Chapter 10

Noise

SCOTTISHPOWER RENEWABLES

Table of contents

List of Figures

List of Technical Appendices

Chapter 10
Noise

10.1 Introduction

1. Hayes McKenzie Partnership Limited (HMPL) have undertaken an assessment of the potential noise levels resulting from the introduction of the proposed Clauchrie Windfarm, located in South Ayrshire, on behalf of ITPEnergised (ITPE).

2. The operational assessment has been carried out according to the recommendations of ETSU-R-97, The Assessment and Rating of Noise from Wind Farms, and the best practice guidance published by the Institute of Acoustics, A Good Practice Guide to the Application of ETSU-R-97 for the Assessment and Rating of Wind Turbine Noise (GPG) and its associated Supplementary Guidance documents. These documents are referred to within web based planning guidance provided by the Scottish Government.

3. Noise limits for properties neighbouring the proposed Development have been derived from data obtained during a survey of background noise levels in the area, and corresponding on-site wind speeds, in accordance with ETSU-R-97. Two monitoring locations were chosen as representative of dwellings closest to the proposed Development but with due regard to the potential impact from the existing Mark Hill windfarm development. Noise limits based on background noise monitoring undertaken as part of the planning application for Mark Hill Windfarm (which is operated by ScottishPower Renewables) have also been used to inform the assessment provided here.

4. Predictions of the noise levels associated with the operation of the proposed Development, based on the installation of Vestas V150 5.6 MW wind turbines, have been compared with the noise limits derived as discussed above.

5. The cumulative impact of the proposed Development operating in combination with Mark Hill Windfarm has also been provided and with due regard to the relative differences in the size and scale of the schemes.

6. A discussion of the potential impacts relating to the construction of the proposed Development, including from possible blasting within the proposed borrow pits, is provided in terms of relevant guidance; BS5228 Code of Practice for Noise and Vibration Control on Construction & Open Sites. However, a detailed assessment is not provided as the relative distances from turbine construction activities and neighbouring properties will mean that potential noise levels are well within typical limits in this regard.

10.2 Legislation, Policy and Guidelines

10.2.1 PAN1/2011, Planning and Noise

7. Planning Advise Note PAN1/2011 (Scottish Government 2011) identifies two sources of noise from wind turbines; mechanical noise and aerodynamic noise. It states that “good acoustical design and siting of turbines is essential to minimise the potential to generate noise”. It refers to the “web based planning advice” on renewables technologies for onshore wind turbines.

8. The accompanying Technical Advice Note to PAN1/2011, Assessment of Noise, lists BS 5228, Noise and Vibration Control on Construction and Open Sites (see Paragraphs 25 to 27) as being applicable for Environmental Impact Assessment (EIA) and planning purposes.

10.2.2 Web Based Planning Advice, Onshore Wind Turbines

9. The web based planning advice on onshore wind turbines (Scottish Government, 2014) states that the sources of noise are “the mechanical noise produced by the gearbox, generator and other parts of the drive train; and the aerodynamic noise produced by the passage of the blades through the air” and that “there has been significant reduction in the mechanical noise generated by wind turbines through improved turbine design”. It states that “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 windfarm 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”. It notes that “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”.

10. It introduces the Institute of Acoustics (IOA) A Good Practice Guide to the Application of ETSU-R-97 for the Assessment and Rating of Wind Turbine Noise (GPG), and states that “The Scottish Government accepts that the guide represents current industry good practice”.

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

11. ETSU-R-97, The Assessment and Rating of Noise from Wind Farms (DTI, 1996), presents the recommendations of the Working Group on Noise from Wind Turbines, set up in 1993 by the Department of Trade and Industry (DTI) as a result of difficulties experienced in applying the noise guidelines existing at the time to windfarm noise assessments. The group comprised independent experts on wind turbine noise, windfarm developers, DTI personnel and local authority Environmental Health Officers. In September 1996 the Working Group published its findings by way of report ETSU-R-97. This document describes a framework for the measurement of windfarm noise and contains suggested noise limits, which were derived with reference to existing standards and guidance relating to noise emission from various sources.

12. ETSU-R-97 recommends that, although noise limits should be set relative to existing background and should reflect the variation of both turbine and background noise with wind speed. This can imply very low noise limits in particularly quiet areas, in which case “it is not necessary to use a margin above background in such low-noise environments. This would be unduly restrictive on developments which are recognised as having wider global benefits. Such low limits are, in any event, not necessary in order to offer a reasonable degree of protection to the wind farm neighbour”.

13. For day-time periods, the noise limit is 35-40 decibel (dB) L_{A90} or 5 dB above the 'quiet daytime hours' prevailing background noise, whichever is the greater. The actual value within the 35-40 dB L_{A90} range depends on the number of dwellings in the vicinity; the effect of the limit on the number of kWh generated; and the duration of the level of exposure.

14. For night-time periods the noise limit is 43 dB L_{A90} or 5 dB above the prevailing night-time hours background noise, whichever is the greater. The 43 dB L_{A90} lower limit is based on a sleep disturbance criteria of 35 dB(A) with an allowance of 10 dB for attenuation through an open window and 2 dB subtracted to account for the use of L_{A90} rather the L_{Aeq} (see Paragraph 18).

15. Where the occupier of a property has some financial involvement with the proposal, the day and night-time lower noise limits are increased to 45 dB L_{A90} and consideration can be given to increasing the permissible margin above background. These limits would be applicable up to a wind speed of 12 m/s measured at 10 m height on the site. However, this is not relevant to the proposed Development.

16. Quiet day-time periods are defined as evenings from 18:00-23:00 plus Saturday afternoons from 13:00-18:00 and Sundays from 07:00-18:00. Night-time is defined as 23:00-07:00. The prevailing background noise level is set by calculation of a best fit curve through values of background noise plotted against wind speed as measured during the appropriate time period with background noise measured in terms of $L_{A90,t}$. The $L_{A90,t}$ is the noise level which is exceeded for 90% of the measurement period ‘t’. It is recommended that at least 1 weeks’ worth of measurements is required.

17. Where predicted noise levels are low at the nearest residential properties, a simplified noise limit can be applied, such that noise is restricted to a level of 35 dB L_{A90} for wind speeds up to 10 m/s at 10 m height. This removes the need for extensive background noise measurements for smaller or more remote schemes.

18. It is stated that the $L_{A90,10min}$ noise descriptor should be adopted for both background and windfarm noise levels and that, for the windfarm noise, this is likely to be between 1.5 and 2.5 dB less than the L_{Aeq} measured over the same period. The $L_{Aeq,t}$ is the equivalent continuous 'A' weighted sound pressure level occurring over the measurement period t. It is often used as a description of the average noise level. Use of the L_{A90} descriptor, the level exceeded for 90% of the measurement period, for windfarm noise allows reliable measurements to be made without corruption from relatively loud, transitory noise events from other sources.

19. ETSU-R-97 also specifies that a penalty should be added to the predicted noise levels, where any audible tone is present. The level of this penalty, as shown on page 10 of the executive summary, is described and varies according to the level by which any tonal components exceed audibility.

20. With regard to multiple windfarms in a given area, ETSU-R-97 specifies that the absolute noise limits and margins above background should relate to the cumulative effect of all wind turbines in the area contributing to the overall turbine noise received at the properties in question. Existing windfarms should therefore not be considered as part of prevailing background noise level and noise limits should be compared with cumulative predictions for proposed wind turbines operating in combination with existing sites.

10.2.4 A Good Practice Guide to the Application of ETSU-R-97

21. In May 2013, the Institute of Acoustics (IoA) published A Good Practice Guide to the Application of ETSU-R-97 for the Assessment and Rating of Wind Turbine Noise (IoA, 2013). This was subsequently endorsed by the Scottish Government. The publication of the Good Practice Guide (GPG) followed a review of current practice carried out for the Department of Energy and Climate Change (DECC, 2011) and an IoA discussion document which preceded the GPG (IoA, 2012).

22. The GPG includes sections on Context; Background Data Collection; Data Analysis and Noise Limit Derivation; Noise Predictions; Cumulative Issues; Reporting; and Other Matters including Planning Conditions; Amplitude Modulation; Post Completion Measurements; and Supplementary Guidance Notes. The Context section states that the guide "presents current good practice in the application of the ETSU-R-97 assessment methodology for all wind turbine development 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". It adds that "the noise limits in ETSU-R-97 have not been examined as these are a matter for Government".

23. As well as expanding on and, in some areas, clarifying issues which are already referred to in ETSU-R-97, additional guidance is provided on noise prediction and a preferred methodology for dealing with wind shear.

10.2.5 BS 8233 Guidance on Sound Insulation and Noise Reduction for Buildings

24. British Standard (BS) 8233 (BSI, 2014) advises the use of ETSU-R-97 when assessing windfarm noise impact and states that reliable estimates of windfarm noise levels can be made by implementing the procedures set forth in the IOA GPG. It draws particular attention to the issues of amplitude modulation (AM); however, it goes on to state that such adverse effects cannot be predicted at the planning stage.

10.2.6 BS 5228 Code of Practice for Noise and Vibration Control on Construction and Open Sites

25. BS 5228:2009 + A1:2014 (BSI, 2009 + 2014) provides example criteria for the assessment of the significance of construction noise effects and a method for the prediction of noise levels from construction activities. Two example methods are provided for assessing significance.

