Chapter 10

Noise

Table of contents

List of Figures

Chapter 10
Noise

10.1 Introduction

1. This chapter assesses the potential noise effects of the proposed Development, located north west of Kirkcowan in Dumfries and Galloway, as detailed on **Figure 4.1a**. The levels of noise likely to occur at local residential properties as a result of the operation of the proposed Development have been assessed in respect of the proposed Development in isolation, and cumulatively with other local windfarm developments. Potential noise effects from construction activities and any borrow pit workings have also been assessed. Noise from the proposed solar array has been scoped out as operational noise level will not be audible at residential receptor locations.

10.2 Legislation, Policy and Guidelines

10.2.1 PAN1/2011, Planning and Noise

2. 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 (Scottish Government, 2014).

3. 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 23 to 25**) as being applicable for Environmental Impact Assessment (EIA) and planning purposes.

10.2.2 Web Based Planning Advice, Onshore Wind Turbines

4. 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 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*". 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*". The document goes on to reference the GPG document discussed below in terms of assessing noise associated with wind turbine developments.

5. 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

6. 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.

7. ETSU-R-97 recommends that, although noise limits should be set relative to existing background and should reflect the variation of both wind 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*".

8. For day-time periods, the noise limit is 35-40 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.

9. 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 13**).

10. 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 are applicable up to a wind speed of 12 m/s measured at 10 m height on the site.

11. 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.

12. Where predicted noise levels are low at the nearest residential properties a simplified noise limit can be applied, such that noise is restricted to the minimum ETSU-R-97 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.

13. 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 for windfarm noise allows reliable measurements to be made without corruption from relatively loud, transitory noise events from other sources.

14. 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 is described and is related to the level by which any tonal components exceed audibility.

15. With regard to multiple windfarms in a given area, ETSU-R-97 specifies that the absolute noise limits and margins above background levels should relate to the cumulative effect of all wind turbines in the area contributing to the noise received at the properties in question. Existing windfarms should therefore be included in cumulative predictions of noise levels for the proposed Development wind turbines and are not be considered as part of the prevailing background noise.

16. All windfarms that contribute operational noise levels within 10 dB of the limit applicable to cumulative noise should be included within the cumulative noise assessment, and this criterion is used to define the study area. If predicated operational noise levels from individual windfarms are more than 10 dB below the cumulative noise limit their contribution to overall noise levels can be considered to be negligible, and therefore do not need to be considered in detail.

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

17. 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).

18. 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*".

19. 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.

20. With regard to cumulative noise the GPG states that '*The HMP Report*[1] *states that "If an existing wind farm has permission to generate noise levels up to ETSU-R-97 limits, planning permission noise limits set at any future neighbouring wind farm would have to be at least 10 dB lower than the limits set for the existing wind farm to ensure there is no potential for cumulative noise impacts to breach ETSU-R-97 limits (except in such cases where a higher fixed limit could be justified)". Such an approach could prevent any further wind farm development in the locality, and a more detailed analysis can be undertaken on a case by case basis*'.

21. In this case, if operational noise from the proposed Development is assessed against noise limits that are set at 10 dB below those already consented for the Operational Kilgallioch Windfarm, cumulative noise impacts will not cause a breach of the ETSU-R-97 limits.

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

22. 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

23. 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.

24. 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}.

25. 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 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)

26. 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)*'.

27. It has been noted that complaints about windfarm noise have, in many cases, 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.

28. 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.

29. This resulted in the inclusion of a mechanism to assess and regulate AM effects in the standard form of a condition (RUK, 2013), frequently applied to windfarm developments as 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.

30. 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.

31. 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.

32. 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.

33. 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.

[1] Hayes McKenzie Partnership Ltd. Report on "*Analysis of How Noise Impacts are considered in the Determination of Wind Farm Planning Applications*" Ref HM: 2293/R1 dated 06 April 2011

10.2.8 Wind Shear

34. 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 m 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.

35. 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 17 to 21**. 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.

36. In this case as predicted operational noise levels are being compared with a fixed noise limit across all wind speeds, as long as the noise limit is met under conditions when the wind turbines are operating at their maximum noise output, the limits will be met regardless of the levels of wind shear.

