded by the introduction of the IOA GPG in May 2013.

2.6 ETSU-R-97 The Assessment and Rating of Noise from Wind Farms

2.6.1 As wind farms started to be developed in the UK in the early 1990's, it became apparent that existing noise standards did not fully address the issues associated with the unique characteristics of wind farm developments and there was a need for an agreed methodology for defining acceptable noise limits for wind farm developments. This methodology was developed for the former Department of Trade and Industry (DTI) by the Working Group on Noise from Wind Turbines (WGNWT).

2.6.2 The WGNWT comprised a number of interested parties including, amongst others, Environmental Health Officers, wind farm operators, independent acoustic consultants and legal experts who:

'…between them have a breadth and depth of experience in assessing and controlling the environmental impact of noise from wind farms.'

2.6.3 In this way it represented the views of all the stakeholders that are involved in the assessment of noise impacts of wind farm developments. The recommendations of the WGNWT are presented in the DTI Report – ETSU-R-97 *'The Assessment and Rating of Noise from Wind Farms (1996).'*

2.6.4 The basic aim of the WGNWT in arriving at the recommendations was the intention to provide:

'Indicative noise levels thought to offer a reasonable degree of protection to wind farm neighbours, without placing unreasonable restrictions on wind farm development or adding to the costs and administrative burdens on wind farm developers or local authorities.'

2.6.5 ETSU-R-97 makes it clear from the outset that any noise restrictions placed on a wind farm must balance the environmental impact of the wind farm against the national and global benefits that would arise through the development of renewable energy sources:

'The planning system must therefore seek to control the environmental impacts from a wind farm whilst at the same time recognising the national and global benefits that would arise through the development of renewable energy sources and not be so severe that wind farm development is unduly stifled.'

2.6.6 Where noise at the nearest noise sensitive receptors is limited to an L_{A90} of 35 dB(A) up to wind speeds of 10 ms^{-1} at a height of 10 m, then it does not need to be considered in the noise assessment, as protection of the amenity of these properties can be controlled through a simplified noise limit. In this regard ETSU-R-97 states that:

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

2.6.7 The ETSU-R-97 assessment procedure specifies that where noise is greater than the simplified limit of 35 dB L_{A90} noise limits should be set relative to existing background noise levels at the nearest receptors. These limits should reflect the variation in both turbine source noise and background noise with wind speed. Absolute lower limits, different for daytime and night-time, are applied where low levels of background noise are measured. The wind speed range that should be considered ranges between the cut-in wind speed for the turbines (usually about 2 to 3 ms^{-1}) and up to 12 ms^{-1}, where all wind speeds are referenced to a 10 metre measurement height.

2.6.8 Separate noise limits apply for daytime and for night-time. Daytime limits are chosen to protect a property's external amenity, and night-time limits are chosen to prevent sleep disturbance indoors, with windows open.

2.6.9 The daytime noise limit is derived from background noise data measured during so-called 'quiet periods of the day', which 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 10 minute background noise levels using the $L_{A90,10min}$ measurement index are logged continuously over a range of wind speed conditions. These measured noise levels are then plotted against concurrent 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 daytime noise limit, sometimes referred to as a 'criterion curve', is then set at a level 5 dB(A) above the best fit curve over the desired wind speed range; subject to an appropriate daytime fixed minimum limit:

'For wind speeds where the best fit curve to the background noise data lies below a level of 30 - 35 dB(A) the criterion curve is set at a fixed level in the range 35 - 40 dB(A). The precise choice of criterion curve level within the range 35 - 40 dB(A) depends on a number of factors: the number of noise affected properties, the likely duration, the level of exposure and the potential impact on the power output of the wind farm. The quiet daytime limits have been set in ETSU-R-97 on the basis of protecting the amenity of residents whilst outside their dwellings in garden areas.'

2.6.10 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 $L_{A90,\ 10\ minute}$ noise levels measured over the night-time periods are plotted against concurrent wind speed data and a 'best fit' correlation is established. The night-time noise limit is also based on a level 5 dB(A) above the best fit curve over the 0 - 12 ms^{-1} wind speed range, with a fixed minimum limit of 43 dB L_{A90}.

2.6.11 The exception to the setting of both the daytime and night-time fixed minimum limits occurs where a property occupier has a financial involvement in the wind farm development. Paragraph 24 of ETSU-R-97 states:

'The Noise Working Group recommends that both day and night-time lower fixed limits can be increased to 45 dB(A) and that consideration should be given to increasing the permissible margin above background where the occupier of the property has some financial involvement in the wind farm.'

2.6.12 ETSU-R-97 provides a robust basis for determining the noise limits for wind turbine(s) and since its introduction has become the accepted standard for such developments across the UK.

2.7 Current Good Practice

A Good Practice Guide on the Application of ETSU-R-97

2.7.1 In May 2013, the Institute of Acoustics issued *'A Good Practice Guide to the Application of ETSU-R-97 for the Assessment and Rating of Wind Turbine Noise'* (IOA GPG). The document provides guidance on background data collection, data analysis and limit derivation, noise predictions, cumulative issues, reporting requirements and other matters such as noise related planning conditions.

2.7.2 The Authors of the IOA GPG sets out the scope of the document in Section 1.2:

'This guide presents current good practice in the application of the ETSU-R-97 assessment methodology for all wind turbine developments above 50 kW, reflecting the original principles within ETSU-R-97, and the results of research carried out and experience gained since ETSU-R-97 was published. The noise limits in ETSU-R-97 have not been examined as these are a matter for Government.'

2.7.3 The guidance document was endorsed, on behalf of Scottish Government by the Cabinet Secretary for Finance, Employment and Sustainable Growth, Mr John Swinney MSP [7]. The recommendations included in the IOA GPG have been considered and applied throughout this noise assessment for the Proposed Development.

2.7.4 The IOA GPG refers to six Supplementary Guidance Notes and where applicable these have also been considered in this report.

2.7.5 The guidance contained within ETSU-R-97 and the IOA GPG has therefore been used to assess and rate the operational noise emissions from the Proposed Development.

3 Potential Impacts

3.1 Operational Noise Sources

3.1.1 Wind turbines may emit two types of noise. Firstly, aerodynamic noise is a more natural sounding 'broad band' noise, albeit with 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. Potential sources of mechanical noise include gearboxes or generators.

3.1.2 Aerodynamic noise is usually perceived when the wind speeds are fairly low although at very low wind speeds the blades do not rotate, or rotate very slowly, and so negligible aerodynamic noise is generated. In higher winds aerodynamic noise may be masked by the normal sound of wind blowing through the trees and around buildings. The level of this natural 'masking' noise relative to the level of wind turbine noise is one of the several factors that determine the subjective audibility of the wind turbines [8].

3.2 Infrasound, Low Frequency Noise and Vibration

3.2.1 The term infrasound can be defined as the frequency range below 20 Hz, while low frequency noise (LFN) is typically in the frequency range 20 – 200 Hz [9]. An average young healthy adult has an audible range from 20 Hz to 20,000 Hz, although the sensitivity of the ear varies with frequency and is most sensitive to sounds with frequencies between 500 Hz and 4,000 Hz. Wind turbines do produce low frequency sounds [10], but our threshold of hearing at such low frequencies is relatively high and they therefore go unnoticed. Infrasound from wind turbines is often at levels below that of the noise generated by wind around buildings and other obstacles.

3.2.2 In 2004, the former DTI commissioned The Hayes McKenzie Partnership to report on claims that infrasound or LFN emitted by wind turbine generators (WTGs) were causing health effects. Of the 126 wind farms operating in the UK, five had reported LFN problems, therefore, such complaints are an exception, rather than a general problem that exists for all wind farms. Hayes McKenzie investigated the effects of infrasound and LFN at three wind farms for which complaints had been received and the results were reported in May 2006 [11]. The report concluded that:

- *'infrasound associated with modern wind turbines is not a source which will result in noise levels which may be injurious to the health of a wind farm neighbour;*

- *low frequency noise was measurable on a few occasions but below the existing permitted Night Time Noise Criterion. Wind turbine noise may result in internal noise levels within a dwelling that is just above the threshold of audibility, however at all sites it was always lower than that of local road traffic noise;*
- *that the common cause of complaint was not associated with LFN, but the occasional audible modulation of aerodynamic noise especially at night. Data collected showed that the internal noise levels were insufficient to wake up residents at these three sites. However once awoken, this noise can result in difficulties in returning to sleep.'*

3.2.3 The Applied and Environmental Geophysics Research Group at Keele University was commissioned by the Ministry of Defence (MOD), the DTI and the British Wind Energy Association (BWEA) to undertake microseismic and infrasound monitoring of LFN and vibrations from wind farms for the purposes of siting wind farms in the vicinity of Eskdalemuir in Scotland. Whilst the testing showed that vibration can be detected several kilometres away from wind turbines, the levels of vibration from wind turbines were so small that only the most sophisticated instrumentation can reveal their presence and they are almost impossible to detect. Nevertheless, the Renewable Energy Foundation alleged potential adverse health effects and when that story was picked up in the popular press, notably the Scotsman, the report's authors expressed concern over the way in which their work had been misinterpreted and issued a rebuttal statement [(12)] in August 2005:

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

3.2.4 In response to concerns that wind turbines emit infrasound and cause associated health problems, Dr Geoff Leventhall, Consultant in Noise Vibration and Acoustics and author of the Defra Report on Low Frequency Noise and its Effects, said in the article in the Scotsman ('Wind farm noise rules 'dated'- James Reynolds, 5 August 2005'):

'I can state quite categorically that there is no significant infrasound from current designs of wind turbines.'

3.2.5 An article [(13)] published in the IOA Bulletin (March/April 2009) concluded that there is no robust evidence that either low frequency noise (including 'infrasound') or ground-borne vibration from wind farms, has an adverse effect on wind farm neighbours.

3.2.6 Work [(14)] by Dr Leventhall looked at infrasound levels within the ear compared to external sources and concluded:

'The conclusion is that the continuous inner ear infrasound levels due to internal sources, which are in the same frequency range as wind turbine rotational frequencies, are higher than the levels produced in the inner ear by wind turbines, making it unlikely that the wind turbine noise will affect the vestibular systems, contrary to suggestions made following the measurements at Shirley. The masking effect is similar to that in the abdomen (Leventhall 2009). The body, and vestibular systems, appear to be built to avoid disturbance from the high levels of infrasound which are produced internally from the heartbeat and other processes. In fact, the hearing mechanisms and the balance mechanisms, although in close proximity, have developed to minimise interaction (Carey and Amin 2006).'

3.2.7 More recently during a planning Appeal (PPA-310-2028, Clydeport Hunterston Terminal Facility, approximately 2.5 km south-west of Fairlie, 9 Jan 2018), the health impacts related to LFN associated with wind turbines were considered at length by the appointed Reporter (Mr M Croft). The Reporter considered evidence from Health Protection Scotland and the National Health Service. In addition, he also considered LFN surveys undertaken by the Appellant and the Local Authority, both of which demonstrated compliance with planning conditions and did not identify any problems attributable to the turbine operations; some periods with highest levels of low frequency noise were in fact recorded when the turbines were not operating.

3.2.8 The Reporter concluded that:

- The literature reviews by bodies with very significant responsibilities for the health of local people found insufficient evidence to confirm a causal relationship between wind turbine noise and the type of health complaints cited by some local residents.
- The NHS's assessment is that concerns about health impact are not supported by good quality research.
- Although given the opportunity, the Community Council failed to provide evidence that can properly be set against the general tenor of the scientific evidence.

3.2.9 It is therefore not considered necessary to carry out specific assessments of LFN and it has not been considered further in the noise assessment.

3.3 Amplitude Modulation of Aerodynamic Noise (AM)

3.3.1 In the context of wind turbine noise amplitude modulation describes a variation in noise level over time; for example, observers may describe a 'whoosh whoosh' sound, which can be heard close to a wind turbine as the blades sweep past. Amplitude Modulation of aerodynamic noise is an inherent characteristic of wind turbine noise and was noted in ETSU-R-97, on page 68:

'The modulation or rhythmic swish emitted by wind turbines has been considered by some to have a characteristic that is irregular enough to attract attention. The level and depth of modulation of the blade noise is, to a degree, turbine-dependent and is dependent upon the position of the observer. Some wind turbines emit a greater level of modulation of the blade noise than others. Therefore, although some wind turbines might be considered to have a character that may attract one's attention, others have noise characteristics which are considerably less intrusive and unlikely to attract one's attention and be subject to any penalty.

This modulation of blade noise may result in a variation of the overall A-weighted noise level by as much as 3dBA (peak to trough) when measured close to a wind turbine. As distance from the wind turbine [or] wind farm increases, this depth of modulation would be expected to decrease as atmospheric absorption attenuates the high frequency energy radiated by the blade.'

3.3.2 In recent times the Acoustics community has sought to make a distinction between the AM discussed within ETSU-R-97, which is expected at most wind farms and as such may be considered as 'Normal Amplitude Modulation' (NAM), compared to the unusual AM that has sometimes been heard at some wind farms, hereinafter referred to as 'Other Amplitude Modulation' (OAM). The term OAM is increasingly used to describe an unusual feature of aerodynamic noise from wind turbines, where a greater than normal degree of regular fluctuation in sound level occurs at blade passing frequency, typically once per second. In some appeal decisions it may also be referred to as 'Excess Amplitude Modulation' (EAM). It should be noted that the noise assessment and rating procedure detailed in ETSU-R-97 fully takes into account the presence of the intrinsic level of NAM when setting acceptable noise limits for wind farms.

3.3.3 On 16 December 2013, RenewableUK (RUK) released six technical papers [15] on AM, which reflected the outcomes of research commissioned over the previous three years, together with a template planning condition. Whilst this research undoubtedly improved understanding of Other Amplitude Modulation (OAM) and its effects, it should be noted that at the time of writing it has not been endorsed by any relevant body such as the Institute of Acoustics (IOA).

3.3.4 On 22 January 2014, the IOA released a statement regarding the RUK research and the proposed planning condition to deal with the issue of amplitude modulation from a wind turbine and stated:

'This research is a significant step forward in understanding what causes amplitude modulation from a wind turbine, and how people react to it. The proposed planning condition, though, needs a period of testing and validation before it can be considered to be good practice. The IOA understands that RenewableUK will shortly be making the analysis tool publicly available on their website so that all interested parties can test the proposed condition, and the IOA will review the results later in the year. Until that time, the IOA cautions the use of the proposed planning condition.'

3.3.5 Research regarding amplitude modulation continued. In April 2015, the IOA issued a discussion document entitled *'Methods for Rating Amplitude Modulation in Wind Turbine Noise'*. The document presented three methods that can be used to quantify the level of AM at a given measurement location. After extensive consultation a preferred method of measuring OAM, which provides a framework for practitioners to measure and rate AM, was recommended by the IOA.

3.3.6 On 3 August 2015, the Department for Energy and Climate Change (DECC), now the Department for Business, Energy and Industrial Strategy (BEIS), commissioned independent consultants WSP Parsons Brinkerhoff to carry out a literature review on OAM (which they refer to simply as AM). The stated aims were as follows:

- *To review the available evidence on Amplitude Modulation (AM) in relation to wind turbines, including but not limited to the research commissioned and published by RenewableUK in December 2013;*
- *To work closely with the Institute of Acoustics' AM working group, who are expected to recommend a preferred metric and methodology for quantifying and assessing the level of AM in a sample of wind turbine noise data;*
- *To review the robustness of relevant dose response relationships, including the one developed by the University of Salford as part of the RenewableUK study, on which the correction (or penalty) for amplitude modulation proposed as part of its template planning condition is based;*
- *To consider how, in a policy context, the level(s) of AM in a sample of noise data should be interpreted, in particular determining at what point it causes a significant adverse impact;*
- *To recommend how excessive AM might be controlled through the use of an appropriate planning condition; and*
- *To consider the engineering/cost trade-offs of possible mitigation measures.*

3.3.7 Their report, which was released in October 2016, concluded that there is sufficient robust evidence that excessive AM leads to increased annoyance from wind turbine noise and recommended that excessive AM is controlled through a suitably worded planning condition, which will control it during periods of complaint. Those periods should be identified by measurement using the metric proposed by the work undertaken by the IOA, and enforcement action would rely upon professional judgement by Local Authority Environmental Health Officers based on the duration and frequency of occurrence.

3.3.8 It is not clear within the body of the report which evidence the authors relied upon to arrive at their conclusions, although the Executive Summary states (page 4);

"It is noted that none of the Category 1 or 2 papers have been designed to answer the main aim of the current review in its entirety. The Category 1 studies have limited representativeness due to sample constraints and the artificiality of laboratory environments, whereas the Category 2 studies generally do not directly address the issue of AM WTN exposure-response. A meta - analysis of the identified studies was not possible due to the incompatibility of the various methodologies employed. Notwithstanding the limitations in the evidence, it was agreed with DECC that the factors to be included in a planning condition should be recommended based on the available evidence, and supplemented with professional experience".

3.3.9 The report [16] states that any planning condition must accord with existing planning guidance, and should be subject to legal advice on a case by case basis. Existing guidance would include compliance with the six tests of a planning condition embodied in Circular 4/98. The report's authors did not dictate a particular condition to be used but did suggest that any condition should include the following elements (p5):

- *"The AM condition should cover periods of complaints (due to unacceptable AM);*
- *The IoA-recommended metric should be used to quantify AM (being the most robust available objective metric);*
- *Analysis should be made using individual 10-minute periods, applying the appropriate decibel 'penalty' to each period, with subsequent analysis;*
- *The AM decibel penalty should be additional to any decibel penalty for tonality;* [tonality means mechanical sound already covered by ETSU noise limits]*; and*
- *An additional decibel penalty is proposed during the night time period to account for the current difference between the night and day limits on many sites to ensure the control method works during the most sensitive period of the day."*

3.3.10 At the time of writing there has been no official response to those recommendations from the IOA Noise Working Group and, as yet, no endorsement from any Scottish Government Minister or Department. The recommendation to impose a planning condition and the associated penalty scheme is at odds with the advice from the IOA GPG, which currently states (paragraph 7.2.10):

'7.2.1 The evidence in relation to "Excess" or "Other" Amplitude Modulation (AM) is still developing. At the time of writing, current practice is not to assign a planning condition to deal with AM.'

3.3.11 On that basis Amplitude Modulation has not been considered further in this assessment.

4 Methodology

4.1 Assessing Operational Noise Impact

4.1.1 As is detailed in Section 2.6.6 above, ETSU-R-97 states that where there are very large separation distances between turbines and the closest receptors then a simplified noise condition may be suitable. Due to the large separation distances between the Proposed Development and the nearest receptors (>5 km) the simplified assessment methodology has been adopted for this assessment.

4.1.2 To undertake an assessment of the operational noise impact in accordance with the requirements of ETSU-R-97 and the IOA GPG, the following steps are required:

- Specify the location of the wind turbines for the Proposed Development;
- Identify the locations of all nearby noise sensitive receptors and select a sample of relevant Noise Assessment Locations (NAL);
- Establish for each NAL the 'Total ETSU-R-97 Noise Limits' through consideration of the noise limit already allocated to other schemes in the area;
- Specify the likely noise emission characteristics of the wind turbines for the Proposed Development and all nearby cumulative wind turbines;
- Calculate the likely noise immission levels due to the cumulative operation of all relevant wind turbines and compare it to the Total ETSU-R-97 Limits;
- If required, determine the 'Site Specific Noise Limits' which take allowance of the noise immissions due to other schemes; and
- Calculate the likely noise immission levels due to the operation of the Proposed Development on its own and compare it to the Proposed Development's 'Site Specific Noise Limits'.