26. The first is based on the use of criteria defined in Department of the Environment Advisory Leaflet (AL) 72, Noise Control On Building Sites (DoE, 1976), which sets a fixed limit of 70 dB(A) in rural suburban and urban areas away from main roads and traffic. Noise levels are generally taken as façade L_{Aeq} values with free-field levels taken to be 3 dB lower giving an equivalent noise criterion of 67 dB L_{Aeq}.

27. The second is based on noise change but applies minimum criteria of 45, 55 and 65 dB L_{Aeq} for night-time (23:00-07:00), evening and weekends (19:00-23:00 weekdays, 13:00-23:00 Saturdays and 07:00-23:00 Sundays), and daytime (07:00-19:00) including Saturdays (07:00-13:00) respectively. These limits are applicable when existing noise levels are low, which they would be at the proposed Development Site, and have a duration of one month or more. It should be noted that the time period to which each limit applies also defines the time averaging period for the calculated L_{Aeq}.

10.2.7 Blade Swish (Amplitude Modulation of Aerodynamic Noise)

28. The variation in noise level associated with turbine operation, at the rate at which turbine blades pass any fixed point of their rotation (the blade passing frequency), is often referred to as blade swish and amplitude or aerodynamic modulation (AM) and is an inherent feature of wind turbine noise. This affect is identified within ETSU-R-97, where it is envisaged that '… modulation of blade noise may result in variation of the overall A-Weighted noise level by as much as 3 dB(A) (peak to trough) when measured close to a wind turbine... ' and that at distances further from the turbine where there are '… more than two hard, reflective surfaces, then the increase in modulation depth may be as much as 6 dB(A) (peak to trough)'.

29. It has been noted that complaints to planning authorities regarding windfarm noise in the UK, where they have occurred, have often been specifically concerned with amplitude modulation. This is also apparent from ETSU-R-97, where it is noted that 'it is the regular variation of the noise with time that, in some circumstances, enables the listener to distinguish the noise of the turbines from the surrounding noise'. The modulation of noise may affect perceived annoyance for sounds with the same overall sound pressure level.

30. RenewableUK (RUK), the main renewable energy trade association in the UK, completed research into the causes and subjective effects of AM (RUK, 2013) following various reports of increased levels of AM being experienced at dwellings neighbouring some wind turbine sites. This has concluded that the predominant cause is likely to be from individual blades going in and out of stall as they pass through regions of higher wind speed at the top of their rotation under high wind shear conditions. Subjective tests carried out by Salford University, using loudness matching techniques, have demonstrated the extent to which higher levels of modulation depth result in increased perceived loudness.

31. This resulted in the inclusion of a mechanism to assess and regulate AM effects in the standard form of a potential planning condition (RUK, 2013), which could be applied to windfarm developments in the same way as that included in the IoA GPG. The IoA reviewed this mechanism and released a discussion document (IoA, 2015) which reviews several different methods for rating amplitude modulation in wind turbine noise and subsequently released a recommended method (IOA, 2016) by which to characterise the peak to trough level in any given 10 minute period.

32. Although this document provides a definitive approach for the quantification of amplitude modulation, it does not provide any comment on what could be defined as an unacceptable level of AM nor any kind of penalty scheme, such as for tonal content, by which the overall turbine noise level should be corrected to account for its presence. This has subsequently been covered by a DECC-commissioned project looking at human response to the amplitude modulated component of wind turbine noise; results were presented, prior to the publication of the final report, at the IoA Acoustics 2016 conference (Perkins et al., 2016). The approach recommended by Parsons Brinkerhoff remains a subject of debate and has not been adopted/agreed by the Scottish Government.

33. The combination of these two documents provides both a method of quantification of the level of amplitude modulation over a given 10 minute period and the appropriate penalty to apply where necessary. This is in addition to any penalty for tonal noise.

34. It should be noted that most windfarms operate without significant AM, and that it is not possible to predict the likely occurrence of AM, but, like tonal noise, AM can be covered by a suitably worded planning condition. One proposed wording for such a condition can be seen in an article jointly authored by a number of consultants working in the area in the November/December 2017 issue of the Institute of Acoustics' Acoustics Bulletin magazine (McKenzie et al., 2017). Currently, AM is typically addressed in response to any complaints via a measurement scheme that refers to emerging best practice in this regard.

35. There are no standard or agreed methods by which to predict, with any certainty, the likelihood of amplitude modulation occurring at a level requiring a penalty at a particular development, only some indicators such as relatively high wind shear conditions under certain circumstances or particular turbine designs and/or dimensions for example.

10.2.8 Wind Shear

36. Wind shear, or more specifically vertical wind shear, is the rate at which wind speed increases with height above ground level. This has particular significance to wind turbine noise assessment where background noise measurements are referenced to measurements of wind speed at 10 metres height, which is suggested as appropriate by ETSU-R-97, but which is not representative of wind at hub-height, which is what affects the noise generated by the turbines.

37. The preferred method of accounting for wind shear in noise assessments is by referencing background noise measurements to hub height wind speed. Hub height wind speed may be determined directly by using a tall mast or remote sensing technology (i.e. LiDAR or SoDAR) or indirectly from measurements at a number of heights below hub height in order to calculate the hub height wind speed during the background noise survey period, as described in the GPG referred to in Paragraphs 21 to 23. The hub height wind speeds are then converted to 'standardised 10 m wind speeds', assuming standardised conditions as used by turbine manufacturers when specifying turbine sound power levels.

10.2.9 Tonal Noise

38. ETSU-R-97 notes that, at the time the report was written, where complaints had been made over noise from existing windfarms, the tonal character of the noise from machinery in the nacelle had been the feature that had caused greatest annoyance. The recommendation was, therefore, that any assessment carried out should include a correction to the predicted noise levels according to the level of any tonal components in the noise. A specific tonal assessment methodology is described in the report which is based on the well-established Joint Nordic Method for the Evaluation of Tones in Broadband Noise (DMoE, 1984) which has now been superseded by a revised version (Pederson et al., 1999) although this revision makes no substantive difference to the ETSU-R-97 methodology. A scale of corrections for tonal noise is included where the penalty is increased as the tone level increases above audibility to a maximum of 5 dB. The necessity of minimising tonal components in the noise output from the turbines is well understood by the turbine manufacturers and a guarantee should always be sought that any tonal noise will be below that requiring a penalty under the ETSU-R-97 scheme.

10.2.10 Infra-sound

39. Infra-sound is noise occurring at frequencies below that at which sound is normally audible, i.e. at less than about 20 Hz, due to the significantly reduced sensitivity of the ear at such frequencies. In this frequency range, for sound to be perceptible, it has to be of very high amplitude and it is generally considered that when such sounds are perceptible then they can cause considerable annoyance.

40. Wind turbines have been cited by some as producers of infra-sound. This has, however, been due to the high levels of such noise, as well as audible low frequency thumping noise, occurring on older 'downwind' turbines of which many were installed in the USA prior to the large scale take up of wind power production in the UK. Downwind turbines are configured with the blades downwind of the tower such that the blades pass through the wake left in the wind stream by the tower resulting in a regular audible thump, with infra-sonic components, each time a blade passes the tower. Virtually all modern larger turbines are of the upwind design; that is with the blades upwind of the tower, such that this effect is eliminated.

41. A study into low frequency noise from windfarms (ETSU/DTI, 2006) concluded that "infrasound noise emissions from wind turbines are significantly below the recognised threshold of perception for acoustic energy within this frequency range. Even assuming that the most sensitive members of the population have a hearing threshold which is 12 dB lower than the median hearing threshold, measured infrasound levels are well below this criterion". It goes on to state that, based on information from the World Health Organisation, "there is no reliable evidence that infrasound below the hearing threshold produce physiological or psychological effects" and that "it may therefore be concluded that infrasound associated with modern wind turbines is not a source which may be injurious to the health of a wind farm neighbour".

42. A considerable amount of research has been conducted in regards to the levels of infrasound that wind turbines emit (ETSU/DTI, 1997) (Styles et al., 2005) (Turnball et al., 2012). All reliable evidence suggests that at typical residential distances (e.g. at 500 m or more), the levels of infrasound from a windfarm are significantly below accepted thresholds of perception. Even when measured in close proximity to a wind turbine, the measured levels of infrasound are still below accepted thresholds of perception. This suggests that infrasound is not an issue for neighbours in the vicinity of wind turbines.

10.2.11 Low Frequency Noise

43. Noise from modern wind turbines is essentially broad band in nature in that it contains similar amounts of noise energy in all frequency bands from low to high frequency. As distance from a windfarm site increases, the noise level decreases as a result of the spreading out of the sound energy and also due to air absorption which increases with increasing sound frequency. This means that, although the energy across the whole frequency range is reduced, higher frequencies are reduced more than lower frequencies with the effect that as distance from the site increases the ratio of low to high frequencies also increases. This effect is not specific to wind turbines and may be observed with road traffic noise or natural sources, such as the sea, where higher frequency components are diminished relative to lower frequency components at long distances. At such distances, where residential properties are typically located in relation to windfarm developments, the overall noise level is so low, such that any bias in the frequency spectrum is insignificant.

10.2.12 Vibration

44. The ETSU study referenced at Paragraph 42 (ETSU/DTI, 1997) found that vibration from wind turbines, as measured at 100 m from the nearest machine, was well below the criteria recommended for human exposure in critical working areas such as precision laboratories (BSI, 2008). At greater distances from turbines vibration levels are even lower. This has been confirmed by the Keele University study (Styles et al., 2005), which showed vibration levels of around 10^{-8} $m.s^{-2}$ at a distance of 2.4 km from the Dun Law Windfarm site under high wind conditions, orders of magnitude lower than the criteria referred to above which specify levels in the region of 0.005 $m.s^{-2}$.