10.2.9 Tonal Noise

37. ETSU-R-97 notes that 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 from the chosen turbine supplier 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

38. 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 annoyance.

39. 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.

40. 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*".

41. 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). The evidence suggests that at typical residential distances (e.g. at 500 m or more), the levels of infrasound from a windfarm are below accepted thresholds of perception. Even when measured in close proximity to a wind turbine, the measured levels of infrasound are 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

42. Low frequency noise is sound in the audible frequency range, and is usually described as covering the range 20 to 200 Hz. 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 a 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. However, at such distances, the overall noise level is so low, such that any bias in the frequency spectrum is insignificant.

10.2.12 Vibration

43. The ETSU study referenced at **Paragraph 42** above (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

44. The potential audibility of noise from the 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 time of day and other factors including, particularly in rural areas, wind speed. The potential audibility of wind turbine noise can be determined by comparing the predicted turbine noise with the measured background noise level. 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

45. 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.

46. It should be noted that guidance from the WHO on night noise levels is 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.

47. 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.

48. 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 above) than by average noise level.

10.3 Consultation

10.3.1 The Energy Consents Unit

49. The Energy Consents Unit (ECU) stated in their Scoping Opinion that '*The cumulative noise assessment should be carried out in line with relevant legislation and standards as detailed in section 11 of the scoping report. This should include details about the representative background noise survey locations agreed with the relevant Planning Authority'*.

10.3.2 Dumfries and Galloway Council

50. The Environmental Health Department of DGC were consulted on the methodology as to the operational noise assessment, including the cumulative assessment and the derivation of relevant noise limits applicable to the proposed Development.

51. It was agreed with Dumfries and Galloway Council (DGC) that because of the number of operational windfarms in the vicinity, baseline noise monitoring would not be required or practicable as it would not be possible to accurately establish background noise levels in the absence of existing windfarm noise.

52. It was proposed that, as it was anticipated that noise from the proposed Development would be likely to be more than 10 dB below the consented limits for the Operational Kilgallioch Windfarm (see **Section 10.3.4**), appropriate noise limits for the proposed Development could be derived. DGC confirmed during a phone call on 21 August 2019 that this approach was acceptable. **Table 10.3.1** below summaries the points that were agreed with DGC. It should be noted that although attempts were made, no written confirmation of this discourse with DGC has been obtained. The ECU confirmed in an email on the 01 of November 2019, that they were in agreement that sufficient effort had been made to obtain written agreement.

Area of Agreement	Description
Construction Noise Assessment Methodology	Due to the large separation distances (see **Table 10.6.1**, below) from the turbines to the nearest noise sensitive receptors, significant construction noise effects are not anticipated and a detailed assessment of construction noise effects is scoped out of detailed assessment, with a commitment to adhere to Best Practice means of controlling noise from construction activities, as advocated by BS 5228.
Operational Windfarm Noise Assessment Methodology	It was agreed via the Scoping Report that the assessment would be carried out according to ETSU-R-97 and the IOA GPG.
Specific Cumulative Operational Noise Assessment	It was agreed that noise limits for the proposed Development could be derived on the principle that if they are at least 10 dB below existing noise limits then this would ensure that cumulative noise would remain within relevant limits.
Amplitude Modulation	AM was scoped out of assessment in the Scoping Report. The nearest noise sensitive receptors are around 3 km from the proposed turbine layout and therefore no significant effects with regards to AM are anticipated.
Low Frequency and Infrasound	Low frequency noise and infrasound was scoped out of further assessment in the Scoping Report as no significant effects are anticipated as described in **Section 10.2** above.
Cumulative Noise	Cumulative noise would be assessed according to the IOA GPG.
Baseline Noise Survey	Baseline noise measurements would not be undertaken due to the level of cumulative windfarm activity nearby.