4.1.3 In order to consider the steps outlined above the assessment has been split into three separate stages:

- Stage 1 – establish the Total ETSU-R-97 Noise Limits for each NAL - As detailed in Section 1.2.4 conditions relating to noise have been set in the relevant Decision Notices for the neighbouring operational / consented schemes and these have been used to derive the Total ETSU-R-97 Noise Limits for all NALs;
- Stage 2 – undertake a cumulative assessment, where required, to determine whether the Proposed Development can operate concurrently with the other proposed, consented or operational wind farm developments; and
- Stage 3 – establish the Proposed Development Site Specific Noise Limits (at levels below the Total ETSU-R-97 Noise Limits, where limit apportionment is required) and compare the noise predictions from the Proposed Development on its own against these proposed limits.

4.1.4 There are a range of turbine makes and models that may be appropriate for the Proposed Development. The final selection of turbine will follow a competitive tendering process and thus the final model of turbine may differ from those on which this assessment has been based. However, the final choice of turbine will comply with the noise limits which have been established for the site.

4.2 Consultation

Scoping Opinion (dated December 2018)

4.2.1 The Highland Council's response including the following in relation to noise:

'Noise - it is accepted that the nearest noise sensitive property is some distance away from the turbines there are significant wind farms schemes in this locality which give rise to background noise levels and potential concerns over cumulative noise levels in excess of guidance I benchmarks. The EHO will want to know what the predicted noise levels of the selected turbines are and what the predicted cumulative levels are - including which projects are being taken into account. It may be that a future condition might for example a 3dB margin above predicted levels.'

Pre-application Report (dated December 2019)

4.2.2 As part of the pre-application advice provided by Highland Council, additional information was provided in relation to the noise assessment. The Council stated that *'the target noise levels are either a simplified 35 dB at wind speed up to 10m/s or if background noise data available a composite standard of 35 dB daytime and 38 dB night time or up to 5dB above background levels. These limits would also apply to cumulative noise levels from more than one development.'*

4.2.3 The Highland Council also requested that the cumulative assessment take account of predicted and consented levels and that if a reduction is made for a controlling property or another reason then it should be made clear in the assessment.

4.2.4 This additional information is outwith the official Scoping Response from the Council, however for completeness the additional information has been considered in the assessment.

4.3 Setting the Total ETSU-R-97 noise limits (Stage 1)

Identify Existing Noise Limits

4.3.1 Noise limits have already been established at the closest receptors as part of the planning conditions set for two wind farms (Stronelairg and Dell) and proposed at another wind farm (Glenshero). No noise related conditions were included within the Decision Notice for Corriegarth.

4.3.2 Extracts of the Decision Notices containing the noise conditions are included in Annex 2 and further information is included within Section 5 below.

Noise Impact Criteria in ETSU-R-97

4.3.3 The acceptable limits for wind turbine operational noise are clearly defined for all time periods by the application of the ETSU-R-97 methodology. Consequently, the test applied to operational noise is whether or not the predicted wind turbine noise immission levels at nearby noise sensitive properties lie below the ETSU-R-97 noise limits. Depending on the levels of background noise, the satisfaction of the ETSU-R-97 derived limits can lead to a situation whereby, at some locations under some wind conditions and for a certain proportion of the time, the wind turbine noise would be audible.

4.4 Assessment of likely effects and the requirement for a cumulative assessment (Stage 2)

4.4.1 The IOA GPG (2013) includes a detailed section on cumulative noise and provides guidance on where a cumulative assessment is required. Section 5.1.4 and 5.1.5 of the GPG state:

'During scoping of a new wind farm development consideration should be given to cumulative noise impacts from any other wind farms in the locality. If the proposed wind farm produces noise levels within 10 dB of any existing wind farm/s at the same receptor location, then a cumulative noise impact assessment is necessary.

Equally, in such cases where noise from the proposed wind farm is predicted to be 10 dB greater than that from the existing wind farm (but compliant with ETSU-R-97 in its own right), then a cumulative noise impact assessment would not be necessary.'

4.4.2 An assessment will be undertaken at each of the noise sensitive receptors proximate to the Proposed Development and other nearby operational and proposed wind farm developments to determine whether the wind turbine noise immissions from the Proposed Development are within 10 dB of the wind turbine noise immissions from the other schemes. If the predictions are found to be within 10 dB of each other, then a cumulative noise assessment will be undertaken to determine the likely impacts of the Proposed Development, however, if wind turbine immissions are greater than 10 dB apart then a cumulative noise assessment will not be required.

Noise Prediction / Propagation Model

4.4.3 The ISO 9613-2: 1996 *'Acoustics – Attenuation of sound during propagation outdoors Part 2: General method of calculation'* [17] model algorithm provides a robust prediction method for calculating the noise immission levels at the nearest receptors. A European Commission (EC) research project into wind farm noise propagation over large distances, published as 'Development of a Wind Farm Noise Prediction Model,' JOULE project JOR3-CT95-0051 in 1998, identified a simplified version of ISO 9613-2 as the most suitable at that time, but the full method has been used for this assessment.

4.4.4 The use of ISO 9613-2 is discussed in the IOA GPG which states, in Section 4.1.4:

'ISO 9613-2 standard in particular, which is widely used in the UK, can be applied to obtain realistic predictions of noise from on-shore wind turbines during worst case propagation conditions (i.e. sound speed gradients due to downwind conditions or temperature inversions), but only provided that the appropriate choice of input parameters and correction factors are made.'

4.4.5 There is currently no standard approach to specifying error bands on noise predictions. Table 5 of ISO 9613-2 suggests, at best, an estimated of accuracy of ± 3 dB(A). The work undertaken as part of the EC research study concluded that the ISO 9613-2 algorithm reliably predicted noise levels that would generally occur under downwind propagation conditions.

4.4.6 The ISO 9613-2 model can take account of the following factors that influence sound propagation outdoors:

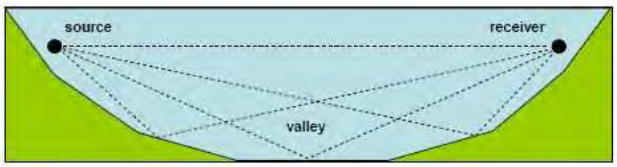
- Geometric divergence;
- Atmospheric absorption;
- Reflecting obstacles;
- Screening;
- Vegetation; and
- Ground attenuation.

4.4.7 The model uses as its acoustic input data the octave band sound power output of the turbine and calculates, on an octave band basis, attenuation due to the factors above, as appropriate.

4.4.8 The IOA GPG quotes a comparative study undertaken in Australia that indicated ISO 9613-2 can, in some conditions, under-predict ground attenuation effects and the potential for additional reflection paths 'across a valley', whilst slightly over-predicting on flat terrain. It should be noted, however, that the wind farm layouts studied were untypical for the UK, with rows of turbines spreading over 10 km on an elevated ridge. It also should be noted that no correction for background contribution was undertaken and the monitoring locations were located as far as 1.7 km from the nearest turbine, where turbine noise may be at similar levels to background noise and therefore difficult to differentiate. For the study's modelling work topographic height data was included as an input, which is consistent with ISO 9613-2 methodology generally, but use of topographic data is only used to consider the propagation path between source and receiver, and to test for topographic effects as detailed below in accordance with the IOA GPG.

4.4.9 The IOA GPG states that a *'further correction of +3 dB should be added to the calculated overall A-weighted level for propagation 'across a valley', i.e. a concave ground profile or where the ground falls away significantly between a turbine and the receiver location.'* The potential reflection paths are illustrated in Schematic 4.1 below.

Schematic 4.1: Multiple reflection paths for sound propagation across concave ground



Source: IOA GPG, page 21, Figure 5

4.4.10 A formula from the JOULE Project JOR3-CT95-0051 dated 1998 is suggested for determining whether a correction is required.

$$h_m \geq 1.5 \times (abs\ (h_s - h_r) / 2)$$

where h_m is the mean height above the ground of the direct line of sight from the receiver to the source (as defined in ISO 9613-2, Figure 3), and h_s and h_r are the heights above local ground level of the source and receiver respectively).

4.4.11 The calculation of h_m requires consideration of the digital terrain model and needs to be performed for each path between every turbine and every receiver. Interpretation of the results of the calculation above and the subsequent inclusion of a concave ground profile correction requires careful consideration with any topographical variation considered in the context of a site.

4.4.12 The IOA GPG also discusses the potential for topographical screening effects of the terrain surrounding a wind farm and the nearby noise sensitive receptors. Although barrier screening effects in ISO 9613-2 can make corrections of up to 15 dB, the IOA GPG states that where there is no line of sight between the highest point on the rotor and the receiver location a reduction of no more than 2 dB may be applied.

4.4.13 The modelling parameters used for this assessment are detailed in Section 6.3.

4.5 Setting the Site Specific Noise Limits (Stage 3)

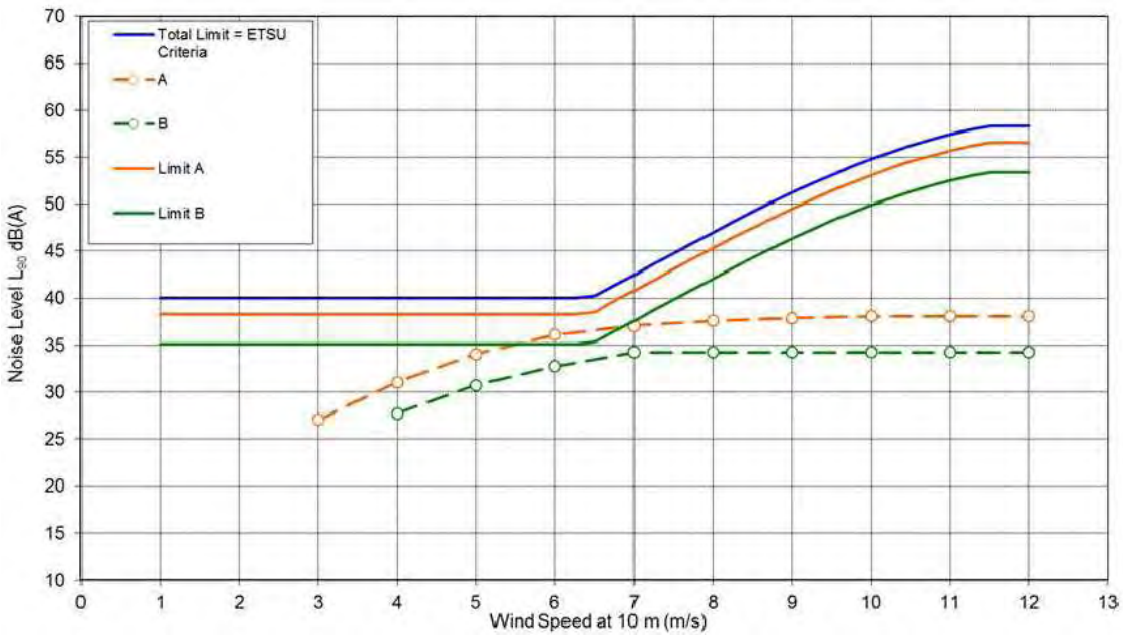
4.5.1 Summary Box 21 of the IOA GPG states:

'Whenever a cumulative situation is encountered, the noise limits for an individual wind farm should be determined in such a way that no cumulative excess of the total ETSU-R-97 noise limit would occur.'

4.5.2 In order to determine site specific noise limits at receptors in proximity to the Proposed Development limit apportionment has been undertaken. The limit apportionment has considered the noise limit already allocated to other wind farms in the area.

4.5.3 This approach is demonstrated in Graph 4.1 below. In this example the total limit (shown in blue) is shared between a consented wind farm (A) and a proposed development (B). The two noise limits for a given receptor (the solid orange and green lines) when added together equate to the Total ETSU-R-97 noise limit, and the predicted levels for each wind farm (the dashed lines) meet the specific limits established for consented wind farm and the proposed development.

Graph 4.1: Limit Apportionment Example



4.5.4 The limit derivation can also be undertaken with consideration to the amount of headroom between another schemes(s) predictions and the Total Noise Limit. With regard to this Section 5.4.11 of the IOA GPG states:

'In cases where there is significant headroom (e.g. 5 to 10 dB) between the predicted noise levels from the existing wind farm and the Total Noise Limits, where there would be no realistic prospect of the existing wind farm producing noise levels up to the Total Noise Limits, agreement could be sought with the LPA as to a suitable predicted noise level (including an appropriate margin to cover factors such as potential increases in noise) from the existing wind farm to be used to inform the available headroom for the cumulative assessment without the need for negotiation or cumulative conditioning. This may be the case particularly at low wind speeds.'

4.5.5 With this in mind, an additional 2 dB buffer has been added to the other schemes' turbine noise predictions. This is considered to be a suitable buffer in accordance with Section 5.4.11 of the IOA GPG and would represent a 60% increase in emitted noise levels from the other schemes.

4.5.6 Further information on the approach to apportionment is provided in Section 6.6 below.

5 Baseline

5.1 Existing Noise Limits (Stage 1)

5.1.1 Noise limits have already been established at the closest receptors to the Proposed Development for consented wind farms (Stronelairg and Dell) and proposed for Glenshero Wind Farm.

5.1.2 An extract from the noise conditions/ suggested noise conditions are included within Table 5.1 below and a copy of the full noise related planning conditions are included within Annex 2.

Table 5.1 Extract of Noise Conditions/ Suggested Noise Conditions

Wind Farm	Extract from Decision Notice/ Noise Condition Discussions
12/02560/S36 - Stronelairg	28. *The Wind Turbine Noise Level, including the application of any tonal penalty specified in ETSU-R-97 at pages 99-109, shall not exceed 35 dB LA90, 10min at any Noise-Sensitive Premises. This condition shall only apply at wind speeds up to 10m/s measured or calculated using the methods described in 'Prediction and Assessment of Wind Turbine Noise' (published in IOA Bulletin March/April 2009).*
13/02456/S36 - Corriegarth	No specific operational noise condition included within Decision Notice.
14/02879/FUL / PPA-270-2183 – Dell	23 Noise - *Noise immissions from the combined effect of the turbines received at any dwelling lawfully existing or with planning permission as at the date of this permission, when measured in accordance with the methods specified in paragraphs 98 — 104 of "The Assessment and Rating of Noise from Wind Farms ("ETSU 1997) shall not exceed 35dB(A) L90 10 mins at wind speeds measured on site of up to 10ms measured at 10m above ground level. Reason: to protect nearby residents from undue noise and disturbance.*
18/04733/S36 - Glenshero	Highland Council EHO Response - *no objection to the application subject to a standard noise condition being attached which limits noise levels to no more than 3dB above the levels predicted in Table 9.10 of the Noise Section 9 of the Environmental Impact Assessment Report.*

5.1.3 Due to the distances between the Proposed Development and the NALs, background noise monitoring has not been undertaken for the Proposed Development.

6 Noise Assessment Results

6.1 Noise Assessment Locations

6.1.1 Noise assessment locations (NAL) refer to the position on the curtilage denoted by the blue house symbol on Figure A1.1 (Annex 1). A total of four noise sensitive receptors were chosen as representative NALs. The NALs chosen were the closest receptors to the Proposed Development and other wind farm developments. Predictions of wind turbine noise have been made at each of the NAL as detailed in Table 6.1.

6.1.2 This approach ensures that the report models the worst case (loudest) noise immission level expected at each group of noise sensitive receptors, as, generally speaking, sound levels decrease due to the attenuating factors described in Section 6.3 and thus the closer to a noise source, the higher the noise level.

Table 6.1 Noise Assessment Locations

Noise Assessment Location (NAL)	Easting (m)	Northing (m)	Elevation (m Above Ordnance Datum)	Approximate Distance to Nearest Cloiche Turbine (m)
NAL1 – Killin Lodge	252673	808997	330	5,800
NAL2 – Crathie	258349	794404	299	7,566
NAL3 - Garvabeg	252766	794886	297	6,458
NAL4 – Melgarve	246328	796097	351	5,030

6.2 Noise Emission Characteristics of the Wind Turbines

6.2.1 There are a range of wind turbine models that may be suitable for installation at the Proposed Development. This assessment considers the GE 3.8-130 3.8 MW with a 84.9 m hub height. For the cumulative assessment the turbines used are summarised in Annex 4.

6.2.2 Noise data for the various cumulative schemes considered in this assessment have been obtained from the manufacturers data or taken from the values quoted within the individual schemes ES and have been analysed in detail by TNEI. Due to the differences in the way in which levels are provided by the different manufacturers, TNEI has accounted for uncertainty using the guidance contained within Section 4.2 of the IOA GPG (2013). Details of the sound power level and octave data used for the turbines considered in this assessment are included in Annex 3.

6.2.3 Manufacturer data is usually supplied based on a specific hub height though values are presented as standardised to 10 m height. The noise model used in this assessment alters turbine noise data to account for different hub heights where applicable. The hub height considered for the Proposed Development is 84.9 m. The hub heights considered for the other wind farm developments are summarised in Annex 4.

6.2.4 The location of the wind turbines are shown on Figure A1.2 and grid references are included in Annex 4.

6.3 Noise Propagation Parameters

6.3.1 As detailed in Section 4.4 above, the full version of the ISO 9613-2 model has been used to calculate the noise immission levels at the nearest receptors.

6.3.2 For the purposes of the present assessment, all noise level predictions have been undertaken using a receiver height of 4 m above local ground level, mixed ground (G=0.5) and air absorption coefficients based on a temperature of 10 °C and 70 % relative humidity to provide a realistic impact assessment. The modelling parameters reflect current good practice as detailed within the IOA GPG.

6.3.3 The wind turbine noise immission levels are based on the L_{A90} noise indicator in accordance with the recommendations in ETSU-R-97, which were obtained by subtracting 2 dB from the turbine sound power level data (L_{Aeq} indicator).

6.3.4 A topographical assessment has been undertaken between each NAL and each wind turbine location to determine whether any concave ground profiles exist between the source and receiver (noise sensitive receptor). Analysis undertaken using a combination of CadnaA [17] and an Excel model found that if the formula in the IOA GPG is applied directly a +3 dB correction is required for some turbines at a number of receptors and this is summarised in Annex 4.

6.3.5 In addition, an assessment has been undertaken to determine whether any topographical screening effects of the terrain occur where there is no direct line of site between the highest point on the turbine rotor and the NAL. Upon analysis of each NAL it was found that a barrier correction of -2 dB could be applied for some turbines at a number of receptors and this is also detailed in Annex 4. In reality, there is significant screening at some of the locations so more attenuation may occur in practice and the use of a 2 dB value is therefore considered to be conservative. All corrections have been applied, where necessary, in all of the Tables and Graphs in this report.

6.3.6 The need to include a concave ground/screening correction may change depending on the final location of the turbines (following micrositing) and the final turbine hub height. Nevertheless, turbine noise levels will have to meet the noise limits established in this report regardless of any increases in noise propagation caused by topography. Therefore, should consent be granted for the Proposed Development, the need to apply a concave slope correction will need to be considered by the Applicant prior to the final selection of a turbine model for the Proposed Development.

6.3.7 The cumulative assessment has taken into account directivity effects in line with good practice. The directivity of wind turbines has been recognised for some time. Building on earlier work by NASA, in 1988 Wyle Laboratories studied sound propagation using an omnidirectional loudspeaker source elevated 80 ft above ground, in upwind, downwind and cross wind situations, and in both flat and hilly terrain, then compared those measurements to measured data from actual wind turbines. Their study quantified directivity factors for a limited frequency range, but was unable to conclusively demonstrate the anticipated directivity effects on real wind turbines. It also highlighted, but was unable to explain, measured differences observed between flat and hilly terrain.

6.3.8 Hubbard (1990) described a number of factors believed to influence propagation and directivity, notably refraction caused by vertical wind and temperature gradients. In the downwind direction the wind gradient causes the propagating sound to bend towards the ground, whereas in the upwind direction the sound will curve upwards, away from the ground. Upwind of the turbine this results in a region of increased attenuation termed the 'shadow zone'. The excess attenuation is frequency dependent, with lowest frequencies least attenuated. Relating this to the earlier NASA studies, Hubbard noted that the distance from the source to the edge of the shadow zone is relative to the wind speed gradient and the elevation of the source, which for a typical turbine source was calculated to be approximately 5 times the source height.