10.2.13 Audibility

45. The potential audibility of noise from proposed wind turbines depends to a large extent on the amount by which the predicted turbine noise level exceeds the noise from other sources (the baseline or background noise level) and the presence of any acoustical 'features' which distinguish it. Such other noise may be steady and unchanging, but is more likely to be continuously variable depending on the time of day and other factors including, particularly in rural areas, wind speed.

46. The results of baseline noise measurements carried out for the proposed Development are expressed in terms of the level exceeded for 90 % of each 10-minute interval which are shown plotted against wind speed on the assessment charts. The potential audibility of wind turbine noise from the proposed Development, for the quiet day-time and night-time hours and for worst case downwind propagation from the Site towards the various measurement locations, can be determined by comparing the predicted turbine noise with the measured background noise level for each 10 minute measurement period. Where predicted noise levels are around the same level as the background noise this suggests that the noise source may be just audible, with perceived audibility increasing with margin above background and also when taking into account any significant acoustic features such as tonality or amplitude modulation. Similarly, where predicted noise levels are lower than the existing background noise levels, audibility decreases with margin below other background noise.

10.2.14 Sleep Disturbance

47. The potential for sleep disturbance depends on the average and maximum levels of noise in sleeping areas during the night time period. The night-time noise limits in ETSU-R-97 aim to protect against sleep disturbance by limiting the amount of turbine noise external to dwellings assuming a worst case of inhabitants sleeping with the windows open for ventilation. The internal noise levels in such circumstances can be calculated by assuming a 10-15 dB reduction in noise from outside to inside. The World Health Organisation (WHO) published recommendations in 1999 to the effect that average night-time noise levels in sleeping areas should not exceed 30 dB L_{Aeq} (WHO, 1999). Although this figure relates to overall noise level in sleeping areas, the potential for sleep disturbance specifically from turbine noise, for worst case downwind propagation with windows open, can

be evaluated for each dwelling by subtracting 10-15 dB from the predicted turbine noise level and comparing with this criterion, after also adding 2 dB to convert the predicted turbine noise level to an L_{Aeq} value.

48. It should be noted that guidance from the WHO on night noise levels, in the form of the Night Noise Guidelines for Europe (WHO, 2009), recommends that the population is not exposed to average external night-time noise levels, over a whole year, of more than 40 dB L_{Aeq}. This average yearly noise level will depend on the variation in wind speed, wind direction and noise from other sources over each year period.

49. Further to the above, the latest guidance from the WHO (WHO, 2018) conditionally recommends that turbine noise should not exceed an L_{den} of 45 dB. L_{den} is the average noise level over one year, where noise during evening and night-time periods is penalised with a 5 and 10 dB correction respectively. In the case of wind turbine noise, which is continually varying from day to day, depending on the wind speed and direction, it will be almost impossible to establish compliance with this limit through measurement alone.

50. It should also be noted that potential difficulty in getting to sleep, either at the start of the night or once awoken by other sources, may be more related to audibility indoors under specific circumstances (see Paragraph 47 above) than by average noise level.

10.3 Consultation

51. South Ayrshire Council (SAC) planning department were consulted on the proposed approach to background noise monitoring, the general methodology for the assessment, the level of construction noise assessment to be provided, cumulative operational assessment, and the operational noise limits that are to be put forward in terms of the proposed and cumulative impacts associated with the Development. It was proposed that Little Shalloch, which is derelict, should not be included within the assessment and evidence was supplied to support this. However, there was no direct response from the council in this respect. Furthermore, the dwelling known as Ballmalloch is also known to be derelict.

52. The approach was reviewed by Accon UK Ltd (Accon), a noise consultancy working on behalf of SAC, and no objections to the proposals were highlighted. Further details were requested from SAC as to how the relative height differences between the existing Mark Hill Windfarm and the proposed Development, which affects the calculated standardised 10 m height wind speed for levels of wind shear other than for reference conditions, would be considered. It was agreed in further consultation with Accon that a suitable method for dealing with this issue would be identified as the proposed Clauchrie site layout evolved as this left some flexibility in how the issue may be dealt with and reported in the EIA Report. There were no concerns raised with this approach and the method used is described within the Mitigation section. Furthermore, the derived prevailing background noise levels within the ES which supported the Mark Hill planning application are expected to be related to standardised rather than measured 10 m height wind speeds. This aspect was also referenced within the response to the proposed approach although the specific methodology by which this calculation was made is unclear.

10.4 Assessment Methodology and Significance Criteria

10.4.1 Assessment Methodology

53. The assessment of the noise levels associated with the proposed Development have been undertaken in accordance with ETSU-R-97 and the GPG for both the scheme operating in isolation and cumulatively with the existing Mark Hill Windfarm (i.e. via the comparison of derived noise limits with predicted operational noise levels at neighbouring dwellings). There are no other windfarms in the vicinity of the proposed Development that would result in combined operational noise effects of any relevance. **Table 10.4.1** shows the co-ordinates of the receptors considered within this chapter.

Table 10.4.1 Assessment Locations

Location	Easting	Northing
Shalloch Well	227038	586179
White Clauchrie	229533	586267
Ferter	230705	587496
Ballmalloch (Derelict)	226841	584295
Mark	225008	587882
Little Shalloch (Derelict)	226223	588122

54. Construction noise (including forestry felling) has been discussed in general terms and with due regard to typical guidance on this matter.

10.4.1 Noise Prediction Methodology

55. Noise predictions have been carried out using International Standard ISO 9613, Acoustics - Attenuation of Sound During Propagation Outdoors. The propagation model described in Part 2 of this standard (ISO, 1996) provides for the prediction of sound pressure levels based on either short-term downwind (i.e. worst case) conditions or long term overall averages. In this case only the former has been considered except where otherwise indicated.

56. The ISO propagation model calculates the predicted sound pressure level by taking the source sound power level for each turbine in separate octave bands and subtracting a number of attenuation factors according to the following:

$$\text{Predicted Octave Band Noise Level} = L_W + D - A_{geo} - A_{atm} - A_{gr} - A_{bar} - A_{misc}$$

57. These factors are discussed in detail below. The predicted octave band levels are summed together to give the overall ‘A’ weighted predicted sound level.

58. The turbine co-ordinates used for the assessment have been provided by ITPE.

10.4.1.1 L_W - Source Sound Power Level

59. The sound power level of a noise source is normally expressed in dB re:1pW. Noise predictions for the proposed Clauchrie turbines are based on the sound power levels for the Vestas V150 5.6 MW turbine with a hub-height of 125 m and with serrated trailing edges (STEs) installed on the blades, as provided by the turbine manufacturer.

60. The sound power levels for the turbine model are taken from specification documents provided by the manufacturer with 2 dB added to account for uncertainty. As such, the assumed sound power levels are likely to be comparable to a declared sound power level i.e. derived according to the methodology detailed within IEC 61400-14 (IEC, 2005).

61. The provided source noise data is referenced to wind speeds experienced at the hub-height of the turbine. As a result, the data has been converted to reference standardised 10 m height wind speeds in accordance with procedures defined within IEC-61400-11 (IEC, 2012).

62. The existing Mark Hill Windfarm Development is located directly to the south-west of the proposed Clauchrie Windfarm Development. The source noise levels for the installed Gamesa G87 turbines at Mark Hill have been taken from information from the manufacturer of the turbines for a hub-height of 67 m and including 2 dB of uncertainty (similarly to that discussed for the Clauchrie candidate turbine model).

63. **Table 10.4.2** provides the overall source noise levels used for the noise predictions, including for the uncertainty explained at Paragraph 60 & 62, and taking into account the conversion from hub-height to standardised wind speeds, explained at Paragraph 61.

Table 10.4.2 Turbine Source Sound Power Levels, dB L_{WA}

Turbine	Standardised 10 m Height Wind Speed (m/s)									
	3	4	5	6	7	8	9	10	11	12
Vestas V150										
Unrestricted (M0)	94.6	98.6	103.2	105.9	106.9	106.9	106.9	106.9	106.9	106.9
Mode SO0 (M1)	94.6	98.6	103.1	105.7	106.0	106.0	106.0	106.0	106.0	106.0
Mode SO2 (M2)	94.3	98.7	102.6	104.0	104.0	104.0	104.0	104.0	104.0	104.0
Mode SO3 (M3)	94.3	98.7	102.3	103.0	103.0	103.0	103.0	103.0	103.0	103.0
Mode SO4 (M4)	94.3	98.7	101.8	102.0	102.0	102.0	102.0	102.0	102.0	102.0
Mode SO5 (M5)	94.3	98.7	100.8	101.0	101.0	101.0	101.0	101.0	101.0	101.0
Mode SO6 (M6)	94.3	98.7	99.7	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Gamesa G87										
Unrestricted	94.8	98.5	103.6	107.5	108.4	108.4	108.4	108.4	108.4	108.4

64. The octave band noise spectrums used for the noise predictions are shown at **Table 10.4.3**. The data for the Vestas V150 5.6 MW turbine is based on further data obtained from Vestas, normalised to the maximum sound power level for the unrestricted mode of operation. The Gamesa G87 octave band data for the Mark Hill Windfarm is taken from typical octave band data for the turbine and also normalised to the maximum sound power level shown in **Table 10.4.2**.