Table 10.3.1 Summary of Consultation with Dumfries and Galloway Council

10.3.3 Effects Scoped out of the Noise Assessment

54. The potential effects that have been scoped of out further assessment within the noise assessment are set out in **Table 10.3.2** below:

Effect Scoped Out	Reasoning
Construction Noise	Noise from construction activities is considered, however a detailed assessment is not required due to the large separation distances of onsite construction activities and noise sensitive receptors.
Construction Vibration	There will be no perceptible vibration from onsite construction activities.
Amplitude Modulation	The noise limits allow for a certain amount of blade swish. Significant levels of AM are unlikely given distance to the noise sensitive receptors, but the probability cannot be quantified. AM can be controlled by a condition attached to planning permission if required.
Tonal Noise	Modern wind turbines are generally not tonal, however, the assessment is carried out for a candidate turbine, and therefore the levels of any tonal noise for the turbine eventually selected for the site is unknown. Tonal noise can be controlled through a condition attached to the planning permission, if required.
Low Frequency Noise	Wind turbines are not significant generators of low frequency noise and levels of low frequency noise are insignificant in relation to the overall audible broadband noise levels.
Infrasound	Infrasound will be significantly below the levels of human perception at the identified noise sensitive receptor locations.
Wind Shear	The noise assessment has been carried out by assessing predicted operational noise (including cumulative noise) against fixed limits, such that the levels of wind shear are irrelevant to the assessment.
Noise from the Solar Array	A solar array forms part of the proposed Development. Noise from any of the onsite ancillaries will not be audible at any residential receptors and is therefore not considered further.

Table 10.3.2 Effects Scoped Out of Detailed Assessment

10.3.4 Noise Limits for the Operational Kilgallioch Windfarm

56. The Operational Kilgallioch Windfarm was granted consent in February 2013 by the Scottish Ministers. The decision notice, downloaded from the DPEA[2] website, included planning conditions on operational noise, and the limits are described at *condition 29*, and are reproduced below:

[2] Planning and Environmental Appeals Division (DPEA) of the Scottish Government

"29. That at wind speeds not exceeding 12 metres per second as measured or calculated at a height of 10 metres above ground level at the wind farm, the wind farm noise emission level at any dwelling existing at the date of this permission shall comply with the following:
(a) During night-time hours, as defined in ETSU-R-97 as 23.00 to 07.00 on all days, the wind farm noise emission level shall not exceed 43dB LA90, 10 min or the ETSU-R-97 derived "night hours" noise limit based on the measured LA90, 10 min background noise level plus 5dB(A), whichever is the greater.
(b) At all other times, the wind farm noise emission level shall not exceed 40dB LA90, 10 min or the ETSU-R-97 derived "quiet waking hours" noise limit based on the measured LA90, 10 min background noise level plus 5dB(A), whichever is the greater.
(c) The above noise emission limits may be increased to 45 dB LA90, 10 min or the relevant ETSU-R-97 derived "quiet waking hours" or "night hours" noise limit based on the measured LA90, 10 min noise level plus 5dB(A), whichever is the greater, when measured at any dwelling owned by persons with financial involvement with the wind farm.
(d) Measured background noise levels referred to in this condition shall be those recorded by the regression lines in Chapter 13 Figures 13.1 to 13.14 contained in and forming part of the Environmental Statement.
Reason: To ensure proper environmental control in respect of noise, and to safeguard the amenities of the nearest residential properties."

57. The lowest noise limit applied to operational noise from the consented Operational Kilgallioch Windfarm was 40 dB L_{A90}, but that at night, for financially involved properties, or where the background noise levels[3] were above 35 dB L_{A90} the limit is higher.

10.4 Assessment Methodology and Significance Criteria

10.4.1 Noise Prediction Methodology

58. 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.

59. 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:

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

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

61. The turbine co-ordinates used for the assessment have been provided by ITPEnergised Ltd.

10.4.2 L_W - Source Sound Power Level

62. The sound power level of a noise source is normally expressed in dB re:1pW. Noise predictions for the candidate turbine assumed for proposed Development 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.

63. 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).

[3] Measured background noise levels referred to in the planning condition are stated to be those recorded by the regression lines in Chapter 13, Figures 13.1 to 13.14 in the Operational Kilgallioch Windfarm Environmental Statement submitted on 16 March 2010

64. 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).

65. **Table 10.4.1** provides the overall source noise levels used for the noise predictions, including for the uncertainty explained at **paragraph 63**, and taking into account the conversion from hub-height to standardised wind speeds, explained at **paragraph 64**.