6.3.9 This observation was adopted in the IOA GPG, which states (4.4.2) 'Such reductions (due to "shadow zone" refraction effects) will in practice only progressively come into play at distances of between 5 and 10 turbine tip heights'. 4.4.3 of IOA GPG provides graphical examples of increasing broadband directivity with increasing tip height scaling in both flat and hilly terrain without qualifying either of those designations.

6.3.10 The IOA GPG recommends (Section 4.4.1) that directivity attenuation factors adopted in any assessment should be clearly stated. The TNEI noise model can consider the effect of directivity, and in line with current good practice the attenuation values used are in detailed in Table 6.2. These are based upon the examples given in the IOA GPG (Section 4.4.2), using interpolation where required, and adopt a single attenuation value for receptors located more than 5 tip heights from a receiver.

Table 6.2 Wind Directivity Attenuation Factors used in Modelling

Direction (º)	0	15	30	45	60	75	90	105	120	135	150	165
Attenuation, dB	-10	-9.9	-9.3	-8.3	-6.7	-4.6	-2	0	0	0	0	0
Direction (º)	180	195	210	225	240	255	270	285	300	315	330	345
Attenuation, dB	0	0	0	0	0	0	-2	-4.6	-6.7	-8.3	-9.3	-9.9

6.4 Total ETSU-R-97 Noise Limits (Stage 1)

6.4.1 The Total ETSU-R-97 Noise Limits have been established for each of the NALs detailed in Table 6.1 above. The Total ETSU-R-97 Noise Limits were derived based on the simplified 35 dB criteria detailed in ETSU-R-97, whilst also considering the noise limit that has already been allocated to other schemes in the area.

6.4.2 The Highland Council has requested that the cumulative noise assessment be undertaken against a simplified 35 dB limit, however, at NAL1, the Total ETSU-R-97 Noise limit has effectively already been set at 38 dB, as both Stronelairg and Dell Wind Farms have been allocated 35 dB noise limits at the receptor as part of their consents. Accordingly a Total ETSU-R-97 Noise Limit of 38 dB has been used at NAL1 Killin Lodge.

6.4.3 The Total ETSU-R-97 Noise limits are summarised in Table 6.3 below.

Table 6.3 Total ETSU-R-97 Noise Limits (Applicable to all times of the day)

Location	Wind Speed (ms^{-1}) as standardised to 10m height											
	1	2	3	4	5	6	7	8	9	10	11	12
NAL1 – Killin Lodge	38	38	38	38	38	38	38	38	38	38	38	38
NAL2 – Crathie	35	35	35	35	35	35	35	35	35	35	35	35
NAL3 - Garvabeg	35	35	35	35	35	35	35	35	35	35	35	35
NAL4 – Melgarve	35	35	35	35	35	35	35	35	35	35	35	35

6.5 Predicting the likely effects and the requirement for a cumulative assessment (Stage 2)

6.5.1 In order to protect residential amenity, the IOA GPG (2013) recommendations are that cumulatively, all schemes operate within the 'Total ETSU-R-97 Noise Limits'. This can be found in summary box SB21 of the IOA GPG (2013) which states:

'Whenever a cumulative situation is encountered, the noise limits for an individual wind farm should be determined in such a way that no cumulative excess of the total ETSU-R-97 noise limit would occur.'

6.5.2 The results of the likely cumulative noise assessment are summarised in tabular form in Table 6.4 and show that the Proposed Development can operate concurrently with the proposed, consented and operational wind farms, whilst still meeting the Total ETSU-R-97 Noise limits established in accordance with ETSU-R-97 at the four NALs.

6.5.3 A series of graphs to show the predicted cumulative wind turbine noise from all schemes compared to the Total ETSU-R-97 Noise Limits are included as Figures A1.2a through to Figure A1.2d (Annex 1). There is a set of graphs for each of the NAL and these show the Total ETSU-R-97 Noise Limit (solid red line), the total cumulative noise (yellow dashed line), the predicted noise from all other schemes minus the Proposed Development (solid yellow line), the predicted wind turbine noise from the Proposed Development (solid green line) and predicted levels for individual schemes (dashed lines, various colours).

Table 6.4 ETSU-R-97 Compliance Table – Likely Cumulative Noise – All times of the day

Location		Wind Speed (ms^{-1}) as standardised to 10 m height											
		1	2	3	4	5	6	7	8	9	10	11	12
NAL1 – Killin Lodge	Total ETSU-R-97 Noise Limit	38	38	38	38	38	38	38	38	38	38	38	38
	Predicted Cumulative Wind Turbine Noise L_{A90}	-	-	-	-	-	31.5	33.7	34	34.1	34.1	34.1	34.1
	Exceedance Level L_{A90} (all schemes)	-	-	-	-	-	-6.5	-4.3	-4	-3.9	-3.9	-3.9	-3.9
NAL2 - Crathie	Total ETSU-R-97 Noise Limit	35	35	35	35	35	35	35	35	35	35	35	35
	Predicted Cumulative Wind Turbine Noise L_{A90}	-	-	-	-	-	24.9	26.9	27.1	27.1	27.1	27.1	27.1
	Exceedance Level L_{A90} (all schemes)	-	-	-	-	-	-10.1	-8.1	-7.9	-7.9	-7.9	-7.9	-7.9
NAL3 - Garvabeg	Total ETSU-R-97 Noise Limit	35	35	35	35	35	35	35	35	35	35	35	35
	Predicted Cumulative Wind Turbine Noise L_{A90}	-	-	-	-	-	29	30.9	31.1	31.1	31.1	31.1	31.1
	Exceedance Level L_{A90} (all schemes)	-	-	-	-	-	-6	-4.1	-3.9	-3.9	-3.9	-3.9	-3.9
NAL4 – Melgrave	Total ETSU-R-97 Noise Limit	35	35	35	35	35	35	35	35	35	35	35	35
	Predicted Cumulative Wind Turbine Noise L_{A90}	-	-	-	-	-	28.9	30.7	31	31	31	31	31
	Exceedance Level L_{A90} (all schemes)	-	-	-	-	-	-6.1	-4.3	-4	-4	-4	-4	-4

Note: For the cumulative noise predictions the noise model considers the range of noise data available for each turbine type modelled. For some turbines noise data was not available for wind speeds less than 6 ms^{-1} therefore no cumulative predictions are included for wind speeds less than 6 ms^{-1}.

6.6 Derivation of Site Specific Noise Limits (Stage 3)

6.6.1 As requested by the Highland Council, modelling has been undertaken to consider the other nearby schemes operating at their consented levels or at a reduced level where it was deemed appropriate when considering the options outlined in the IOA GPG. In order to consider each scheme in isolation a comparison was undertaken of the predictions from the individual schemes against their individual noise limits. The apportionment options provided in the IOA GPG were then considered to determine the most appropriate option for each scheme. The findings are summarised below:

- Stronelairg - the difference between the predicted levels and the 35dB noise limit was less than 5dB. The smallest margin between the limit and predictions was a difference of 3 dB at the most sensitive property. Therefore, there was no significant headroom and on that basis the predicted levels were set at the consented levels for that scheme by adding 3 dB to the predictions.
- Dell – there was significant headroom (at least 7.3 dB) between the likely predicted levels and the 35 dB noise limit therefore a +2 dB buffer was added to the predicted levels;
- Corriegarth – there was significant headroom (at least 10.8 dB) between the likely predicted levels and the 35 dB noise limit therefore a +2 dB buffer was added to the predicted levels;
- Glenshero – in accordance with the suggested noise limits for the scheme a +3dB buffer has been added to the predicted levels.

6.6.2 The addition of the buffers listed above resulted in the cautious predictions of wind farm noise taking account of the proportion of the Total ETSU-R-97 Noise Limit that the other existing / Proposed Developments have been allocated / could realistically use. Figures A1.3a-b show the addition of the buffers as detailed above.

6.6.3 Table 6.5 below summarises the approach adopted at each NAL in order to derive the Site Specific Noise Limits for the Proposed Development.

Table 6.5 Limit Derivation Strategy

NAL	Limit Derivation Strategy
NAL1	Both Stronelairg Wind Farm and Dell Wind Farm have been consented with the simplified 35 dB(A) noise limit. This effectively means that a total cumulative noise limit already exists at NAL1 Killin Lodge of 38 dB(A). The noise predictions from Stronelairg Wind Farm suggests that the wind farm is using the majority of the noise limit at the receptor therefore for the purposes of deriving site specific noise limits it has been assumed that Stronelairg uses its entire noise limit. For the other consented schemes (Dell and Corriegarth Wind Farms) the predictions show that there is significant headroom (>5 dB buffer) between the predictions from the individual schemes and the 35 dB noise limit. In accordance with Section 4.5 above, a +2 dB buffer has therefore been added to the turbine noise predictions; this is considered to be a suitable buffer in accordance with Section 5.4.11 of the IOA GPG and would represent a 60% increase in emitted noise levels from the other schemes. For Glenshero, a +3 dB buffer has been added to predicted levels in accordance with the suggested levels discussed as part of the planning application for the scheme. The resulting 'cautious' predictions of cumulative wind turbine noise have then been logarithmically subtracted from the Total ETSU-R-97 Noise Limit to determine the 'residual noise limit' (Site Specific Noise Limit), which are detailed in Table 6.6. Where the residual noise limit is >35 dB the limit has been set at 35 dB..
NALs 2-4	For the consented/operational schemes (Stronelairg, Dell and Corriegarth Wind Farms) the predictions show that there is significant headroom (>5 dB buffer) between the predictions from the individual schemes and the 35 dB noise limit, therefore on that basis a Total ETSU-R-97 Noise Limit of 35 dB has been deemed appropriate for these receptors. In order to determine the Site Specific Noise Limits, a +2 dB buffer was added to the turbine noise predictions; this is considered to be a suitable buffer in accordance with Section 5.4.11 of the IOA GPG and would represent a 60% increase in emitted noise levels from the other schemes. For Glenshero, a +3 dB buffer has been added to predicted levels in accordance with the suggested levels discussed as part of the planning application. The resulting 'cautious' predictions of cumulative wind turbine noise have then been logarithmically subtracted from the Total ETSU-R-97 Noise Limit to determine the 'residual noise limit' (Site Specific Noise Limit), which are detailed in Table 6.6.

6.6.4 Table 6.6 shows the Site Specific Noise Limits, noise predictions for the Proposed Development and the exceedance level. A negative exceedance demonstrates compliance with the Site Specific Noise Limits.

Table 6.6 Site Specific Noise Limits Compliance Table – All times of the Day

Location		Wind Speed (ms^{-1}) as standardised to 10 m height											
		1	2	3	4	5	6	7	8	9	10	11	12
NAL1 – Killin Lodge	Site Specific Noise Limit	35.0	35.0	35.0	35.0	35.0	35.0	33.5	32.7	32.7	32.7	32.7	32.7
	Predicted Wind Turbine Noise L_{A90}	-	-	11.9	13.9	18.2	21.7	23.1	23.1	23.1	23.1	23.1	23.1
	Exceedance Level	-	-	-23.1	-21.1	-16.8	-13.3	-10.4	-9.6	-9.6	-9.6	-9.6	-9.6
NAL2 – Crathie	Site Specific Noise Limit	35.0	35.0	35.0	35.0	35.0	34.4	33.9	33.8	33.8	33.8	33.8	33.8
	Predicted Wind Turbine Noise L_{A90}	-	-	8.2	10.2	14.5	18.0	19.4	19.4	19.4	19.4	19.4	19.4
	Exceedance Level	-	-	-26.8	-24.8	-20.5	-16.4	-14.5	-14.4	-14.4	-14.4	-14.4	-14.4
NAL3 - Garvabeg	Site Specific Noise Limit	33.8	33.8	33.8	33.8	33.8	32.9	31.0	30.5	30.5	30.5	30.5	30.5
	Predicted Wind Turbine Noise L_{A90}	-	-	11.8	13.8	18.1	21.6	23.0	23.0	23.0	23.0	23.0	23.0
	Exceedance Level	-	-	-22.0	-20.0	-15.7	-11.3	-8.0	-7.5	-7.5	-7.5	-7.5	-7.5
NAL4 – Melgarve	Site Specific Noise Limit	34.1	34.1	34.1	34.1	34.1	33.4	32.2	31.9	31.9	31.9	31.9	31.9
	Predicted Wind Turbine Noise L_{A90}	-	-	14.2	16.2	20.5	24.0	25.4	25.4	25.4	25.4	25.4	25.4
	Exceedance Level	-	-	-19.9	-17.9	-13.6	-9.4	-6.8	-6.5	-6.5	-6.5	-6.5	-6.5

6.6.5 The predicted wind turbine noise immission levels meet the Site Specific Noise Limits under all conditions and at all locations for all times of the day. A series of graphs to show the predicted wind turbine noise from the Proposed Development compared to the Site Specific Noise Limits are included as Figures A1.4a - A1.4d (Annex 1). There is a set of graphs for each of the NALs, which show the Total ETSU-R-97 Noise Limit (solid red line), the Site Specific Noise Limit (dashed red line) and the predicted wind turbine noise from the Proposed Development (solid green line).

6.7 Micrositing

6.7.1 It should be noted that the need to include a concave ground profile correction and/or barrier correction may change depending on the final location of the turbines (following micrositing) and the final turbine hub height. Nevertheless, turbine noise levels will have to meet the noise limits established in this report regardless of any changes in noise propagation caused by topography. Should consent for the Proposed Development be granted, the need to apply a concave ground profile/ barrier correction will need to be considered by the Applicant prior to the final selection of a turbine model for the site.

7 Conclusions

7.1.1 This report has assessed the potential impact of operational noise from the Proposed Development on the residents of nearby receptors. The guidance contained within ETSU-R-97 and current good practice (IOA GPG) has been used to assess the potential noise impact of the Proposed Development.

7.1.2 A cumulative assessment was undertaken at four NALs which were selected because they are the closest to the Proposed Development and other nearby schemes. The cumulative assessment results show that the predicted cumulative wind farm noise immission levels would meet the 'Total ETSU-R-97' derived noise limits at receptor locations surrounding the Proposed Development.

7.1.3 'Site Specific Noise Limits' have also been derived which take account of the other wind farms. The Site Specific Noise Limits assume that all consented turbines and proposed turbines (Glenshero) are built and that all existing turbines continue to operate for the lifetime of the consent and that their noise immissions are as per the levels considered in this assessment.

7.1.4 An assessment was undertaken to determine whether the Proposed Development could operate within the Site Specific Noise Limits and it was found that at all receptors' wind turbine noise immissions were below these limits when considering the GE 3.8-130 3.8 MW as a candidate turbine.

7.1.5 At some locations, under some wind conditions and for a certain proportion of the time, operational wind farm noise from the Proposed Development may be audible; however, it would be at an acceptable level in relation to the ETSU-R-97 guidelines.

7.1.6 There are a number of wind turbine makes and models that may be suitable for the Proposed Development. Should the Proposed Development receive consent, the final choice of turbine would be subject to a competitive tendering process. The final choice of turbine would, however, have to meet the noise limits determined and contained within any condition imposed. A set of suggested operational noise conditions are included within Annex 5.

8 Glossary of Terms

AOD: Above Ordnance Datum is the height above sea level.

Amplitude Modulation: a variation in noise level over time; for example observers may describe a 'whoosh whoosh' sound, which can be heard close to a wind turbine as the blades sweep past.

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.

Background Noise: the noise level rarely fallen below in any given location over any given time period, often classed according to daytime, evening or night-time periods. The L_{A90} indices (see below) is often used to represent the background noise level.

Bin: subset or group into which data can be sorted; in the case of wind speeds, bins are often centred on integer wind speeds with a width of 1 m/s. For example the 4 m/s bin would include all data with wind speeds of 3.5 to 4.5 m/s.

Dawn Chorus: noise due to birds which can occur at sunrise.

Broadband Noise: noise with components over a wide range of frequencies.

Decibel (dB): the ratio between the quietest audible sound and the loudest tolerable sound is a million to one in terms of the change in sound pressure. A logarithmic scale is used in noise level measurements because of this wide range. The scale used is the decibel (dB) scale which extends from 0 to 140 decibels (dB) corresponding to the intensity of the sound level.

dB(A): the ear has the ability to recognise a particular sound depending on its pitch or frequency. Microphones cannot differentiate noise in the same way as the ear, and to counter this weakness the noise measuring instrument applies a correction to correspond more closely to the frequency response of the human ear. The correction factor is called 'A Weighting' and the resulting measurements are written as dB(A). The dB(A) is internationally accepted and has been found to correspond well with people's subjective reaction to noise. Some typical subjective changes in noise levels are:

- a change of 3 dB(A) is just perceptible;
- a change of 5 dB(A) is clearly perceptible;
- a change of 10 dB(A) is twice (or half) as loud.

Directivity: the property of a sound source that causes more sound to be radiated in one direction than another.

Frequency: the pitch of a sound in Hz or kHz. See Hertz.

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. Described using the term 'G', and ranges between 0 (hard), 0.5 (mixed) and 1 (soft).

Hertz (Hz): sound frequency refers to how quickly the air vibrates, or how close the sound waves are to each other (in cycles per second, or Hertz (Hz)).

L_w: is the sound power level. It is a measure of the total noise energy radiated by a source of noise, and is used to calculate noise levels at a distant location. The L_{WA} is the A-weighted sound power level.

L_{eq}: is the equivalent continuous sound level, and is the sound level of a steady sound with the same energy as a fluctuating sound over the same period. It is possible to consider this level as the ambient noise encompassing all noise at a given time. The $LA_{eq,T}$ is the A-weighted equivalent continuous sound level over a given time period (T).

L_{90}: index represents the noise level exceeded for 90 percent of the measurement period and is used to indicate quieter times during the measurement period. It is often used to measure the background noise level. The $L_{A90,10min}$ is the A-weighted background noise level over a ten minute measurement sample.

Noise emission: the noise energy emitted by a source (e.g. a wind turbine).

Noise immission: the sound pressure level detected at a given location (e.g. the nearest dwelling).

Night-Time Hours: ETSU-R-97 defines the night-time hours as 23.00 to 07.00 every day.

Quiet Daytime Hours: ETSU-R-97 defines the amenity hours as 18.00 to 23.00 Monday to Friday, 13.00 to 23.00 on Saturdays and 07.00 to 23.00 on Sundays.

Sound Level Meter: an instrument for measuring sound pressure level.

Sound Power Level: the total sound power radiated by a source, in decibels.

Sound Pressure Level: a measure of the sound pressure at a point, in decibels**.**

Standardised Wind Speed: a wind speed measured at a height different than 10 m (generally measured at the turbine hub height) which is expressed to a reference height of 10 m using a roughness length of 0.05 for standardisation purpose (in accordance with the IEC 61400-11 standard).

Tonal Noise: noise which covers a very restricted range of frequencies (e.g. a range of ≤20 Hz). This noise can be more annoying than broadband noise.

Wind Shear: the increase of wind speed with height above the ground.

9 References

1. **ETSU for the DTI (Department of Trade and Industry.** *The Working Group on Noise from Wind Turbines ETSU-R-97 The Assessment and Rating of Noise from Wind Farms'.* 1996.

2. **Institute of Acoustics.** *Good Practice Guidance on the application of ETSU-R-97 for wind turbine noise assessment.* 2013.

3. **The Scottish Government.** Scottish Planning Policy (SPP) http://www.gov.scot/Publications/2014/06/5823. [Online] 2014.

4. **The Scottish Government.** Web Based Renewables Advice: 'Onshore Wind Turbines' – http://www.scotland.gov.uk/Resource/0045/00451413.pdf. [Online] 28 May 2014.

5. **The Scottish Government.** Planning Advice Note PAN 1/2011: Planning and Noise - http://www.scotland.gov.uk/Resource/Doc/343210/0114180.pdf. [Online] 2011.