Table 10.4.3 Octave Band Noise Spectra, dB L_{WA}

Turbine	Total, dB L_{WA}	Octave Band Centre Frequency (Hz)							
		63	125	250	500	1k	2k	4k	8k
Vesta V150	106.9	87.6	95.4	100.2	102.1	100.9	96.8	89.7	79.6
Gamesa G87	108.4	88.9	97.8	103.1	102.6	101.7	98.7	92.1	79.7

65. The predictions provided assume that the wind turbine noise contains no audible tones. Where tones are present, a correction is added to the measured or predicted noise level before comparison with the limits. The audibility of any tones can be assessed by comparing the narrow band level of such tones with the masking level contained in a band of frequencies around the tone called the critical band. The ETSU-R-97 noise limits require a tone correction to be applied to any derived turbine noise levels resulting from noise measurements of the operational turbines which depends on the amount by which the tone exceeds the audibility threshold. A warranty will be sought from the supplier of the turbines to be installed at the site to help to ensure that no tonal penalty would be required in practice.

10.4.1.2 D - Directivity Factor

66. The directivity factor allows for an adjustment to be made where the sound radiated in the direction of interest is higher than that for which the sound power level is specified. In the case of wind turbines, the sound power level is measured in a downwind direction, corresponding to the worst-case propagation conditions considered here and needs no further adjustment except as covered by wind direction effects (as discussed below).

10.4.1.3 A_{geo} - Geometrical Divergence

67. The geometrical divergence accounts for spherical spreading in the free-field from a point sound source resulting in an attenuation depending on distance according to:

$$A_{geo} = 20 \times \log(d) + 11$$

where, d = distance from the turbine

68. A wind turbine may be considered as a point source beyond distances corresponding to one rotor diameter.

10.4.1.4 A_{atm} - Atmospheric Absorption

69. The atmospheric absorption accounts for the frequency dependant linear attenuation with distance over the frequency spectrum according to:

$$A_{atm} = d \times \alpha$$

where, α = the atmospheric absorption coefficient for the relevant frequency band

70. Published values of 'α' from ISO9613 Part 1 (ISO, 1992) have been used, corresponding to a temperature of 10ºC and a relative humidity of 70%, which give relatively low levels of atmospheric attenuation, as given at **Table 10.4.4**. This provides a conservative basis for assessment.

Table 10.4.4 Atmospheric Absorption Coefficients

Octave Band Centre Frequency (Hz)	63	125	250	500	1k	2k	4k	8k
Atmospheric Absorption Coefficient (dB/m)	0.0001	0.0004	0.0010	0.0019	0.0037	0.0097	0.0328	0.1170

10.4.1.5 A_{gr} - Ground Effect

71. Ground effect is the interference of sound reflected by the ground interfering with the sound propagating directly from source to receiver. The prediction of ground effects are inherently complex and depend on the source height, receiver height, propagation height between the source and receiver and the ground conditions. The ground conditions are described according to a variable G which varies between 0 for 'hard' ground (includes paving, water, ice, concrete and any sites with low porosity) and 1 for 'soft' ground (includes ground covered by grass, trees or other vegetation). The GPG recommends that the use of G = 0.5 and a receptor height of 4 m in rural areas are appropriate assumptions for the determination of noise emission levels at receptor locations downwind of wind turbines, provided that an appropriate margin for uncertainty has been included within the source levels for the proposed turbine. Accordingly, predictions provided here are based on G = 0.5 with a receptor height of 4 m.

10.4.1.6 A_{bar} - Barrier Attenuation

72. The effect of any barrier between the noise source and the receiver position is that noise will be reduced according to the relative heights of the source, receiver and barrier and the frequency spectrum of the noise. The barrier attenuations predicted by the ISO 9613 model have, however, been shown to be significantly greater than that measured in practice under downwind conditions. The results of a study of propagation of noise from windfarm sites carried out for ETSU concludes that an attenuation of just 2 dB(A) should be allowed where the direct line of site between the source and receiver is just interrupted and that 10 dB(A) should be allowed where a barrier lies within 5 m of a receiver and provides a significant interruption to the line of site. However, there appears to be no significant barriers between the site and the neighbouring dwellings. As a result, this has not been accounted for within the predictions, with no barrier attenuation being assumed.

10.4.1.7 A_{misc} - Miscellaneous Other Effects

73. ISO 9613 includes effects of propagation through foliage and industrial plants as additional attenuation effects. The attenuation due to foliage has not been included here and any such effects are unlikely to significantly reduce noise levels below those predicted.

10.4.1.8 Concave Ground Profile

74. Studies have shown that sound propagation across a valley or 'concave ground profile' can result in noise levels which are higher than predicted due to a reduced ground effect and/or the focussing effect of the ground shape. Calculating the precise effect of this phenomenon is particularly difficult. However, a simplified approach to allow for it has been suggested in the GPG. Paragraph 4.3.9 in the GPG states that 'A further correction of +3 dB (or +1.5 dB if using G=0.0) should be added to the calculated overall A-weighted noise level for propagation "across a valley", i.e. a concave ground profile, or where the ground falls away significantly, between the turbine and the receiver location. The following criterion of application is recommended:

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

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.'

75. The GPG states that 'Care needs to be exercised when evaluating this condition, as small changes in distances and height may trigger (or not) the criterion when the actual situation has not changed significantly'. It is also evident that the criterion may also be triggered in situations where there is more than one valley between a particular source and receiver, where, in reality, the stated causes of the 'concave ground profile' effect could not occur.

76. The topography between the proposed turbines and the dwellings considered here has been reviewed via inclusion of a digital terrain map (DTM) within the prediction model. This concludes that the ground profile between the Clauchrie and Mark Hill sites and the neighbouring receptors would not result in the condition above being triggered as there clearly is no overall concave topography. As a result, no corrections to the predicted noise levels are required in this regard.

10.4.1.9 Wind Direction

77. When considering the noise levels from the proposed Development operating in combination with Mark Hill Windfarm , it is clear that it is impossible for some dwellings to be directly downwind of all the wind turbines at one time. As such, for the purposes of the cumulative assessment, and the development of a mitigation/curtailment strategy at particular dwelling locations, additional predicted noise levels have been calculated using the above methodology, but with an additional term added in to take into account the effect of wind direction as described below.

78. For any given wind direction, each nearby property can be classified as being either downwind, crosswind, or upwind of each of the turbines. If the location is downwind (+/-80º) of the turbine no correction is required to the predicted turbine noise level. If it is crosswind (facing 90º from a particular receptor +/-10º) to the turbine it is generally agreed that a 2 dB reduction can be made to the predicted turbine noise level. If the property is upwind of the turbine (+/-80º), a reduction is made to the predicted turbine noise level due to wind shadow effects, which depends on distance and the frequency spectrum, as described in the Wyle Research Report, Measurement and evaluation of environmental noise from wind energy conversion systems in Alameda and Riverside Counties (WR, 1988).

10.4.2 Significance Criteria

79. There are no formal significance criteria for assessing noise from windfarms. However, for the purposes of this assessment the noise impact is considered to be not significant if the limits discussed at Paragraphs 13-20 above are met and significant if not.

80. Construction noise is assessed against an adopted daytime criterion of 65 dB L_{Aeq} and the impact is therefore judged to be not significant if this criterion is met (see Paragraphs 25 to 27).

10.5 Baseline Conditions

81. A background noise survey was carried out, as the first stage of the assessment procedure. Two dwelling locations were chosen based on a preliminary turbine layout and with due regard to the existing Mark Hill Windfarm, located to the southwest of the proposed Development.

82. Further dwelling locations as identified at **Figures (10.1 to 10.4**), were considered (i.e. Shalloch Well and Mark) for background noise measurements. However, these were deemed unsuitable as existing turbine noise, from Mark Hill Windfarm would have almost certainly affected the monitoring results (see Paragraph 20). In these instances, reference has been made to background noise monitoring undertaken in support of the planning application for the Mark Hill Windfarm i.e. prior to it becoming operational. Dwellings located further from the proposed Development and the Mark Hill site (i.e. Laglanny, Craigenrae, Meml, White Knowes, Traboyack & Lambdoughty) lie outside the 35 dB L_{A90} noise contour on all relevant Figures. These locations were also deemed unsuitable as potential turbine noise levels fall well below the limit for which background noise monitoring is required (see Paragraph 17).

83. The survey was undertaken over the period from 24th July to the 15th August 2019.

10.5.1 Noise Measurement Positions

84. A description of each of the monitoring locations is provided below.

10.5.1.1 Ferter

85. This dwelling is located to the south of the proposed Development. The noise monitoring equipment was installed within the garden of the property, greater than 3.5 m from the nearest building facade and on a side of the house facing the proposed turbines. Noise sources noted during installation and removal of the equipment included wind in the trees and foliage, faint water noise from a stream near the dwelling, birdsong, garden works, insects, occasional aircraft overhead and equipment designed to repel and/or control midges.

10.5.1.2 White Clauchrie (Proxy)

86. This property is also located to the south of the proposed Development. The residents of the property declined to have the noise monitoring equipment installed within their garden. As a result, the noise monitoring equipment was installed at a location overlooking the property to the north of the dwelling, on land owned by Forestry and Land Scotland (FLS). The equipment was placed to the side of a track in a location considered to have a similar level of tree cover to that at the property for which the measurements are intended to represent. Noise sources noted during installation and removal of the equipment included water noise from a stream/burn in a nearby dip/valley, birdsong, insects, distant aircraft/works and the wind in the surrounding trees and foliage.

10.5.2 Instrumentation

87. The background/baseline noise measurements were made with Larson Davis model LD-820 Sound Level Meters fitted with 1/2" microphones which comply with the Type 1 standard in IEC 651-1:1979 (IEC, 1979). The microphones were fitted with 45 mm radius foam ball windshields surrounded by 125 mm radius secondary windshields of 40 mm thickness, based on recommended design specifications within ETSU W/13/00386/REP, Noise Measurements in Windy Conditions (ETSU/DTI, 1996), and mounted on tripods at a height of approximately 1.2 to 1.5 metres height. Pre-calibration and post calibration checks were carried out using Brüel & Kjær acoustic calibrators (s/n 2699280 & 3009009).

88. Concurrent onsite wind data was obtained from an existing meteorological mast with cup anemometers installed at 70.7, 60, 50 and 30 m height and a wind vane installed at a height of 68 m.

89. Pluvimate rain gauges were installed at both measurement locations.

10.5.3 Measurement Procedure

90. The meters were programmed to measure a number of statistical noise indices, including the L_{A90}, together with the maximum and minimum levels and the L_{Aeq} over consecutive 10-minute intervals. The equipment was synchronised to a Global Positioning System (GPS) time signal and the results were automatically stored at the end of each interval.

91. Calibration of the noise measurement equipment was carried out before the monitoring commenced and was checked at the end. A change of no more than 0.2 dB was noted at any of the measurement locations, which is within normal tolerances.

92. Wind shear has been addressed by relating background noise measurements to 125 m height wind speed (the approximate maximum hub height of the proposed turbines), determined from the wind speed measured at 70.7 and 30 m height above ground level and based on instantaneous wind shear exponent, α, for each period, as derived from the expression:

$$\frac{V_1}{V_2} = \left(\frac{h_1}{h_2}\right)^{\alpha},$$

where, h_1 and h_2 are the respective heights at which wind speeds V_1 and V_2 were measured. Although the relative heights from which the hub-height wind speed is derived does not strictly confirm with the requirements of the GPG (i.e. with the upper cup anemometer height being less than 60% of the potential hub-height of the proposed turbines) this is not considered problematic. The anemometer height specifications proposed within the GPG are arbitrary and do not appear to consider the future potential heights of turbines since the release of the documents.

93. The hub height wind speed has been corrected to 'standardised' 10 m height wind speed using the same methodology as is used by manufacturers to quantify sound power level data as required by IEC 61400-11 (IEC, 2012) and as detailed within the GPG, i.e.:

$$V_{10} = V_h \left(\frac{\ln\left(\frac{10}{z_0}\right)}{\ln\left(\frac{h_h}{z_0}\right)} \right),$$

where, V_{10} and V_h are the 'standardised' 10m height and hub height (h_h) wind speeds respectively, and z_0 is the reference ground roughness length (=0.05 m). In this way, it is ensured that the comparisons of predicted turbine noise level and background level (including any associated noise limits) are made on a like-for-like basis.

94. Rainfall data was taken from the installed rain gauges, which both logged rainfall in 10 minute intervals, time synchronised to a GPS time signal. This allows for corresponding data, where noise levels may be affected by the presence of rainfall, to be removed from the analysis.

10.5.4 Results of Measurements

95. The noise, wind and rain data collected during the measurement campaign, as detailed above, is shown in **Technical Appendix 10.1. Volume 4.**

96. Prevailing background noise levels during the night-time and quiet daytime hours have been derived by plotting the measured L_{A90} background noise levels against the standardised 10 m height wind speeds as described within ETSU-R-97 and the GPG and shown within **Technical Appendix 10.2 (Figures 1 to 4)** for the quiet daytime and night night-time periods defined within ETSU-R-97.

97. Any 10 minute period where rainfall was recorded at either of the measurement locations is shown with dark blue circles and has been removed from the derivation of the prevailing background noise levels from the data collected at all the measurement locations. Other atypical or extraneous noise levels have also been removed from the analysis at some locations and these are identified with green circles.

98. Data collected between 20:00 27th July – 05:00 2nd August, 23:00 4th August – 12:00 8th August and from 9th August until the end of the survey has been removed from the analysis due to relatively high noise levels resulting from increased water flow through streams neighbouring the measurement positions following rainfall. The remaining data set is considered to show the likely lowest levels of background noise experienced at each monitoring location.

99. Third order regression lines have been calculated through the background noise data for each time period at each measurement location to give the prevailing background noise data as required for the derivation of the ETSU-R-97 limits.

100. **Technical Appendix 10.2, Volume 4** shows the prevailing background noise levels for the two measurement locations and for the two time periods suggested within ETSU-R-97 over a range of wind speeds.

101. **Table 10.5.1** shows these in tabular form. These are supplemented by prevailing background noise levels obtained in support of the planning application for Mark Hill Windfarm (see Paragraph 82). Where there is limited or no data on which to base the regression curve (i.e. at higher wind speeds) then background noise levels are assumed to remain at the level corresponding to the highest wind speed for which data is available.

Table 10.5.1 Prevailing Background Noise Levels, dB L_{A90}

Location	Standardised 10 m Height Wind Speed (m/s)									
	3	4	5	6	7	8	9	10	11	12
Night-time										
Mark	32.4	33.3	34.4	35.5	36.8	38.1	39.6	41.1	42.8	44.6
Shalloch Well	20.5	23.4	27.3	31.7	36.2	40.1	43.0	44.3	44.3	44.3
Ferter	25.8	26.5	27.8	29.6	31.7	33.9	36.1	37.9	39.4	40.1
White Clauchrie (Proxy)	28.3	29.2	30.5	32.2	34.2	36.3	38.6	40.8	42.9	44.9
Quiet Daytime										
Mark	31.6	32.6	33.8	35.2	36.7	38.4	40.3	42.3	44.5	46.9
Shalloch Well	23.0	26.2	29.8	33.4	36.8	39.5	41.1	41.3	41.3	41.3
Ferter	28.0	28.4	29.0	29.9	30.7	30.7	30.7	30.7	30.7	30.7
White Clauchrie (Proxy)	30.3	31.1	32.2	33.3	34.3	34.3	34.3	34.3	34.3	34.3

102. **Table 10.5.2** shows the resultant lower daytime, upper daytime and night-time noise limits for each of the relevant measurement/assessment locations (see Paragraphs 13 & 14).

Table 10.5.2 Noise Limits, dB L_{A90}

Location	Standardised 10 m Height Wind Speed (m/s)									
	3	4	5	6	7	8	9	10	11	12
Night-time Noise Limits										
Mark	43.0	43.0	43.0	43.0	43.0	43.1	44.6	46.1	47.8	49.6
Shalloch Well	43.0	43.0	43.0	43.0	43.0	45.1	48.0	49.3	49.3	49.3
Ferter	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	44.4	45.1
White Clauchrie	43.0	43.0	43.0	43.0	43.0	43.0	43.6	45.8	47.9	49.9
Lower Daytime Noise Limits										
Mark	36.6	37.6	38.8	40.2	41.7	43.4	45.3	47.3	49.5	51.9
Shalloch Well	35.0	35.0	35.0	38.4	41.8	44.5	46.1	46.3	46.3	46.3
Ferter	35.0	35.0	35.0	35.0	35.7	35.7	35.7	35.7	35.7	35.7
White Clauchrie	35.3	36.1	37.2	38.3	39.3	39.3	39.3	39.3	39.3	39.3
Upper Daytime Noise Limits										
Mark	40.0	40.0	40.0	40.2	41.7	43.4	45.3	47.3	49.5	51.9
Shalloch Well	40.0	40.0	40.0	40.0	41.8	44.5	46.1	46.3	46.3	46.3
Ferter	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0
White Clauchrie	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0

103. Mark Hill Windfarm has consented daytime noise limits set at the upper range stipulated within ETSU-R-97 (i.e. 40 dB L_{A90} or the background noise levels + 5 dB). As a result, it is considered that the upper limit would also be appropriate for the proposed Development given the potential generating capacity of the proposed windfarm and the precedent set in respect of Mark Hill Windfarm.

104. For a given standardised 10 m height wind speed, as determined from hub height for a given height of turbine, the difference in wind speed at the hub height at a different turbine height, depends on the degree of wind shear

(wind speed-up with height). The Mark Hill Windfarm turbines have a hub-height of 67 m and the proposed Clauchrie turbines could have a hub-height of up to around 125 m. As a result, there may be a discrepancy between the hub height wind speeds at the two sites, and hence the predicted noise level, for a given standardised 10 m height wind speed at either one. This is expressed as a 'shift' in wind speed at one or other of the sites and particularly high levels of wind shear could result in a difference of up to 1-2 m/s for a given standardised 10 m height wind speed at either site especially if considering particularly high levels of wind shear. However, in reality the discrepancy is likely to be < 1 m/s on average, as wind shear conditions are not expected to be particularly high.