6. **The Scottish Government.** Technical Advice Note Assessment of Noise (http://www.scotland.gov.uk/Resource/Doc/343341/0114220.pdf). [Online]

7. **Letter John Swinney, MSP Cabinet Secretary for Finance, Employment and Sustainable Growth to Prof B Shield.** http://www.ioa.org.uk/pdf/scottish-government-endorsement-of-ioa-gpg.pdf. [Online]

8. *Visual and acoustic impact of wind turbine farms in residents Final report.* **Frits van den Berg et al.** s.l. : FP6-2005-Science-and-Society-20 Specific Support Action, 3 June 2008.

9. *Low frequency noise and annoyance.* **HG, Leventhall.** 23, s.l. : Noise & Health Journal, 2004, Vol. 6.

10. *Do wind turbines produce significant low frequency sound levels? Conference paper 11th International Meeting on Low Frequency Noise and Vibration and its Control .* **Berg, G.P. van den.** Maastricht The Netherlands : s.n., 2004.

11. **Department of Trade and Industry.** *The Measurement of LFN at three UK Wind Farms .* 2006 : s.n.

12. **Keele University Rejects Renewable Energy Foundation.** http://archive.is/d3WB. *Low Frequency Noise Research Claims .* [Online]

13. **Institute of Acoustics Bulletin.** *Prediction and assessment of wind turbine noise.* 2009.

14. *Infrasound and the ear, 5th International conference on Wind Turbine Noise.* **Leventhall, G.** Denver : s.n., 2013.

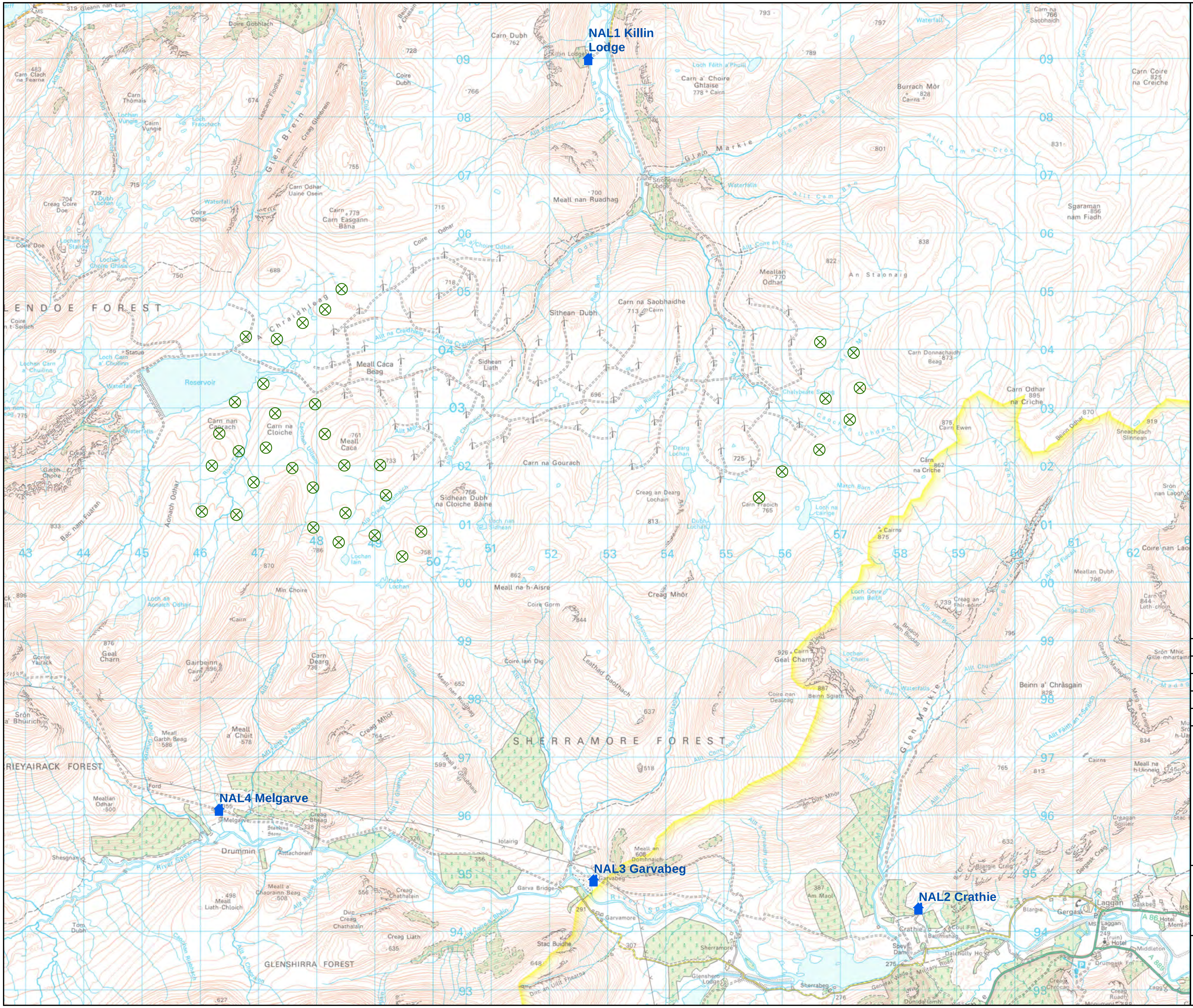
15. **renewable UK.** http://www.renewableuk.com/search/all.asp?bst=amplitude+modulation. [Online]

16. **Department of Energy & Climate Change.** *Wind Turbine AM Review Phase 2 Report.* 2016.

17. **International Standards Organisation.** *ISO9613:1996 'Acoustics – Attenuation of sound during propagation outdoors' – Part 2: General method of calculation.* 1996.

18. **DataKustik Gmbh.** CadnaA Version 4.4.

Annex 1 – Figures



Legend

- Noise Assessment Locations
- Proposed Turbine Location

0 1,000 2,000 Metres

N

REV.	DETAILS	DRAWN	CHK'D	APP'D	DATE
R1	SECOND ISSUE	GC	JM	JM	16/03/2020
R0	FIRST ISSUE	GC	JM	JM	06/02/2020

Project	Cloiche Wind Farm
Client	SSE Renewables Ltd
Title	Wind Turbine and Noise Assessment Locations
Figure No.	A1.1a
Scale	1:60,000 @A3
Doc. Ref.	13333-004

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NAL1 Killin Lodge

NAL4 Melgarve

NAL3 Garvabeg

NAL2 Crathie

Legend

- Noise Assessment Locations

Wind Farm

- Cloiche Wind Farm
- Corriegarth Wind Farm
- Dell Wind Farm
- Glenshero Wind Farm
- Stronelairg Wind Farm

0 1,000 2,000 Metres

N

REV.	DETAILS	DRAWN	CHK'D	APP'D	DATE
R1	SECOND ISSUE	GC	JM	JM	16/03/2020
R0	FIRST ISSUE	GC	JM	JM	06/02/2020

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Client	SSE Renewables Ltd
Title	Cumulative Turbine Locations
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Doc. Ref.	13333-005

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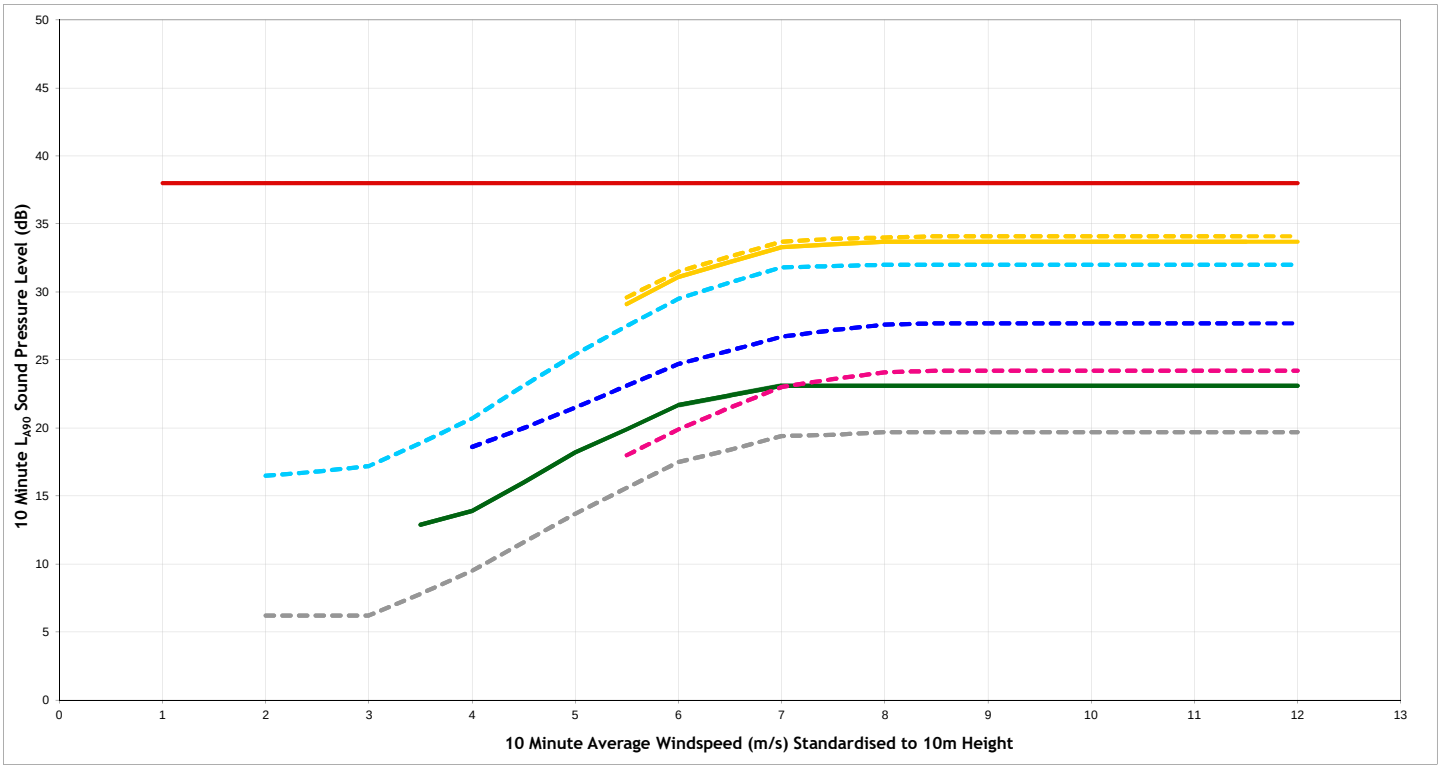
Quiet Daytime - Killin Lodge (NAL1)



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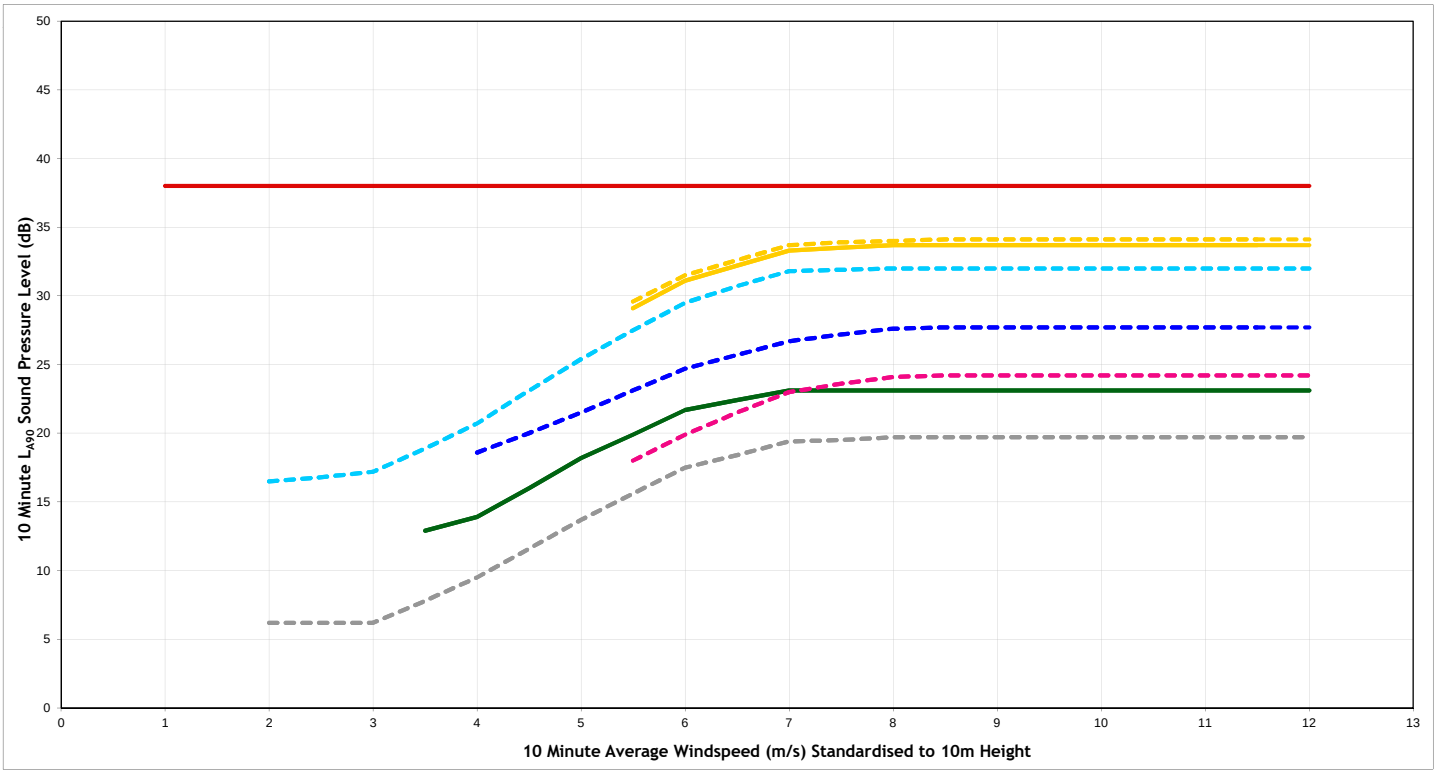

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- Total ETSU-R-97 Noise Limit
- Cloiche Wind Farm
- Cumulative - All Wind Farms
- Cumulative - Other Wind Farms (w/o Cloiche)
- Stronelairg
- Corriegarth
- Dell
- Glenshero

Project	Cloiche Wind Farm
Client	SSE Renewables Ltd
Title	Likely Cumulative Killin Lodge (NAL1)
Figure Number	Figure A1.2a
Drawn	AR
Checked	GC
Date	20/03/2020
Document Reference	13333-Models

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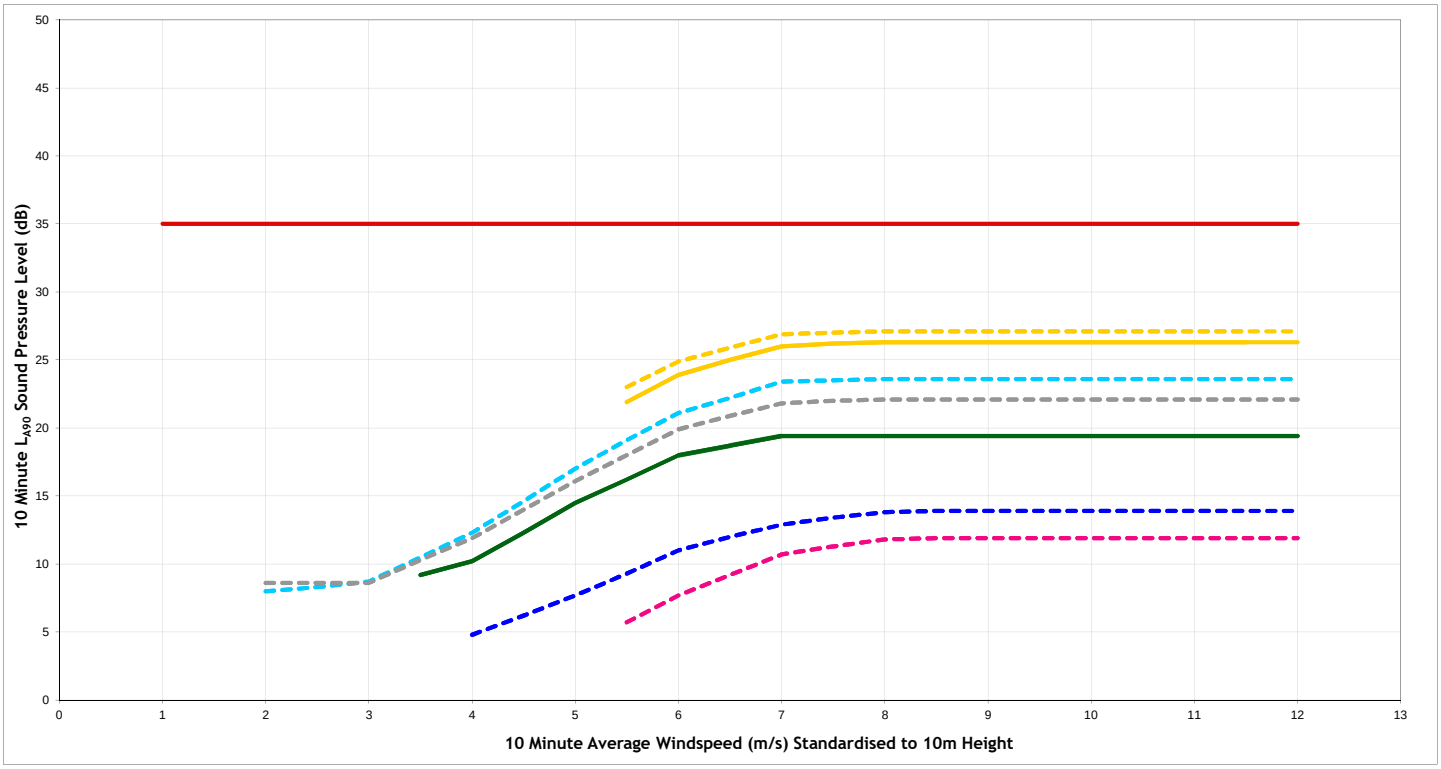