105. In order to maintain a consistent historical basis of assessment for the existing Mark Hill site the noise limits and the corresponding Mark Hill and the combined/cumulative operational turbine noise predictions, the standardised 10 m height Mark Hill wind speed reference (from a hub-height of 67 m) has been maintained for properties located closest to this Site and any potential deviations in wind speed reference from the Mark Hill turbines to the Clauchrie turbines have been considered (i.e. via a potential correction to the Clauchrie noise levels). An alternative approach would be to relate all information to the 125 m Clauchrie hub-height. However, this would require the correction of the Mark Hill background noise data, corresponding limits and associated predicted noise levels to account for the difference in wind speed reference and could be considered to further complicate matters in this respect. This aspect of the assessment is discussed further within the Cumulative Assessment section below.

10.6 Potential Effects

10.6.1 Operational Noise

106. **Technical Appendix 10.3, Volume 4**, shows an initial assessment of the predicted turbine noise levels assuming that all the dwellings considered here are downwind of all turbines simultaneously and that the Clauchrie turbines are operating unrestricted. The predicted turbine noise L_{Aeq} has been adjusted by subtracting 2 dB to give the equivalent L_{A90} as suggested in ETSU-R-97 and reaffirmed within the GPG. The Figures also show the predicted noise levels associated with the Mark Hill development and the cumulative total which are both referred to later in the Chapter.

107. **Table 10.6.1** shows the predicted noise levels associated with the proposed Development operating in isolation for reference.

108. A comparison of the levels shown at **Table 10.6.1** with the limits at **Table 10.5.2** (as provided within **Technical Appendix 10.3**) shows that predicted levels of operational noise generally fall well within the criteria prescribed within ETSU-R-97, with predicted noise levels at Ferter lying between the prescribed lower and upper daytime limits. As a result, operational noise is considered not significant (see Paragraph 79). A number of properties that are located further to the east and north of the proposed Development, which are not included within the Table, are also shown within **Technical Appendix 10.3** for reference/completeness.

Table 10.6.1 Predicted Clauchrie Wind Farm Noise Levels, dB L_{A90}

Location	Standardised 10 m Height Wind Speed (m/s)									
	3	4	5	6	7	8	9	10	11	12
Shalloch Well	21.2	25.2	29.8	32.5	33.5	33.5	33.5	33.5	33.5	33.5
White Clauchrie	21.9	25.9	30.5	33.2	34.2	34.2	34.2	34.2	34.2	34.2
Ferter	24.8	28.8	33.4	36.1	37.1	37.1	37.1	37.1	37.1	37.1
Mark	17.3	21.3	25.9	28.6	29.6	29.6	29.6	29.6	29.6	29.6

10.6.2 Construction Noise

109. The construction of the proposed turbines will occur at distances that are highly unlikely to breach typical construction noise limits prescribed within relevant guidance such as BS 5228 Code of Practice for Noise and Vibration Control on Construction & Open Sites (see Paragraphs 25 to 27). This combined with the temporary nature of the works means that a detailed assessment of the construction noise impacts is not considered necessary. Furthermore, it is not expected that upgrades to local roads and provision of additional tracks relating to construction would occur in close proximity to neighbouring dwellings. As a result, this aspect of the proposed Development is considered not significant (see Paragraph 80).

110. An additional construction noise impact would be blasting associated with the proposed stone extraction from borrow pits in order to obtain materials for the construction of turbine bases and access roads. This type of noise does not typically fall within the assessment of normal construction noise because of the extremely high amplitude and impulsive nature of the waveform. It is very likely that blasting noise could be heard at nearby residential locations, but a construction noise assessment would average noise levels across the day and is therefore not applicable to use for the assessment of blasting noise impacts. Mitigation to reduce the noise impact from blasting activities is set out in Section 10.8.

111. Where highways upgrades and cabling between the site and grid connection is carried out close to residential properties, there may be temporary short term noise impacts, with the level of impact dependant on the specific work required. It is likely, however, that noisy activities near residential properties will generally continue for less than one month, and therefore this short-term noise impact can be considered to be not significant.

10.7 Cumulative Assessment

10.7.1 Operational Noise

112. **Technical Appendix 10.3** shows an assessment of the cumulative turbine noise levels assuming that all the dwellings considered here are downwind of all turbines simultaneously and that the various turbines are operating unrestricted. Similarly, to Section 10.6, detailing the proposed Development operating in isolation, the predicted Mark Hill Windfarm and total cumulative turbine noise L_{Aeq} has been adjusted by subtracting 2 dB to give the equivalent L_{A90}.

113. **Table 10.7.1** shows the predicted noise levels associated with the operational Mark Hill Windfarm operating in isolation and **Table 10.7.2** shows the combined level of noise associated with the operation of the Clauchrie proposal operating simultaneously with Mark Hill Windfarm.

114. A comparison with the total levels shown in **Table 10.7.2** with the limits shown at **Table 10.5.2** (as presented at **Technical Appendix 10.3**) shows that the upper daytime and night-time limits prescribed within ETSU-R-97 would be met at Ferter, White Clauchrie & Mark. Total turbine noise levels at Shalloch Well are predicted to meet the night-time operational noise limit but marginally breach the upper daytime noise limit proposed within ETSU-R-97 and intended for use here (see Paragraph 103) at standardised 10 m height wind speeds of 6 to 7 m/s. The predicted breach only occurs for specific standardised 10 m height wind speeds and may not occur in practice (i.e. due to the level of conservatism applied to the predicted noise levels, see Paragraphs 60 & 62).

115. A comparison of the Mark Hill Windfarm predicted noise levels at **Table 10.7.1** with the relevant noise limits indicates that, with the level of uncertainty applied, predicted levels associated with Mark Hill are higher than the respective noise limits at a 6 m/s standardised 10 m height wind speeds at Shalloch Well. Similarly to the above, this is not expected to occur in practice and is likely due to the level of conservatism in the predicted noise levels provided here. In reality, it is expected that Mark Hill is operating at or below the limiting level at this wind speed.

116. The predicted increase in noise levels at Shalloch Well, due to the introduction of the Clauchrie Development, and at the critical 6 – 7 m/s wind speeds, is just less than 1 dB, with the Clauchrie turbines predicted to be operating at a level approximately 7 dB less than that associated with the Mark Hill scheme. As a result, and although it may not be entirely necessary, it is proposed that mitigation is applied to the proposed turbines such that the resultant increase in noise levels from the proposed Development turbines would be insignificant as compared to that from Mark Hill, preventing a potentially significant cumulative effect.

117. The GPG recommends that, one way of discounting any significant effects from the introduction of another development in the vicinity of an existing site is to ensure that the additional site has noise levels that are around 10 dB below that of the noise generated by the existing site. This corresponds to a predicted increase in noise levels, due to the introduction of the new development, of nearly 0.5 dB.

Table 10.7.1 Predicted Mark Hill Windfarm Noise Levels, dB L_{A90}

Location	Standardised 10 m Height Wind Speed (m/s)									
	3	4	5	6	7	8	9	10	11	12
Shalloch Well	28.0	31.7	36.8	40.7	41.6	41.6	41.6	41.6	41.6	41.6
White Clauchrie	18.1	21.8	26.9	30.8	31.7	31.7	31.7	31.7	31.7	31.7
Ferter	14.3	18.0	23.1	27.0	27.9	27.9	27.9	27.9	27.9	27.9
Mark	26.9	30.6	35.7	39.6	40.5	40.5	40.5	40.5	40.5	40.5

Table 10.7.2 Predicted Total (Cumulative) Wind Farm Noise Levels, dB L_{A90}

Location	Standardised 10 m Height Wind Speed (m/s)									
	3	4	5	6	7	8	9	10	11	12
Shalloch Well	28.8	32.6	37.6	41.3	42.2	42.2	42.2	42.2	42.2	42.2
White Clauchrie	23.4	27.3	32.1	35.2	36.1	36.1	36.1	36.1	36.1	36.1
Ferter	25.1	29.2	33.8	36.6	37.6	37.6	37.6	37.6	37.6	37.6
Mark	27.3	31.1	36.1	39.9	40.8	40.8	40.8	40.8	40.8	40.8

118. When including for the effects of wind direction (see Section 10.4.1.9) the predicted breach of the upper daytime noise limit, at the 6 - 7 m/s standardised 10 m height wind speeds at Shalloch Well, is only expected to occur for certain wind directions. In the instances where a predicted breach of the limit is predicted to occur, the contribution from the proposed Development is 10 dB less than that from Mark Hill Windfarm and these instances can be disregarded (i.e. in line with the recommendations of the GPG, see Paragraph 117).

119. Furthermore, the difference in the hub-heights between the Mark Hill Windfarm and the proposed Development means that, depending on the level of wind shear at the two sites, there is a possibility that the proposed turbines will have reached a standardised wind speed of 7-8 m/s (i.e. a wind speed at which the generating capacity and noise output from the proposed turbines is at a maximum) at the Mark Hill 6 m/s standardised 10 m reference wind speed i.e. the point at which the Mark Hill Windfarm is closest to or operating at the relevant noise limits). Essentially, this means that the Clauchrie predicted noise levels would shift to the left by 1 to 2 m/s in order to maintain consistency with the difference in wind speed references (see Paragraphs 104 & 105). Although, this is not expected to occur in reality as levels of wind shear are not expected to be particularly high.