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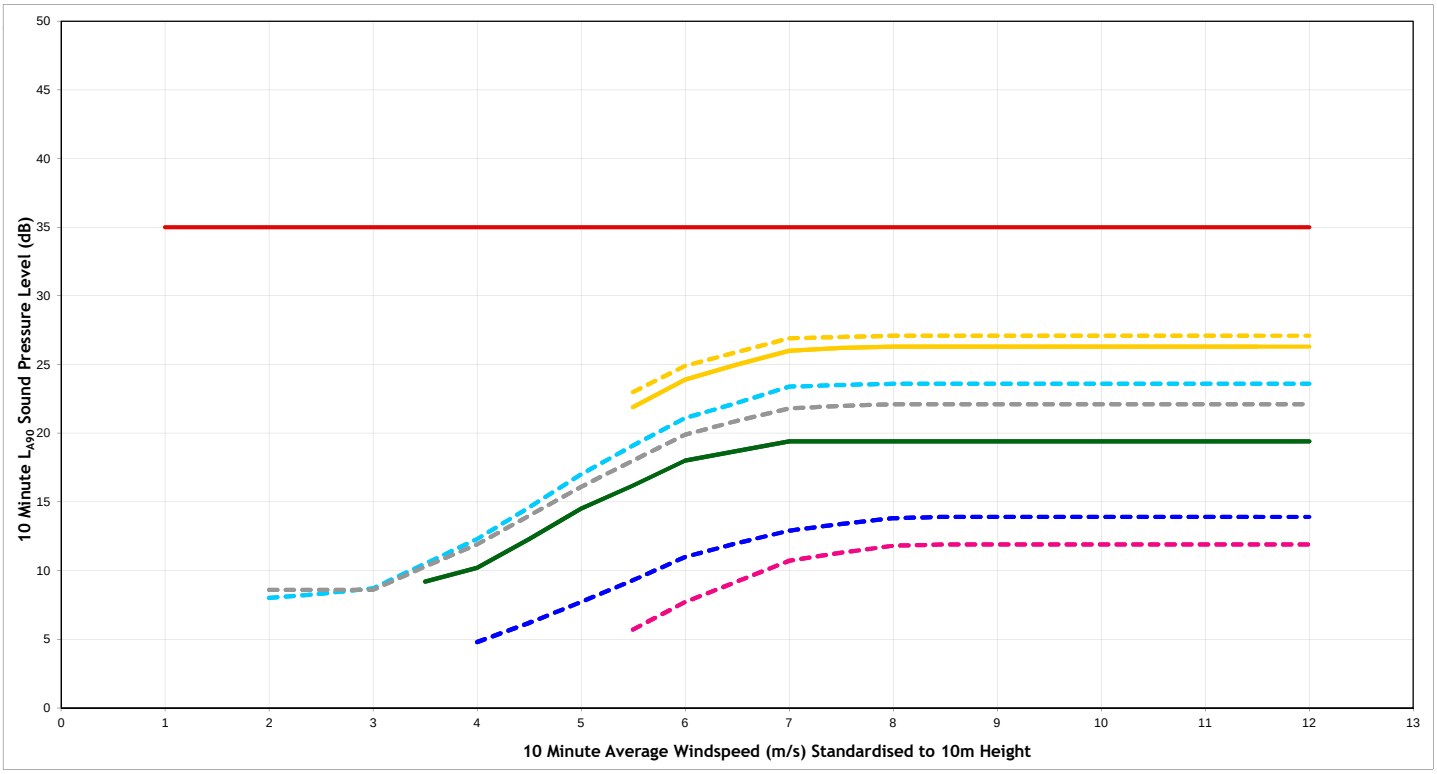

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- Simplified Total ETSU-R-97 Noise Limit
- Cloiche Wind Farm
- Cumulative - All Wind Farms
- Cumulative - Other Wind Farms (w/o Cloiche)
- Stronelairg
- Corriegarth
- Dell
- Glenshero

Project	Cloiche Wind Farm
Client	SSE Renewables Ltd
Title	Likely Cumulative Crathie (NAL2)
Figure Number	Figure A1.2b
Drawn	AR
Checked	GC
Date	20/03/2020
Document Reference	13333-Models

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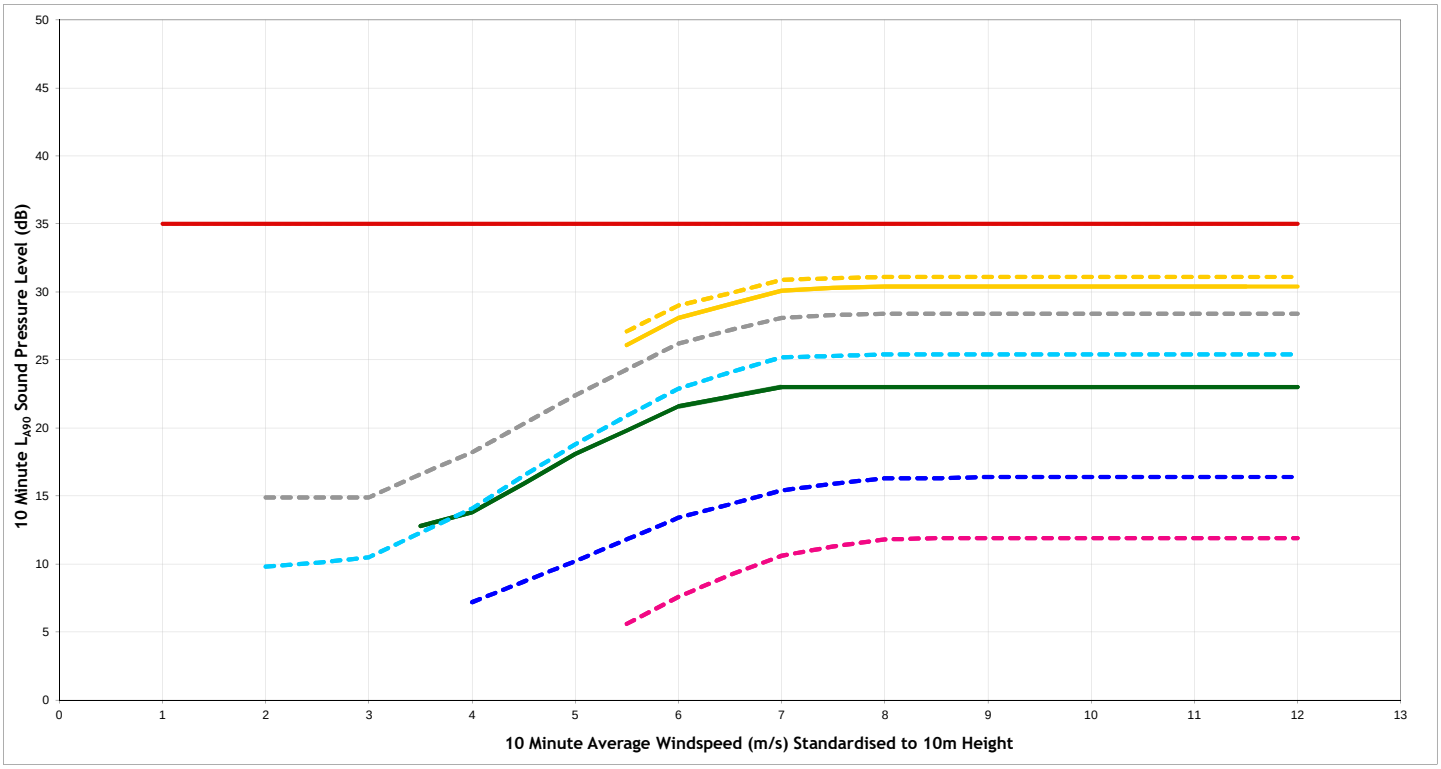

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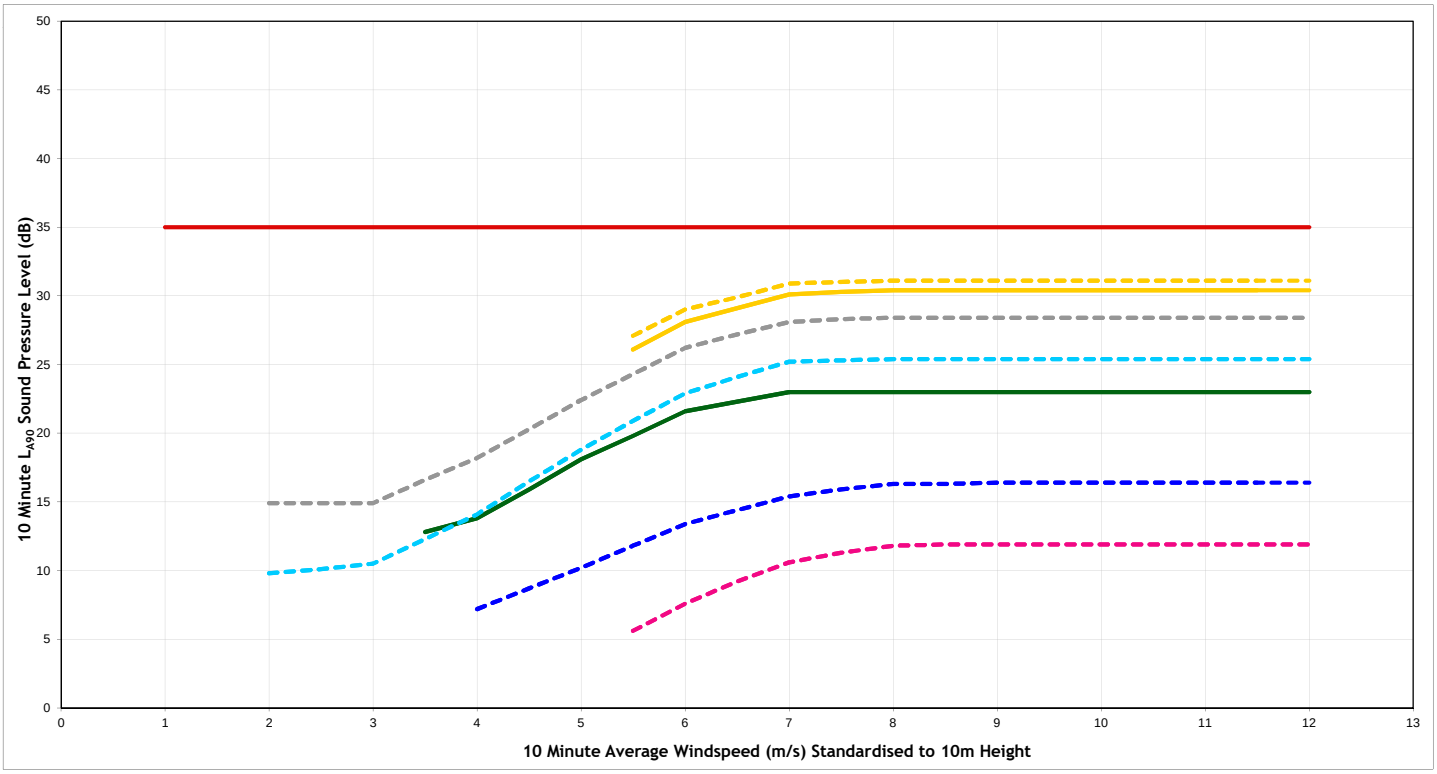

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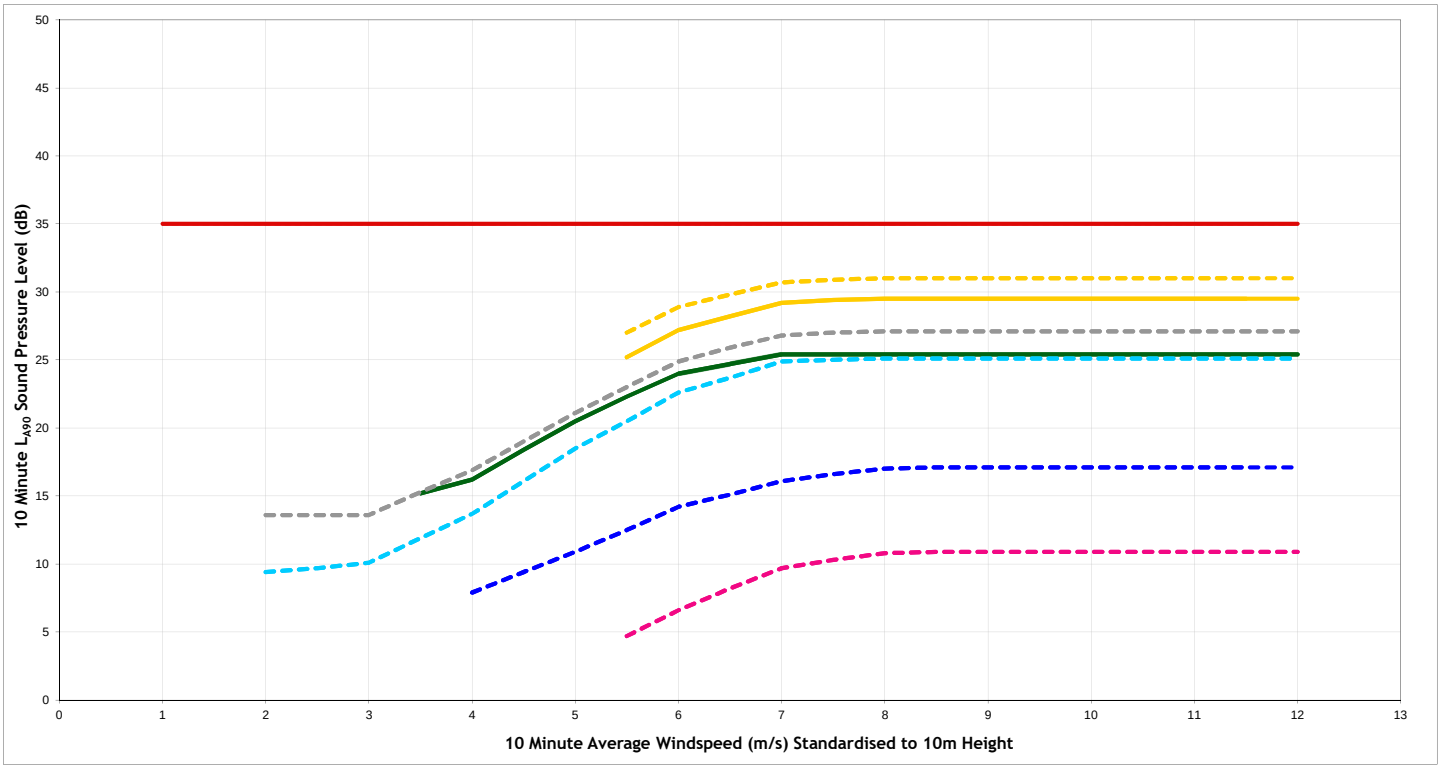
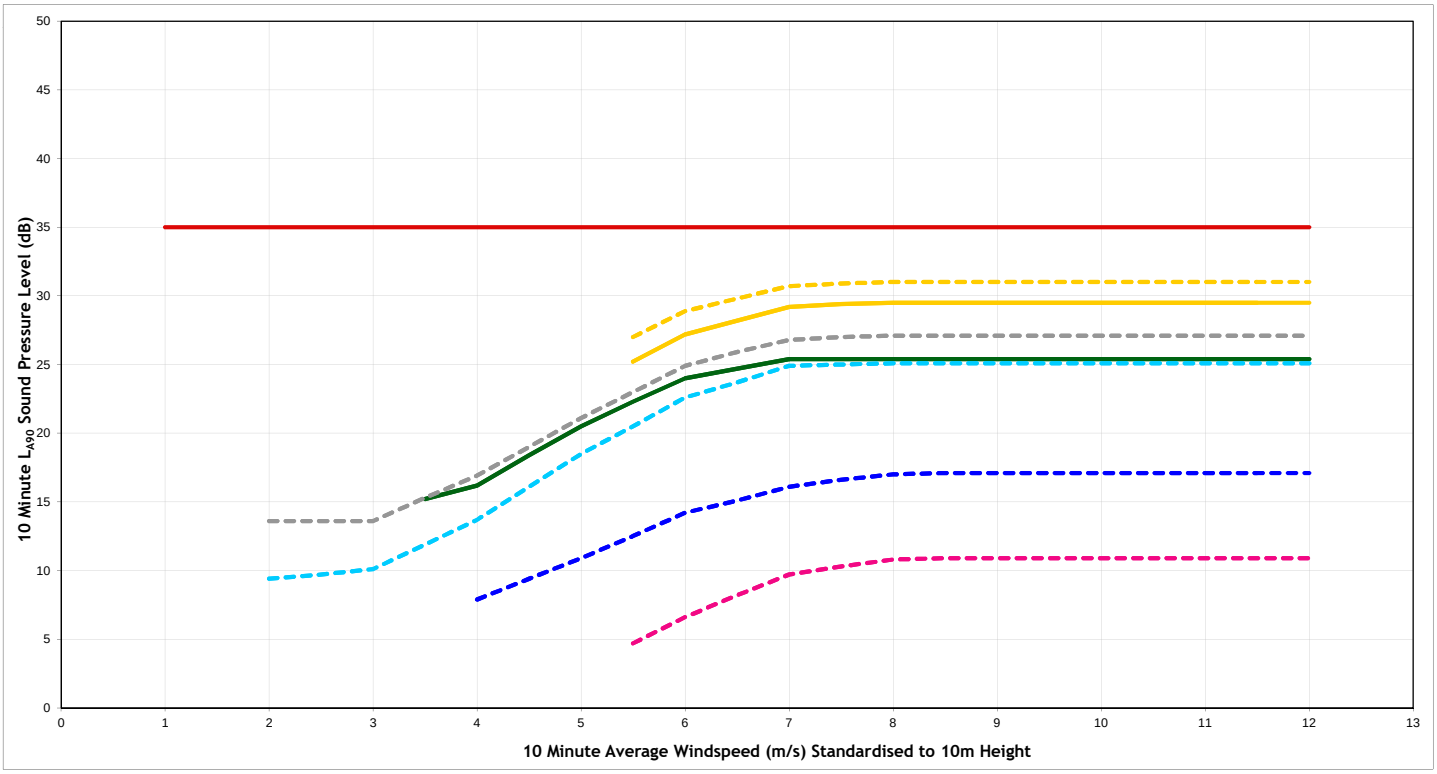
- Simplified Total ETSU-R-97 Noise Limit
- Cloiche Wind Farm
- Cumulative - All Wind Farms
- Cumulative - Other Wind Farms (w/o Cloiche)
- Stronelairg
- Corriegarth
- Dell
- Glenshero

Project	Cloiche Wind Farm
Client	SSE Renewables Ltd
Title	Likely Cumulative Garvabeg (NAL3)
Figure Number	Figure A1.2c
Drawn	AR
Checked	GC
Date	20/03/2020
Document Reference	13333-Models

Quiet Daytime - Melgarve (NAL4)



Night Time - Melgarve (NAL4)



Legend:

- Simplified Total ETSU-R-97 Noise Limit
- Cloiche Wind Farm
- Cumulative - All Wind Farms
- Cumulative - Other Wind Farms (w/o Cloiche)
- Stronelairg
- Corriegarth
- Dell
- Glenshero

Project	Cloiche Wind Farm
Client	SSE Renewables Ltd
Title	Likely Cumulative Melgarve (NAL4)
Figure Number	Figure A1.2d
Drawn	AR
Checked	GC
Date	20/03/2020
Document Reference	13333-Models

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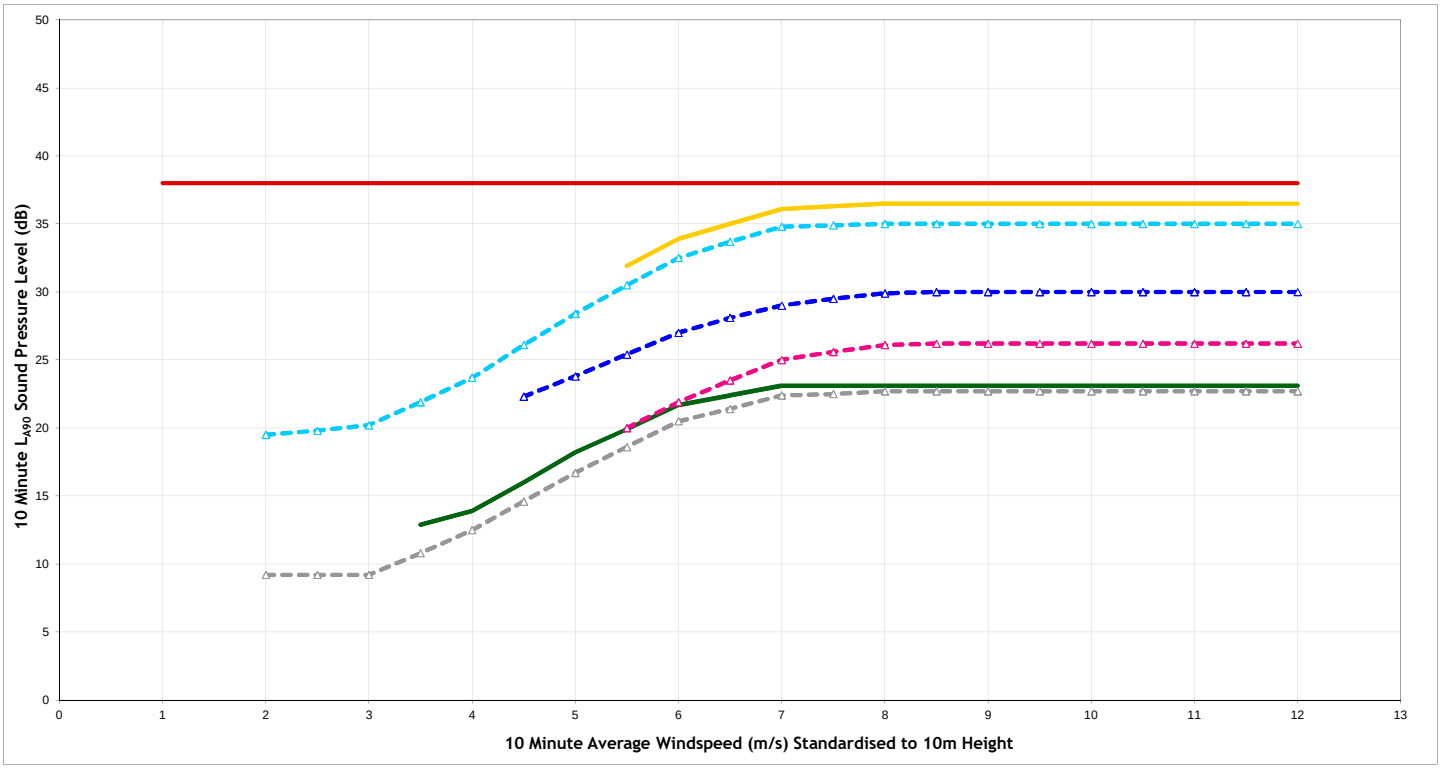
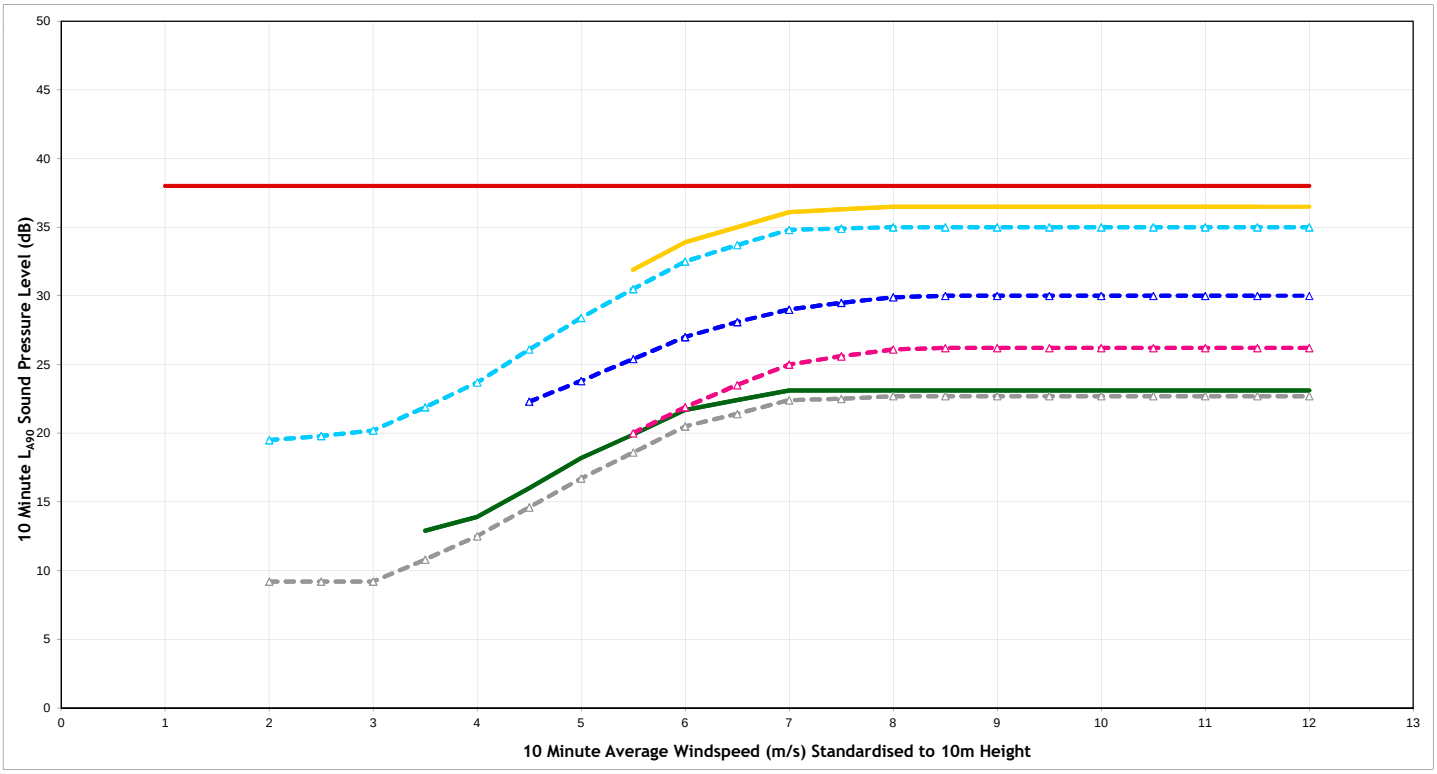
Quiet Daytime - Killin Lodge (NAL1)



Night Time - Killin Lodge (NAL1)



Legend:

- Total ETSU-R-97 Noise Limit
- Cloiche Wind Farm (Likely Effects)
- Cumulative - Other Wind Farms (w/o Cloiche)
- Stronelairg (Cautious Predictions)
- Corriegarth (Cautious Predictions)
- Dell (Cautious Predictions)
- Glenshero (Cautious Predictions)

Project	Cloiche Wind Farm
Client	SSE Renewables Ltd
Title	Cautious Noise Predictions Killin Lodge (NAL1)
Figure Number	Figure A1.3a
Drawn	AR
Checked	GC
Date	20/03/2020
Document Reference	13333-Models

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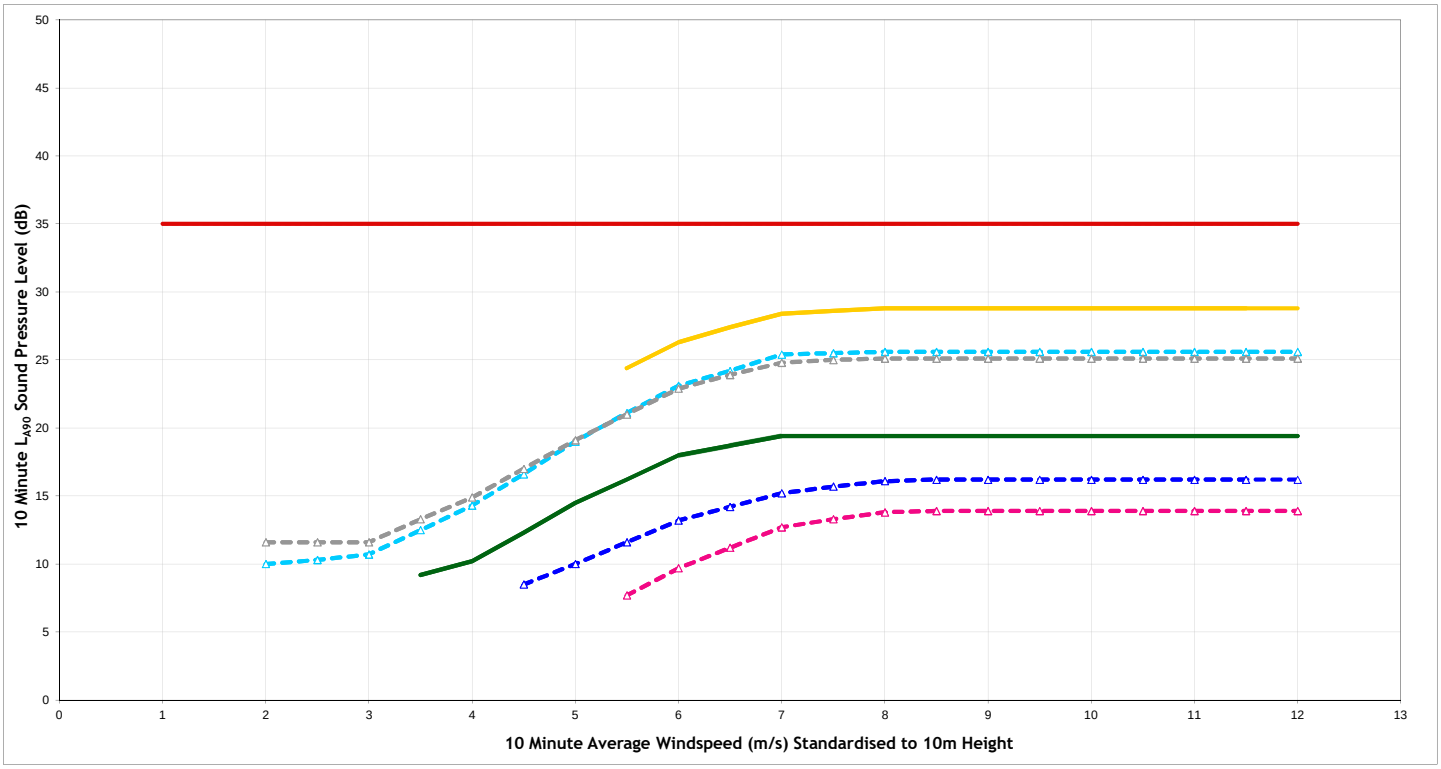
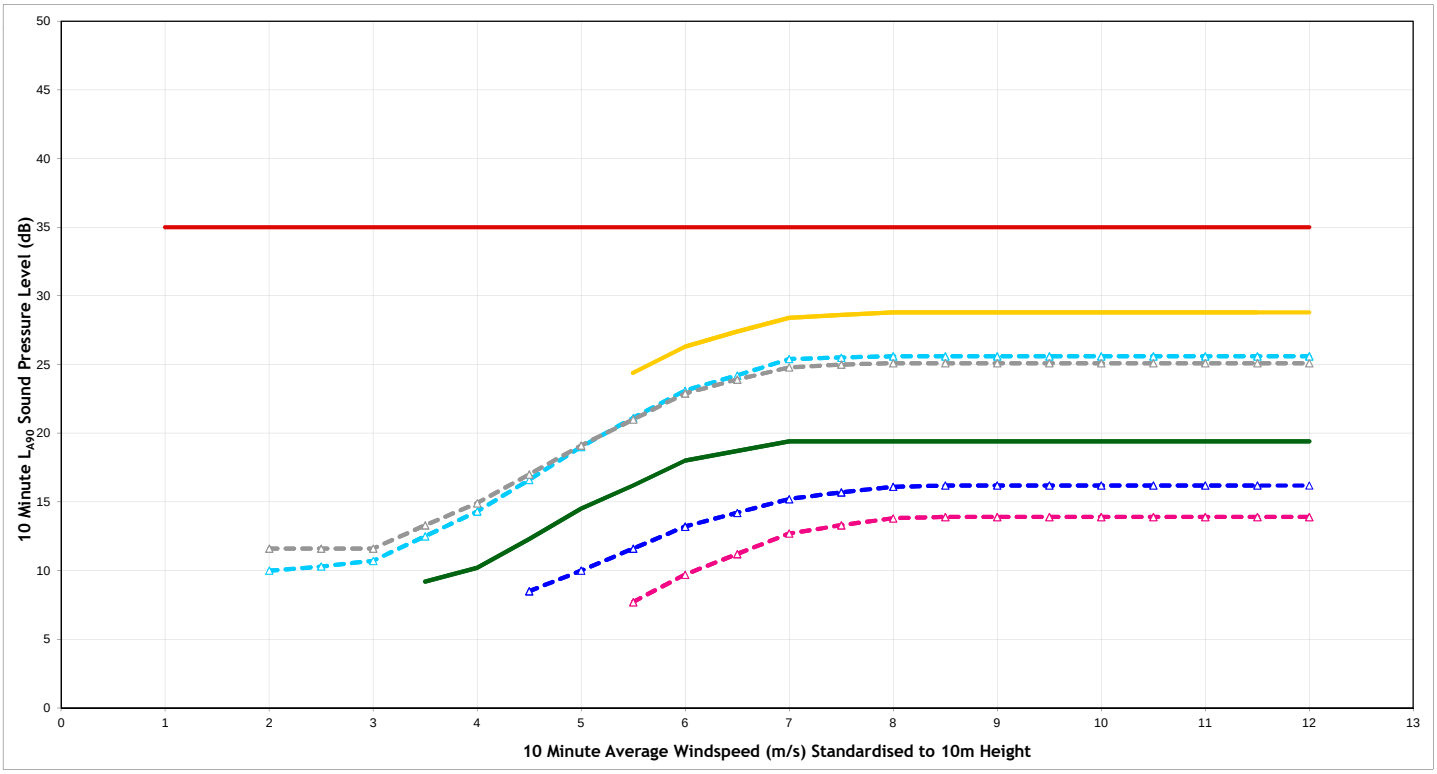
Quiet Daytime - Crathie (NAL2)



Night Time - Crathie (NAL2)

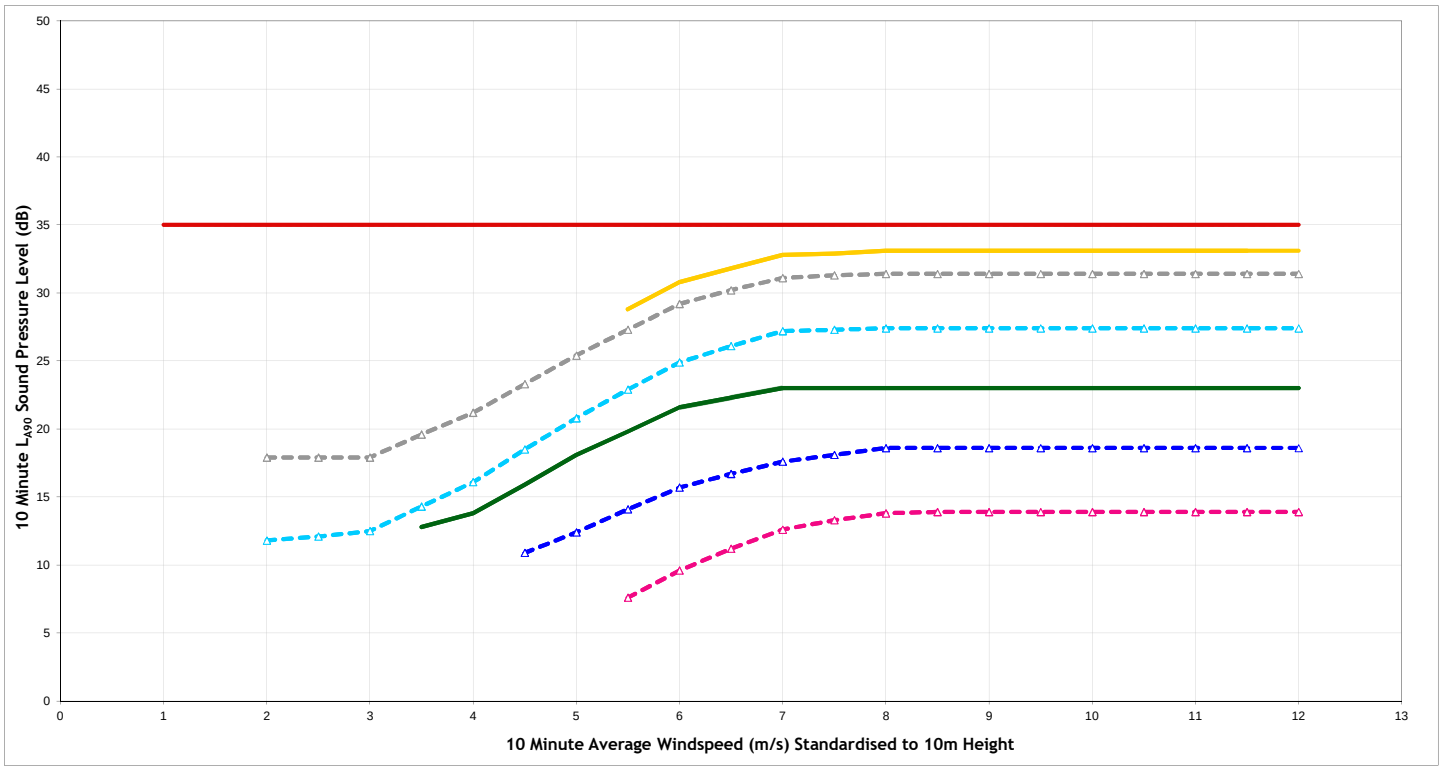


Legend:

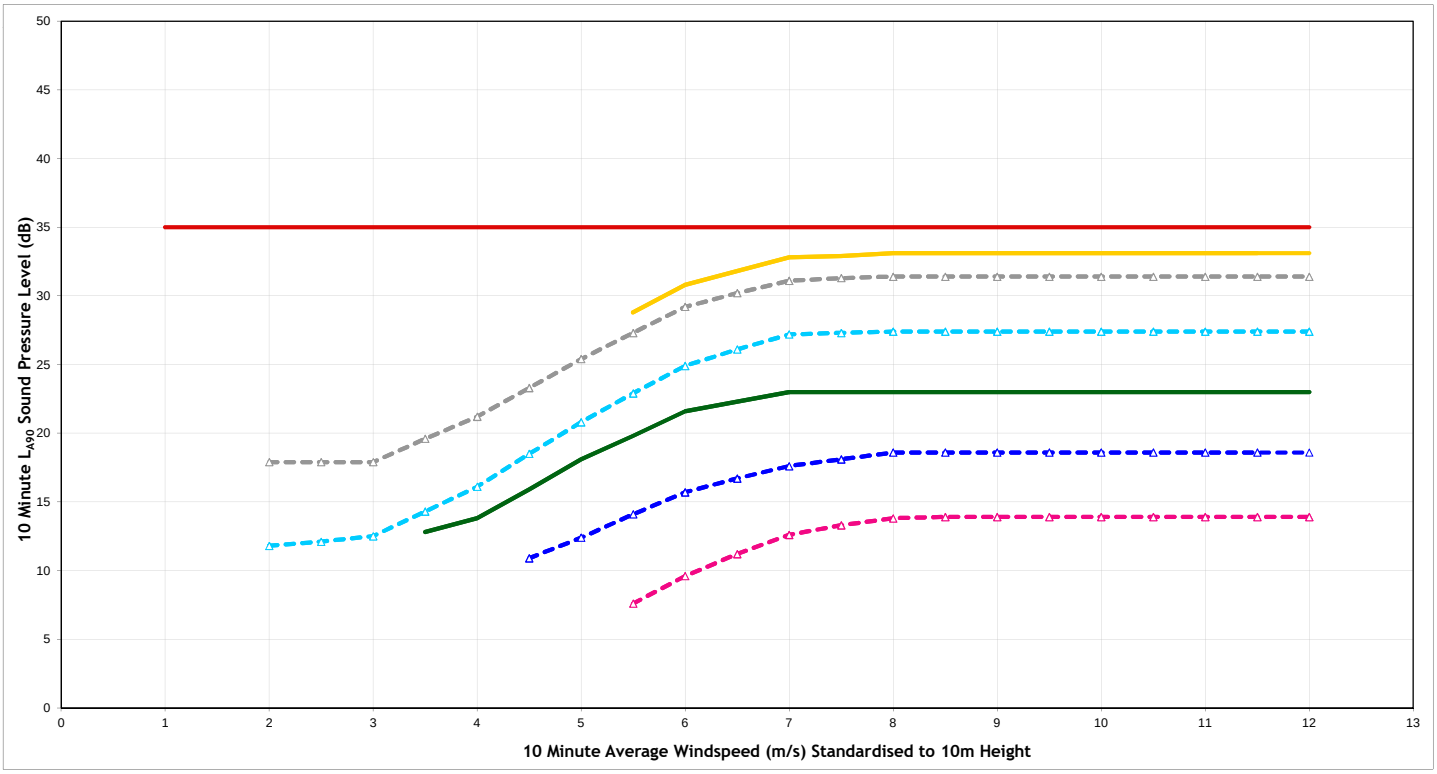
- Total ETSU-R-97 Noise Limit
- Cloiche Wind Farm (Likely Effects)
- Cumulative - Other Wind Farms (w/o Cloiche)
- Stronelairg (Cautious Predictions)
- Corriegarth (Cautious Predictions)
- Dell (Cautious Predictions)
- Glenshero (Cautious Predictions)