120. **Table 10.7.3** shows the predicted noise levels from the proposed Development, Mark Hill, the combined total and the resultant increase in noise levels due to the introduction of the proposed Development, all as a function of wind direction for the critical standardised 10 m height wind speeds of 6 & 7 m/s (as referenced to the Mark Hill site). The Mark Hill turbines are assumed to be operating at their predicted noise level or the respective noise limit, whichever is lower. The proposed Development is assumed to be operating at a standardised 10 m height wind speeds greater than 7 and 8 m/s (as referenced to its own wind speed) to take into account potential differences in wind speed at the hub height of the two sites (see Paragraph 119).

Table 10.7.3 Wind Direction Dependent Predicted Wind Farm Noise Levels at Shalloch Well, dB L_{A90}

Wind Direction (°)	Standardised 10 m Height Wind Speed (m/s, referenced to Mark Hill)							
	6 m/s, 40 dB L_{A90} Limit				7 m/s, 41.8 L_{A90} Limit			
	Combined Total	Mark Hill	Clauchrie	Increase in Noise Level	Combined Total	Mark Hill	Clauchrie	Increase in Noise Level
0º	38.5	36.8	33.5	1.7	39.1	37.7	33.5	1.4
15º	36.8	34.0	33.5	2.8	37.3	34.9	33.5	2.4
30º	35.5	31.2	33.5	4.3	35.9	32.1	33.5	3.8
45º	34.6	27.9	33.5	6.7	34.8	28.8	33.5	6.0
60º	34.2	26.1	33.5	8.1	34.4	27.0	33.5	7.4
75º	34.2	25.6	33.5	8.6	34.3	26.5	33.5	7.8
90º	33.8	26.3	32.9	7.5	33.9	27.2	32.9	6.7
105º	33.9	28.3	32.5	5.6	34.2	29.2	32.5	5.0
120º	34.7	31.8	31.6	2.9	35.2	32.7	31.6	2.5
135º	35.8	34.7	29.4	1.1	36.5	35.6	29.4	0.9
150º	37.7	37.3	27.6	0.4	38.6	38.2	27.6	0.4
165º	38.7	38.5	24.3	0.2	39.5	39.4	24.3	0.1
180º	39.7	39.6	22.0	0.1	40.6	40.5	22.0	0.1
195º	40.1	40.0	20.8	0.1	41.3	41.3	20.8	0.0
210º	40.0	40.0	20.5	0.0	41.5	41.5	20.5	0.0
225º	40.1	40.0	21.1	0.1	41.6	41.6	21.1	0.0
240º	40.1	40.0	22.6	0.1	41.7	41.6	22.6	0.1
255º	40.1	40.0	25.1	0.1	41.7	41.6	25.1	0.1
270º	40.3	40.0	28.2	0.3	41.8	41.6	28.2	0.2
285º	40.4	40.0	29.8	0.4	41.8	41.6	29.8	0.2
300º	40.6	40.0	31.6	0.6	41.8	41.5	31.6	0.3
315º	40.7	40.0	32.6	0.7	41.7	41.1	32.6	0.6
330º	40.3	39.4	33.2	0.9	41.1	40.3	33.2	0.8
345º	39.7	38.5	33.5	1.2	40.4	39.4	33.5	1.0

121. **Table 10.7.3** above shows that instances where combined predicted noise levels exceed the relevant noise limit and the increase in noise levels due to the introduction of Clauchrie is greater than around 0.5 dB only occurs for wind directions of around 300º to 330º at a standardised wind speed of 6 m/s (referenced to Mark Hill). All other wind directions and wind speeds have combined predicted noise levels that are at or below the relevant noise limit or have levels where the associated increase in noise level due to Clauchrie is insignificant.

10.7.2 Construction Noise

122. There are no cumulative effects expected in respect of construction noise. As a result, this is considered not significant.

10.8 Mitigation

10.8.1 Operational Noise

123. The uncertainty in the levels of wind shear between the sites (i.e. the relationship between the wind speeds that the two sites experience) means that any curtailment provided for the Clauchrie site (in order to mitigate the

marginal exceedance of the proposed noise limit) needs to be provided for a relatively wide range of wind speeds in order to prevent a potentially significant cumulative effect.

124. In reality, the predicted significant cumulative effect is a hypothetical scenario which has very limited risk of occurring in practice and, if it did, would only occur for a limited range of wind speeds and directions that are rarely present at the site. The issue is essentially one of slight operational risk for the proposed Development for which it is entirely possible to mitigate against but may require some further work (if the site becomes operational) to determine the specific relationship between the wind speeds and directions at Clauchrie turbines of interest as compared with the dominant Mark Hill turbines, and to then tailor any possible mitigation, if this is ever actually considered to be required, on that basis.

125. Noise mitigation for modern wind turbines is available through noise 'modes' whereby the rotor is slowed at certain wind speeds with resulting reduction in noise and, necessarily, loss of electrical output power. A curtailment strategy can be devised where certain turbines are mitigated in this way for certain combinations of wind speeds and wind direction in order to meet imposed limits on noise.

126. **Technical Appendix 10.4, Volume 4**, provides potential mitigation measures, using the reduced noise modes shown at **Table 10.4.1** (M1, M2, M3…), for a range of wind speeds and directions that can be applied at the proposed Development.

127. The proposed curtailment strategy assumes that the Mark Hill Windfarm site has existing noise levels that are at the planning condition limit specified for Shalloch Well or the predicted noise level, whichever is lower, at the critical wind speeds (i.e. in the instances where the assessment provided here indicates a small risk of combined turbine noise levels exceeding the specified limit at Shalloch Well). The predicted noise levels (see **Table 10.7.3**) are used in all other instances.

128. The curtailment strategy is designed to ensure that, in the instances where predicted cumulative noise levels exceed the limits at Shalloch Well, the contribution of the Clauchrie turbines is 10 dB below the levels from Mark Hill Windfarm (i.e. has an insignificant contribution). Furthermore, the mitigation accounts for the difference in the hub height wind speeds between the two sites and means that the mitigation covers a wider/different range of wind speeds. In reality, it is likely to be the case that mitigation at a standardised 10 m height wind speed of 8 m/s would not be required as this corresponds to relatively high levels of wind shear, and hence discrepancy in hub height wind speed, between the two sites. The curtailment strategy is therefore considered to be provided on a conservative basis.

129. **Table 10.8.1** shows the resulting predicted noise levels of the cumulative assessment, with the proposed mitigation applied, in the same fashion as described for **Table 10.7.3** but for a restricted range of wind directions.

Table 10.8.1 Mitigated Wind Direction Dependent Predicted Wind Farm Noise Levels at Shalloch Well, dB L_{A90}

Wind Direction (°)	Standardised 10 m Height Wind Speed (m/s, referenced to Mark Hill) 6 m/s, 40 dB L_{A90} Limit			
	Combined Total	Mark Hill	Clauchrie	Increase in Noise Level
285°	40.4	40.0	29.8	0.4
300°	40.4	40.0	30.2	0.4
315°	40.4	40.0	30.3	0.4
330°	40.0	39.4	32.0	0.7
345°	39.7	38.5	33.5	1.2

130. The proposed mitigation strategy would result in noise levels that are acceptable under current planning guidelines and the precedent set in respect of the Mark Hill Windfarm noise limits (see Paragraph 103). All wind directions and wind speeds now have combined predicted noise levels that are at or below the relevant noise limit or have levels where the associated increase in noise level due to Clauchrie is insignificant.

10.8.2 Construction Noise

131. Noise during construction works would be controlled by generally restricting works to standard working hours and exclude Sundays, unless specifically agreed otherwise.

132. BS 5228 states that the 'attitude of the contractor' is important in minimising the likelihood of complaints and therefore consultation with the local authorities would be required along with providing information to residents on intended activities.

133. The construction works on-site would be carried out in accordance with:

- relevant EU Directives and UK Statutory Instruments that limit noise emissions from a variety of construction plant;
- the guidance set out in PAN1/2011 and BS 5228: 2009; and
- Section 61 of the Control of Pollution Act 1974 and Section 80 of the Environmental Protection Act.

134. There are no residential properties within 1 km of any road improvements and therefore construction noise is not a consideration.

135. A noise control plan would be produced that includes:

- procedures for ensuring compliance with statutory or other identified noise control limits;
- procedures for minimising noise from construction related traffic on the existing road network;
- procedures for ensuring that all works are carried out in accordance with the principle of "Best Practicable Means" as defined in the Control of Pollution Act 1974; and
- general induction training for site operatives, and specific training for staff having responsibility for particular aspects of controlling noise from the site.

136. Blasting is currently occurring within the site as FLS work various existing borrow pits and, in this regard, it is not a new impact. In terms of the blasting for the proposed Development, the most appropriate mechanism is for a pre-blasting noise management programme to be prepared which would identify the most sensitive receptors that could be potentially affected by blasting noise. The programme would contain details of the proposed frequency of blasting, and proposed monitoring procedures. The operator would inform the nearest residents of the proposed times of blasting and of any deviation from this programme in advance of the operations. The programme would also contain contact details which would be provided to local residents should concerns arise regarding construction and blasting activities. In addition, each blast will be designed carefully to maximise its efficiency and to reduce the transmission of noise.

137. No significant residual operational effects are predicted as cumulative predicted operational noise levels meet the relevant derived noise limits with (or possibly without) mitigation/curtailment applied to the turbines, although it is entirely possible that noise from the proposed Development would be audible at receptor locations at times.

138. Operational noise would, in practice, be controlled via planning conditions which set out noise limits for the proposed Development.