Project	Cloiche Wind Farm
Client	SSE Renewables Ltd
Title	Cautious Noise Predictions Crathie (NAL2)
Figure Number	Figure A1.3b
Drawn	AR
Checked	GC
Date	20/03/2020
Document Reference	13333-Models

Quiet Daytime - Garvabeg (NAL3)



Night Time - Garvabeg (NAL3)

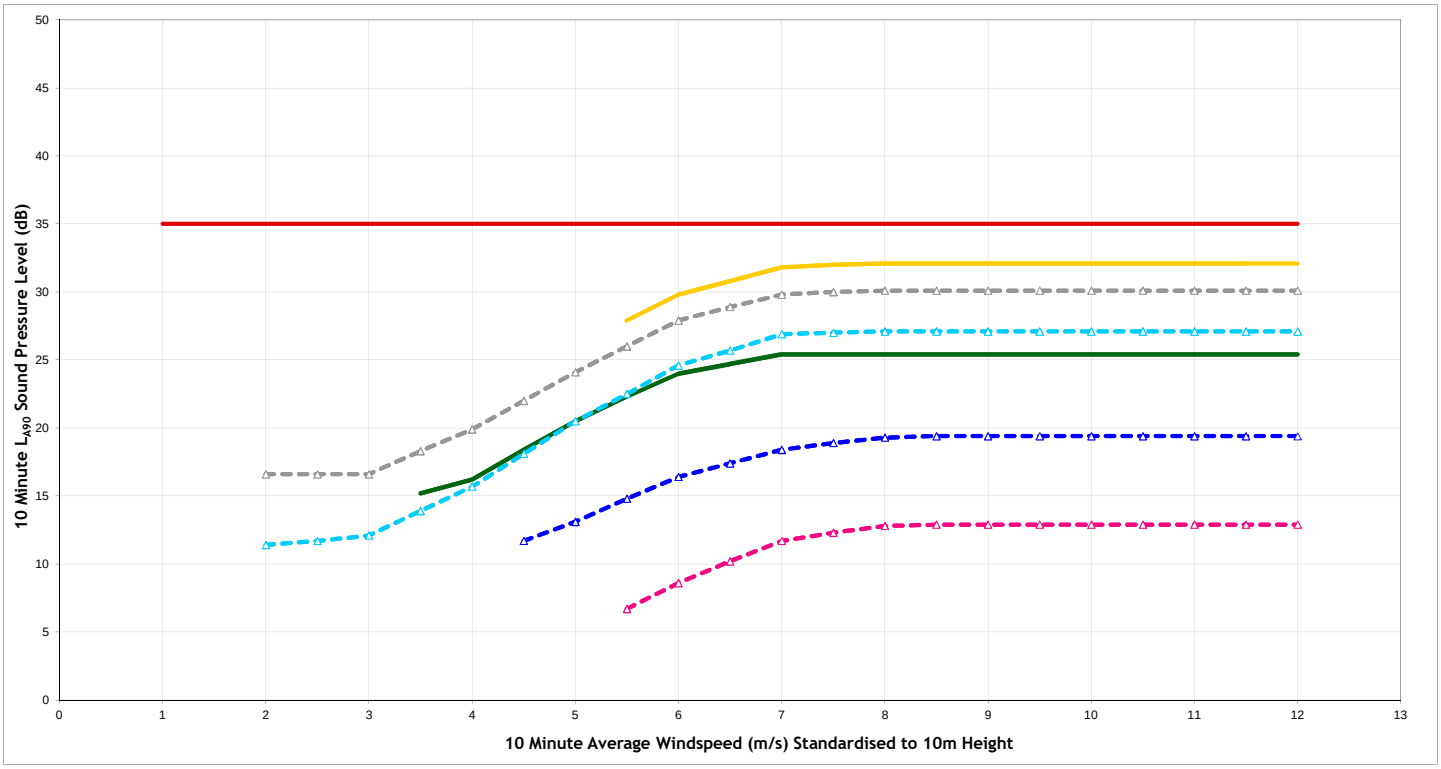


Legend:

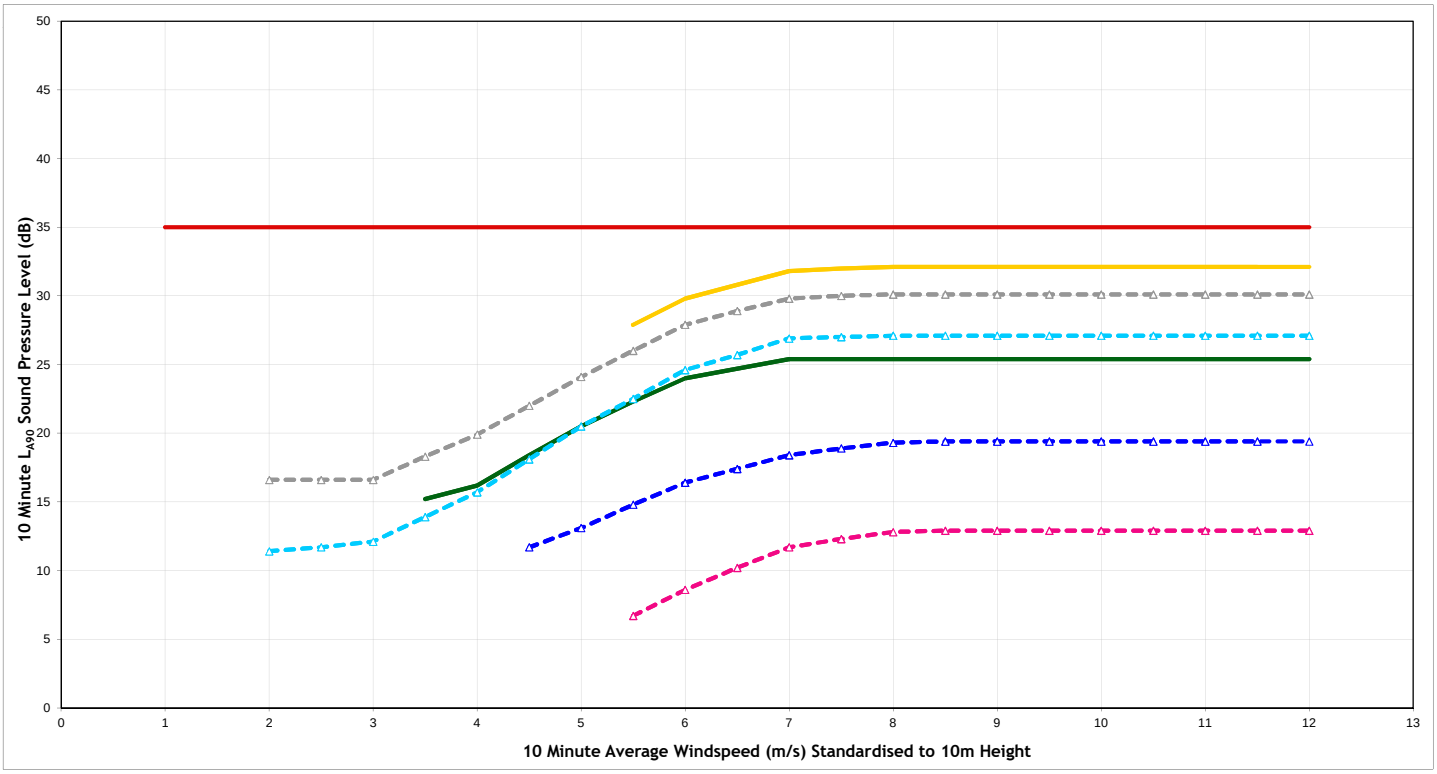
- Total ETSU-R-97 Noise Limit
- Cloiche Wind Farm (Likely Effects)
- Cumulative - Other Wind Farms (w/o Cloiche)
- Stronelairg (Cautious Predictions)
- Corriegarth (Cautious Predictions)
- Dell (Cautious Predictions)
- Glenshero (Cautious Predictions)

Project	Cloiche Wind Farm
Client	SSE Renewables Ltd
Title	Cautious Noise Predictions Garvabeg (NAL3)
Figure Number	Figure A1.3c
Drawn	AR
Checked	GC
Date	20/03/2020
Document Reference	13333-Models

Quiet Daytime - Melgarve (NAL4)



Night Time - Melgarve (NAL4)



Legend:

- Total ETSU-R-97 Noise Limit
- Cloiche Wind Farm (Likely Effects)
- Cumulative - Other Wind Farms (w/o Cloiche)
- Stronelairg (Cautious Predictions)
- Corriegarth (Cautious Predictions)
- Dell (Cautious Predictions)
- Glenshero (Cautious Predictions)

Project	Cloiche Wind Farm
Client	SSE Renewables Ltd
Title	Cautious Noise Predictions Melgarve (NAL4)
Figure Number	Figure A1.3d
Drawn	AR
Checked	GC
Date	20/03/2020
Document Reference	13333-Models

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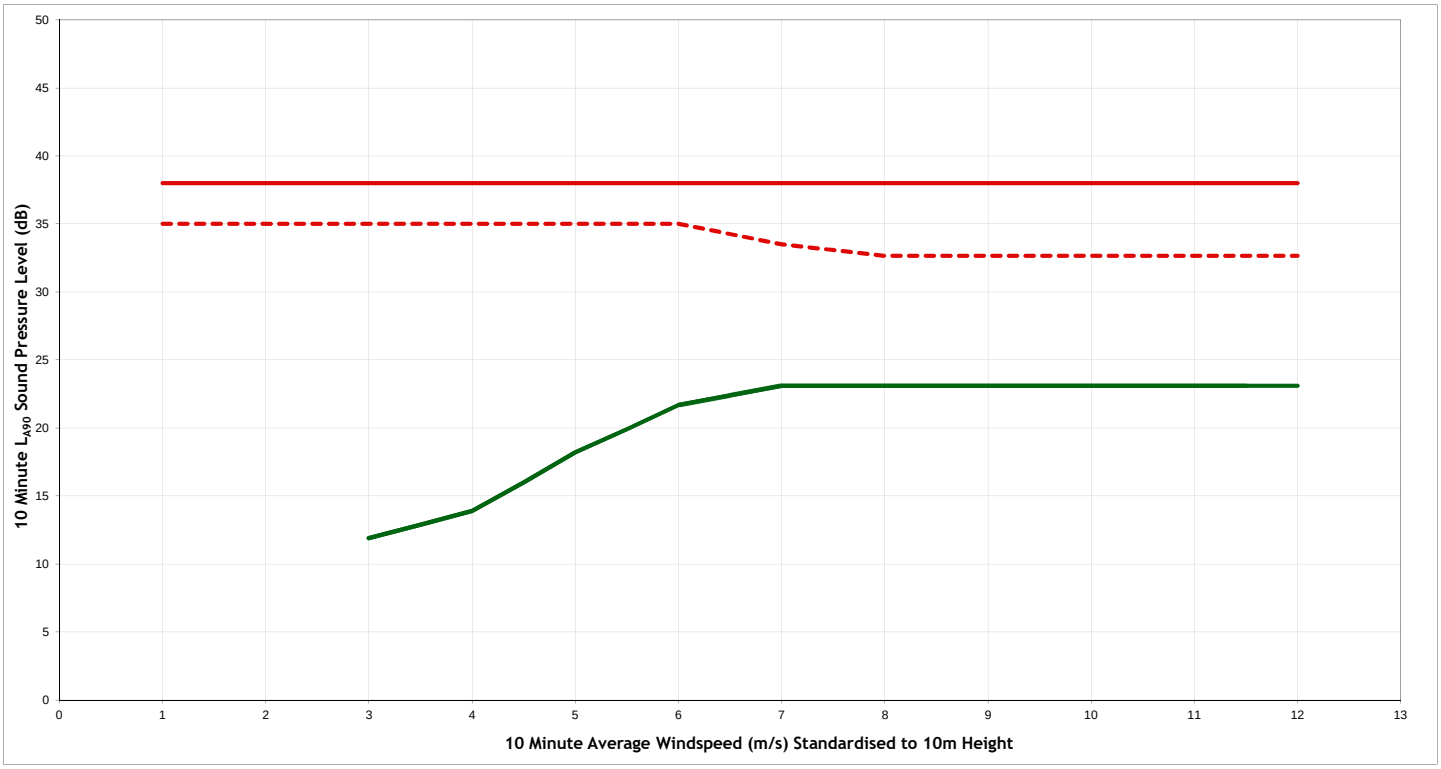
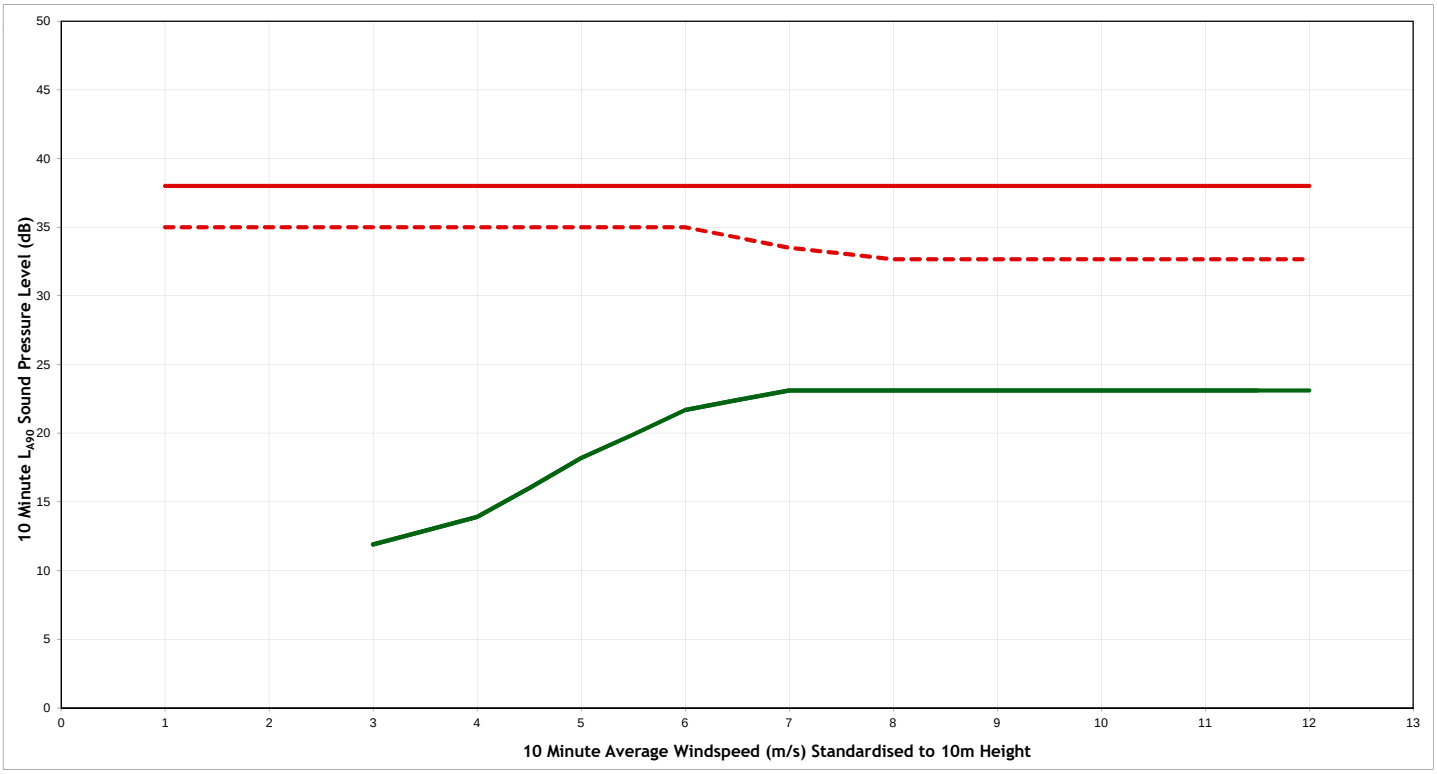
Quiet Daytime - Killin Lodge (NAL1)



Night Time - Killin Lodge (NAL1)

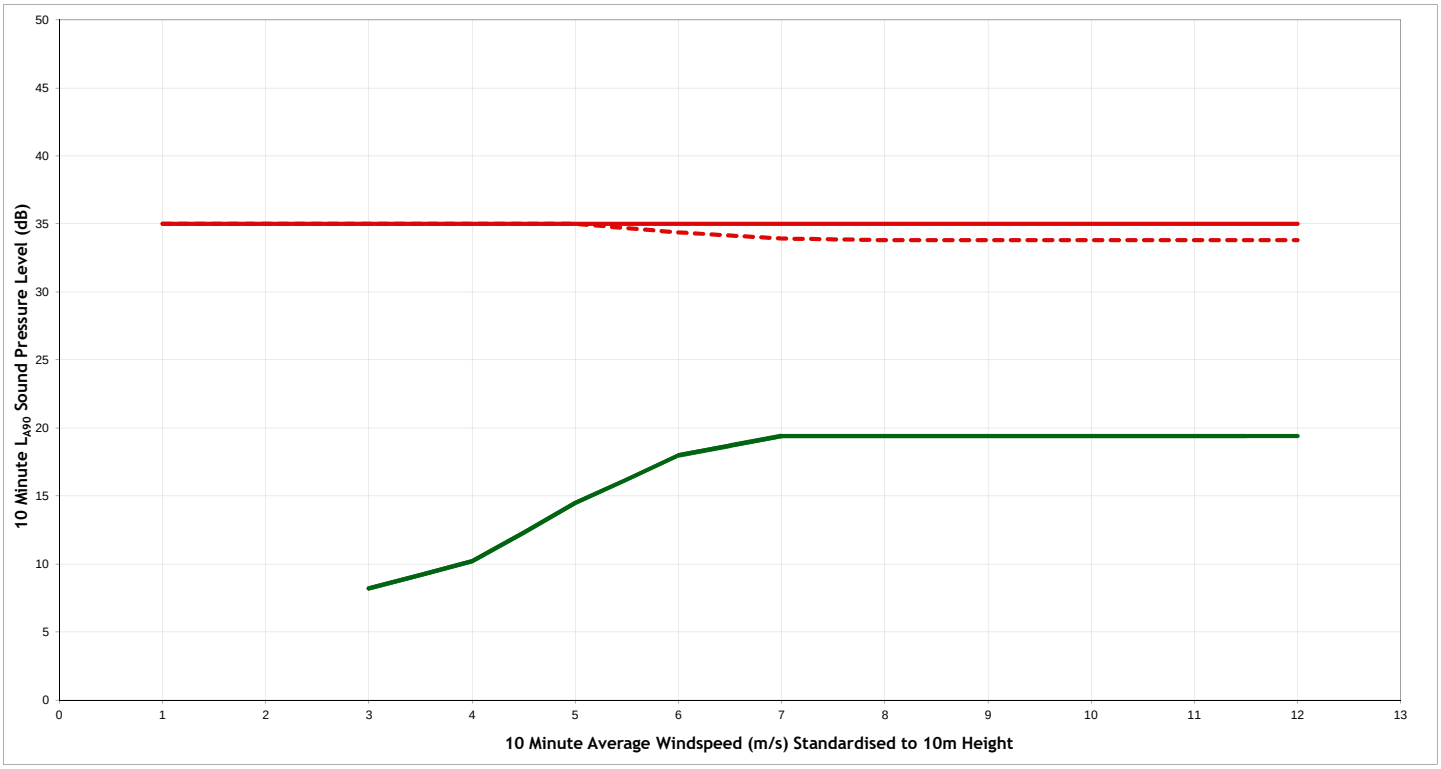


Legend:

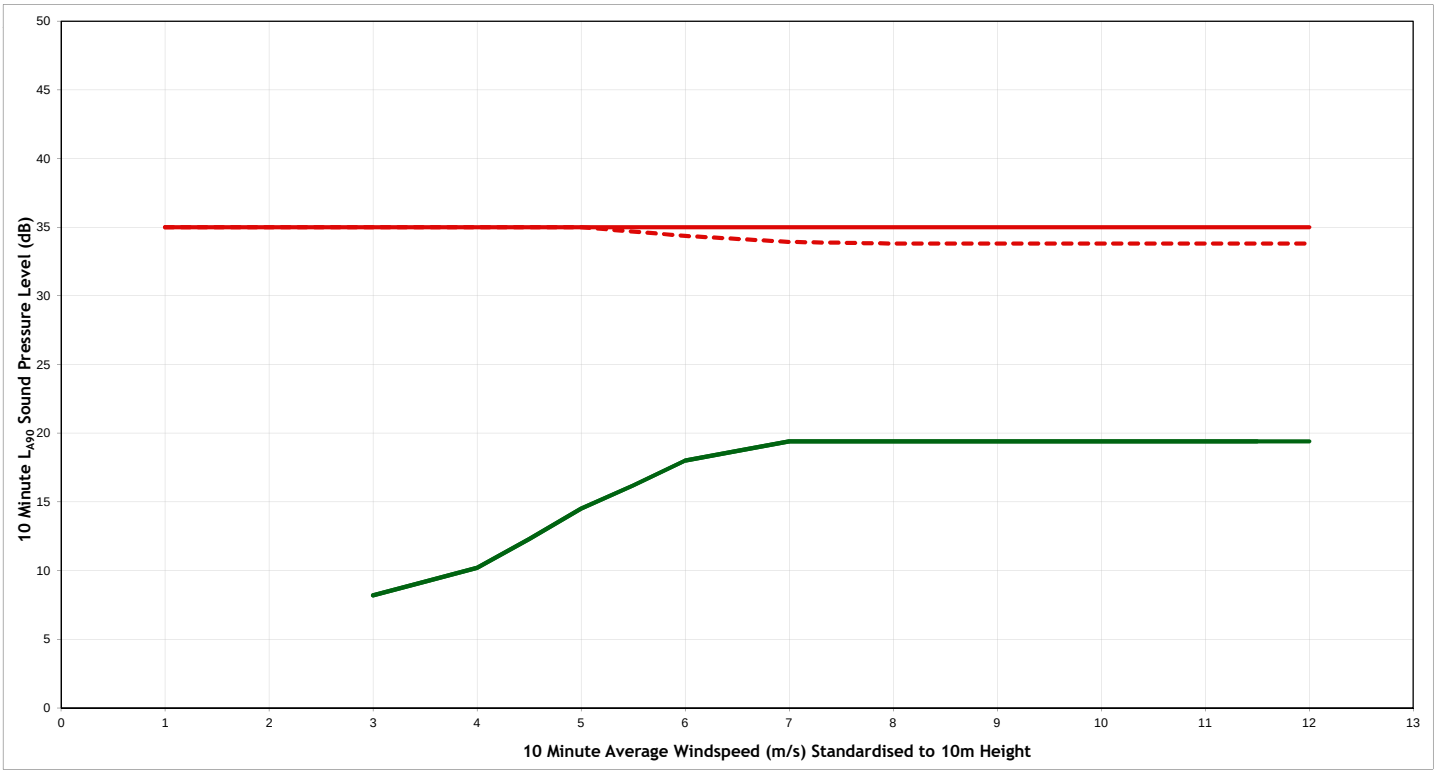
- Total ETSU-R-97 Noise Limit
- Site Specific Limits
- Cloiche Wind Farm (Likely Effects)

Project	Cloiche Wind Farm
Client	SSE Renewables Ltd
Title	Site Specific Limits Killin Lodge (NAL1)
Figure Number	Figure A1.4a
Drawn	AR
Checked	GC
Date	27/03/2020
Document Reference	13333-Models

Quiet Daytime - Crathie (NAL2)



Night Time - Crathie (NAL2)

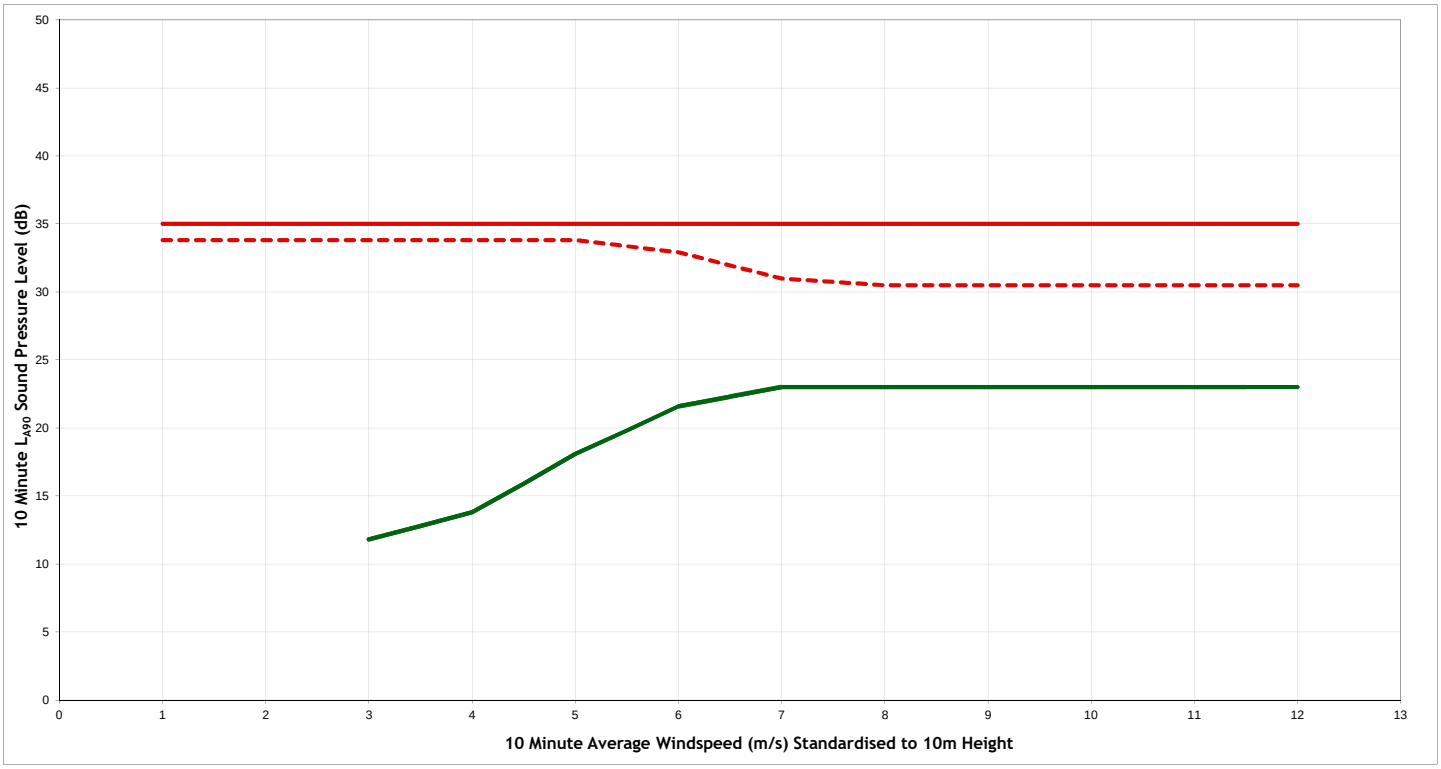


Legend:

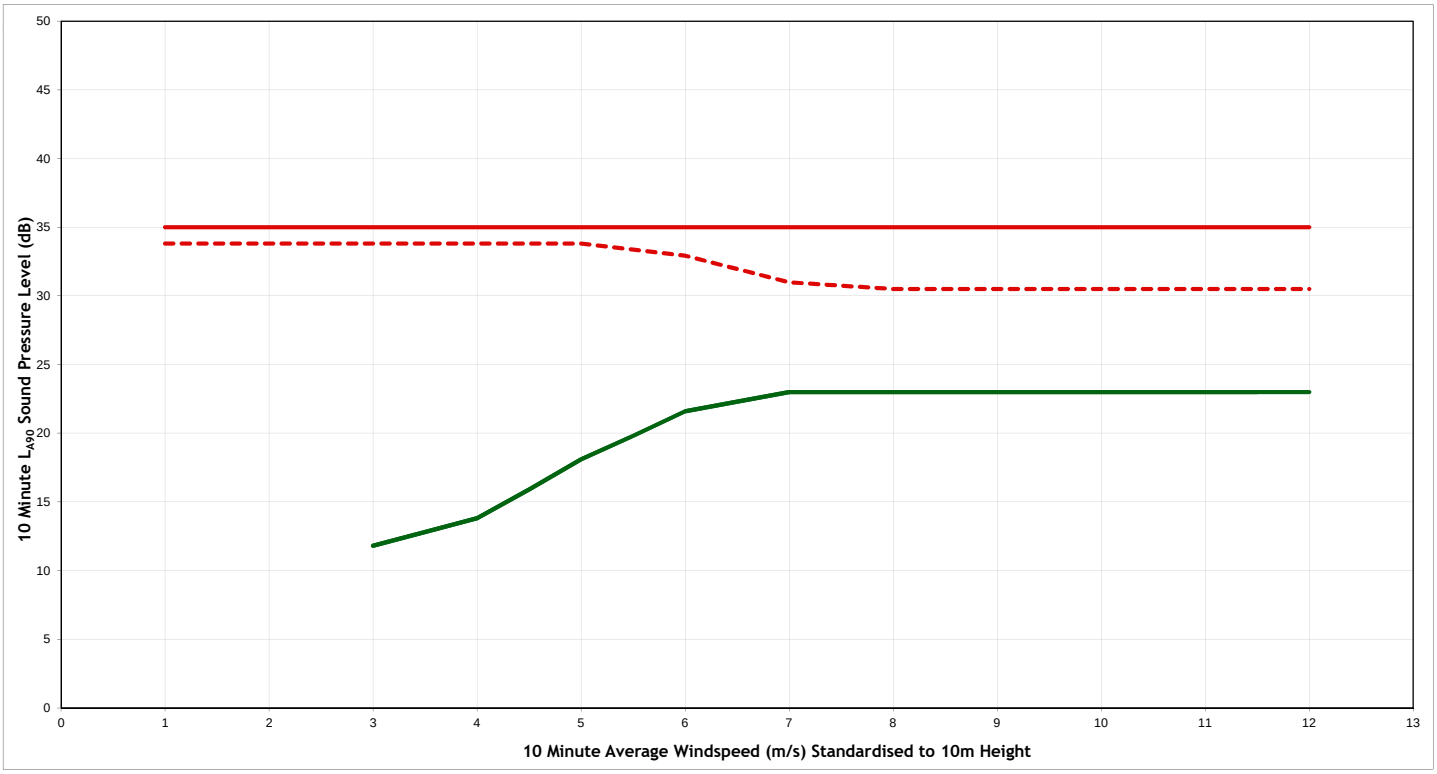
- Total ETSU-R-97 Noise Limit
- Site Specific Limits
- Cloiche Wind Farm (Likely Effects)

Project	Cloiche Wind Farm
Client	SSE Renewables Ltd
Title	Site Specific Limits Crathie (NAL2)
Figure Number	Figure A1.4b
Drawn	AR
Checked	GC
Date	27/03/2020
Document Reference	13333-Models

Quiet Daytime - Garvabeg (NAL3)



Night Time - Garvabeg (NAL3)

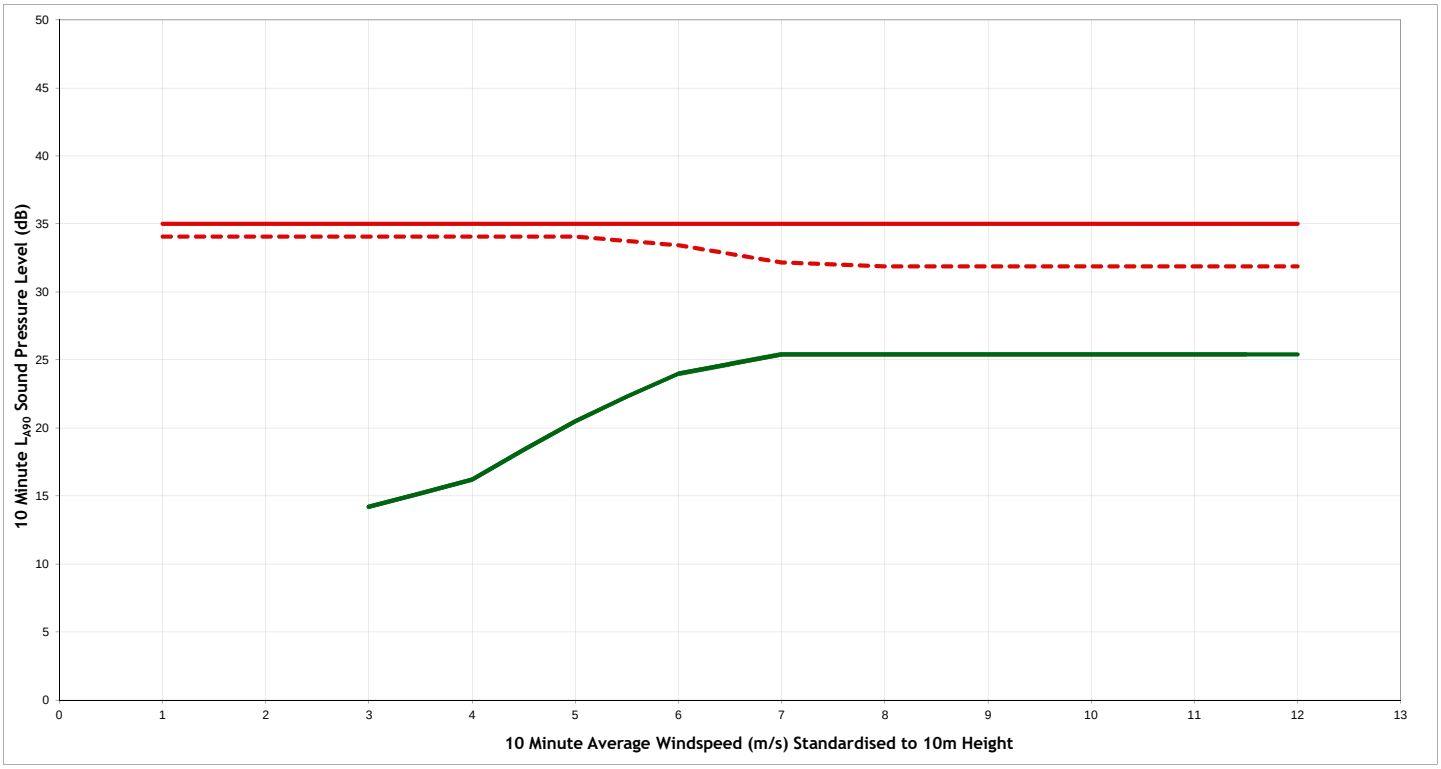


Legend:

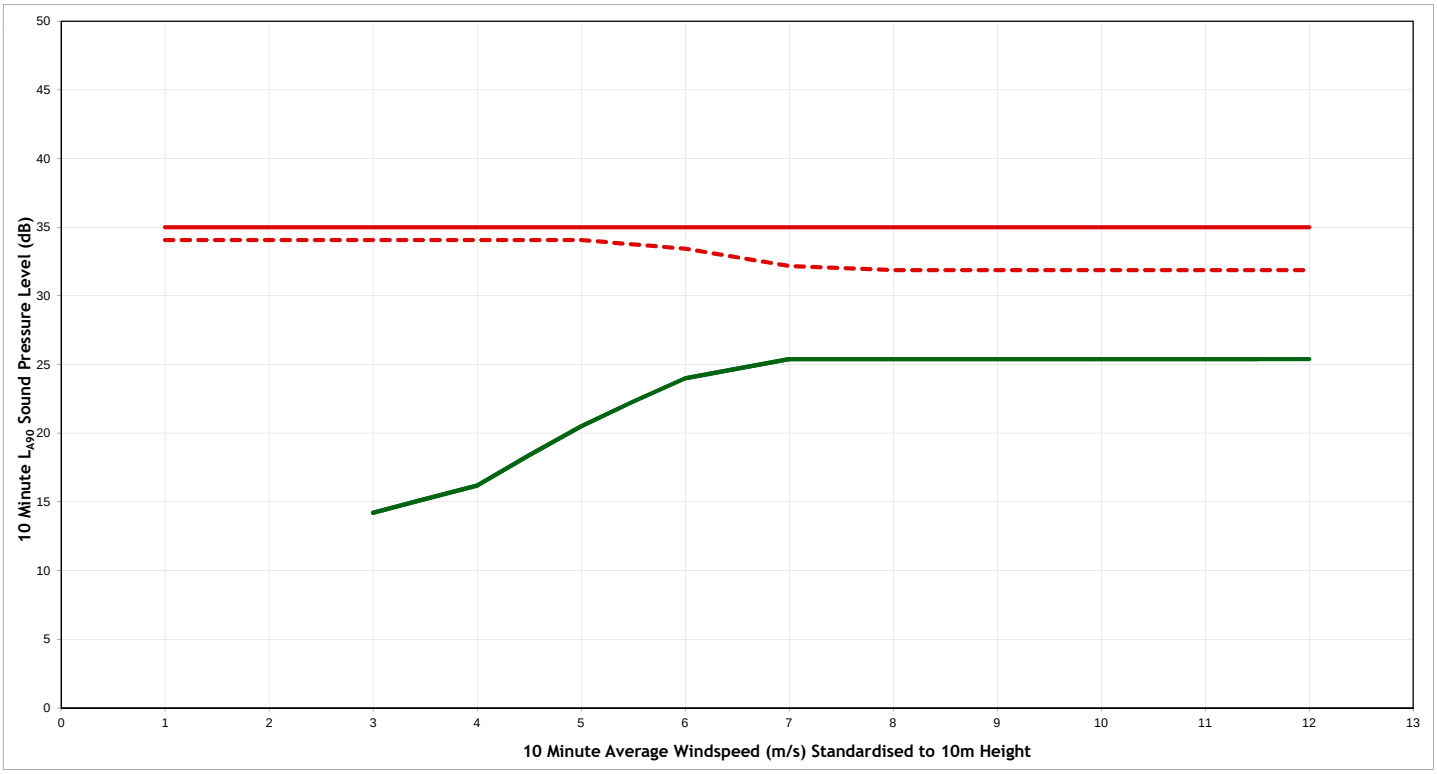
- Total ETSU-R-97 Noise Limit
- Site Specific Limits
- Cloiche Wind Farm (Likely Effects)

Project	Cloiche Wind Farm
Client	SSE Renewables Ltd
Title	Site Specific Limits Garvabeg (NAL3)
Figure Number	Figure A1.4c
Drawn	AR
Checked	GC
Date	27/03/2020
Document Reference	13333-Models

Quiet Daytime - Melgarve (NAL4)



Night Time - Melgarve (NAL4)



Legend:

- Total ETSU-R-97 Noise Limit
- Site Specific Limits
- Cloiche Wind Farm (Likely Effects)

Project	Cloiche Wind Farm
Client	SSE Renewables Ltd
Title	Site Specific Limits Melgarve (NAL4)
Figure Number	Figure A1.4d
Drawn	AR
Checked	GC
Date	27/03/2020
Document Reference	13333-Models

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