10.9 Residual Effects

10.9.1 Operational Noise

139. No significant residual operational effects are predicted as cumulative predicted operational noise levels meet the relevant derived noise limits with (or possibly without) mitigation/curtailment applied to the turbines, although it is entirely possible that noise from the proposed Development would be just audible at receptor locations at times (see Section 10.2.13). However, noise levels will meet planning guidelines in this regard.

140. Operational noise would, in practice, be controlled via planning conditions which set out noise limits for the proposed Development.

10.9.2 Construction Noise

141. No significant residual construction effects are expected as construction noise levels will be below the adopted noise limit, although it is possible that noise from construction activities could be audible at receptor locations at times.

10.10 Summary

142. A noise assessment was carried out in order to determine whether the site meets typical planning requirements in respect of operational noise from wind turbines. The assessment takes in to account the methodologies set out within ETSU-R-97, The Assessment and Rating of Noise from Wind Farms (1996) and the Institute of Acoustic document, A Good Practice Guide to the Application of ETSU-R-97 for the Assessment and Rating of Wind Turbine Noise.

143. Background/baseline noise measurements were undertaken at two locations to the south of the proposed Development.

144. The results of the operational noise assessment indicate that operational noise levels, when considering the proposed Development in isolation, meet the relevant noise limits and no specific mitigation is required. The noise impact is, therefore, determined to be not significant.

145. The cumulative/combined operational noise impact, when taking the existing Mark Hill Windfarm turbines in to account, results in a small risk of turbine noise levels exceeding the noise limits imposed on the Mark Hill Windfarm development for very specific wind speeds and directions. Whilst it is not expected this will not occur in practice, mitigation measures have been suggested that will ensure that cumulative turbine noise levels will meet the relevant limits and ensure that the combined operational noise impacts can be considered not significant.

146. Construction noise levels at neighbouring dwellings are expected to meet typical requirements in this regard and no specific mitigation measures are considered to be required other than that deemed necessary under normal best practice.

Table 10.10.1 Summary Table

Description of Effect	**Significance of Potential Effect**		**Mitigation Measure**	**Significance of Residual Effect**	
	Significance	Beneficial / Adverse		Significance	Beneficial / Adverse
During Construction					
Construction Noise	Not Significant	Adverse	Standard mitigation measures and adherence to various legislation/directives, liaison with local council and residents on noise issues.	Not Significant	Adverse
During Operation					
Operational noise lies well within planning requirements.	Not Significant	Adverse	None necessary. Although, the turbines may be just audible at times.	Not Significant	Adverse
Cumulative Effects					
Minor risk of combined/cumulative operational noise levels exceeding relevant limits at Shalloch Well.	Significant	Adverse	Potential application of appropriate precautionary curtailment measures to the Clauchrie turbines, in order to mitigate impacts.	Not Significant	Adverse

10.11 References

BSI (2008). BS 6472-1, Guide to evaluation of human exposure to vibration in buildings. Vibration sources other than blasting. BSI

British Standards Institute (2009 + 2014). BS 5228 + A1, Code of Practice for Noise and Vibration Control on Construction and Open Sites. BSI

British Standards Institute (2014). BS 8233. Guidance on sound insulation and noise reduction for buildings. BSI

Danish National Agency of Environmental Protection (1984). Measurement of Environmental Noise from Industry - The Joint Nordic Method for the Evaluation of Tones in Broadband Noise (Guideline No. 6). Danish Ministry of Environment

Davis R A, Lower M C (1996). ETSU W/13/00386/REP, Noise Measurements in Windy Conditions, ETSU/DTI

Department of Energy and Climate Change (2011). Report on DECC Research Contract 01.08.09.01/492A (Analysis), Analysis of How Noise Impacts are Considered in the Determination of Wind Farm Planning Applications. Available at: https://www.gov.uk/government/publications/analysis-of-how-noise-impacts-are-considered-in-the-determination-of-wind-farm-planning-applications

Department of Environment (1976). Advisory Leaflet 72, Noise control on building sites, DoE

Department of Trade and Industry (1996). ETSU-R-97, The Assessment and Rating of Noise from Wind Farms. ETSU/DTI Available at: https://webarchive.nationalarchives.gov.uk/+/http:/www.berr.gov.uk/files/file20433.pdf

Department of Trade and Industry (1997). ETSU W/13/00392/REP, Low Frequency Noise and Vibrations Measurement at a Modern Wind Farm. ETSU/DTI.

Department of Trade and Industry (2000). ETSU W/13/00385/REP, A Critical Appraisal of Wind Farm Noise Propagation. ETSU/DTI

Department of Trade and Industry (2006). ETSU W/45/00656/00/00, The Measurement of Low Frequency Noise at 3 UK Windfarms. ETSU/DTI.

Institute of Acoustics (July 2012). Discussion Document on “A Good Practice Guide to the Application of ETSU-R-97 for Wind Turbine Noise Assessment”. IOA

Institute of Acoustics (May 2013). A Good Practice Guide to the Application of ETSU-R-97 for the Assessment and Rating of Wind Turbine Noise. IOA. Available at: https://www.ioa.org.uk/publications/wind-turbine-noise

Institute of Acoustics (2015). Discussion Document on “Methods for Rating Amplitude Modulation in Wind Turbine Noise”. IOA

Institute of Acoustics (2016). A Method for Rating Amplitude Modulation in Wind Turbine Noise - Version 1. IOA. Available at: https://www.ioa.org.uk/sites/default/files/AMWG%20Final%20Report-09-08-2016_1.pdf

International Electrotechnical Commission (1979). IEC 651-1:1979, Sound Level Meters. IEC

International Electrotechnical Commission (2002). IEC 61672-1:2002, Sound level meters - Part 1: Specifications. IEC

International Electrotechnical Commission (2005). IEC 61400-14, Wind turbines - Part 14: Declaration of apparent sound power level and tonality values. IEC

International Electrotechnical Commission (2012). IEC 61400-11, Wind turbine generator systems – Part 11: Acoustic noise measurement techniques. IEC

International Organization for Standardization (1992). ISO 9613-1, Acoustics - Attenuation of sound during propagation outdoors, Part 1: Method of calculation of the attenuation of sound by atmospheric absorption. ISO.

International Organization for Standardization (1996). ISO 9613-2, Acoustics - Attenuation of Sound During Propagation Outdoors, Part 2: General Method of Calculation. ISO

McKenzie et al. (Nov/Dec 2017) Acoustics Bulletin Vol. 42 No. 6, A planning condition for wind turbines, IOA

Pederson et al. (1999) AV 1952/99, Objective Method for Assessing the Audibility of Tones in Noise – Joint Nordic Method – Version 2. Delta.

Perkins et al. (September 2016). A Review of Research into Human Response to the Amplitude Modulated Component on Wind Turbine Noise and Development of a Planning Control Method for Implementation in the UK. UK Proceedings of the Institute of Acoustics Vol. 38. Pt. 1.

RenewableUK (December 2013). Wind Turbine Amplitude Modulation: Research to Improve Understanding as to its Cause and Effect. RUK Available at: https://www.renewableuk.com/page/IndustryStatementOAM/page/CommunitiesEnergy

Renewable UK (December 2013). The Development of a Penalty Scheme for Amplitude Modulated Wind Turbine Noise: Description and Justification. RUK. Available at: https://www.renewableuk.com/page/IndustryStatementOAM/page/CommunitiesEnergy

Renewable UK (December 2013). Template Planning Condition on Amplitude Modulation: Noise Guidance Notes. RUK. Available at: https://www.renewableuk.com/page/IndustryStatementOAM/page/CommunitiesEnergy

Scottish Government (March 2011). PAN1/2011. Planning and Noise. Available at: https://www.gov.scot/publications/planning-advice-note-1-2011-planning-noise/

Scottish Government (May 2014). Onshore Wind Turbines. Available at: https://www.gov.scot/binaries/content/documents/govscot/publications/advice-and-guidance/2014/05/onshore-wind-turbines-planning-advice/documents/9bfeeca0-9a06-4bb1-bc29-306c8f675656/9bfeeca0-9a06-4bb1-bc29-306c8f675656/govscot%3Adocument [Accessed : Jan 2019]

Styles et al. (2005) Microseismic and Infrasound Monitoring of Low Frequency Noise and Vibrations from Wind Farms. Keele University.

Temple Group (December 2013). Summary of Research into Amplitude Modulation of Aerodynamic Noise from Wind Turbines. RUK. Available at: Available at: https://www.renewableuk.com/page/IndustryStatementOAM/page/CommunitiesEnergy

Temple Group (December 2013). Review of RenewableUK's Research into Amplitude Modulation. RUK. Available at: https://www.renewableuk.com/page/IndustryStatementOAM/page/CommunitiesEnergy

Turnbull et al. (April 2012) Measurement and Level of Infrasound from Wind Farms and Other Sources. 40(1). Acoustics Australia.

World Health Organization (1999) Guidelines for Community Noise. WHO

World Health Organization (2009). Night Noise Guidelines for Europe. WHO

World Health Organization (2018). Environmental Noise Guidelines for the European Region. WHO

Wyle Research (1988). Wyle Research Report WR 99-19, Measurement and Evaluation of Environmental Noise from Wind Energy Conversion Systems in Alameda and Riverside Counties. WR.

Clauchrie Windfarm Project Team

ScottishPower Renewables
9th Floor Scottish Power Headquarters
320 St Vincent Street
Glasgow
G2 5AD

clauchriewindfarm@scottishpower.com

SCOTTISHPOWER RENEWABLES