Turbine	Standardised 10 m Height Wind Speed (m/s)									
	3	4	5	6	7	8	9	10	11	12
Vestas V150 5.6 MW STE	94.6	98.6	103.2	105.9	106.9	106.9	106.9	106.9	106.9	106.9

Table 10.4.1 Turbine Source Sound Power Levels, dB L_{WA}

66. The octave band noise spectrums used for the noise predictions are shown at **Table 10.4.2**. The data for Vestas V150 5.6 MW turbine is based on further specifications obtained from Vestas, normalised to the maximum sound power level for the unrestricted mode of operation.

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

Table 10.4.2 Octave Band Noise Spectra, dB L_{WA}

67. The predictions provided assume that the wind turbine noise contains no audible tones. Where tones are present, a correction should be 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 should 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.

10.4.3 D - Directivity Factor

68. 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 this case 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).

10.4.4 A_{geo} - Geometrical Divergence

69. 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

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

10.4.5 A_{atm} - Atmospheric Absorption

71. 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

72. 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 10.4.3**. This provides a conservative basis for assessment.

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

Table 10.4.3 Atmospheric Absorption Coefficients

10.4.6 A_{gr} - Ground Effect

73. 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.

10.4.7 A_{bar} - Barrier Attenuation

74. 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 sight. Whilst some of the turbines are not visible from some of the noise sensitive receptor locations, to ensure a conservative assessment barrier attenuation has not been accounted for within the predictions.

10.4.8 A_{misc} - Miscellaneous Other Effects

75. 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.

10.4.9 Concave Ground Profile

76. 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.'

77. 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.

78. The topography between the turbines and the dwellings considered here has been reviewed via inclusion of a digital terrain map (DTM) within the prediction model. An assessment of the ground profiles between each of the receptors and each of the turbines has been carried out and compared with the mean height criterion detailed at **paragraph 76**. The assessment shows that, based on the DTM used in the model, the mean height criterion is not met at any of the receptors for any of the turbines. Furthermore, the ground profiles were individually reviewed and in most cases the ground is undulating up and down several times between each turbine and each receptor leaving very little opportunity for any reflection paths to occur. This indicates that the ground profile between the Site and the neighbouring receptors would not result in any significant increases in the propagation of noise from the windfarm as the stated effect cannot occur in practice. As a result, no corrections to the predicted noise levels have been made in this regard.

10.4.10 Assessment Methodology

79. The assessment of the noise levels associated with the proposed Development have been undertaken in accordance with ETSU-R-97 and the GPG whereby the scheme operating in isolation has been compared with a noise limit of 30 dB L_{A90} which is 10 dB below the lowest noise limit applied to the Operational Kilgallioch Windfarm (described in **Section 10.3.4** above).

80. As discussed at **paragraph 8** the value used in the 35 – 40 dB L_{A90} range for the lower limiting value for the daytime noise limit depends on a number of factors. The consented limit for Operational Kilgallioch Windfarm and therefore the limit adopted as applicable to cumulative noise is set at the upper value of the ETSU-R-97 daytime range. This is reasonable in this instance given the potential generating capacity of the proposed and existing windfarms, the precedent set in respect of existing turbine development in the vicinity and the relatively few dwellings located nearby.

81. The ETSU-R-97night noise limit is the greater of 43 dB L_{A90} or plus 5 dB above background, and therefore if predicted noise levels meet a 30 dB L_{A90} noise limit then there will also be no significant impact on night-time noise levels.

82. Construction noise has been discussed in general terms and with due regard to typical guidance on this matter.

10.4.11 Significance Criteria

83. There are no formal significance criteria for assessing noise from windfarms. However, for the purposes of this assessment with, the noise impact is considered to be not significant in terms of the EIA Regulations (2017) if the limits proposed here are met. It can therefore be considered that if predicted operational noise levels from the proposed Development are below 30 dB L_{A90} then the noise impact is not significant.

10.5 Baseline Conditions

84. The baseline noise environment at the closest residential noise sensitive receptors around the proposed Development is of a typical rural environment, with background noise levels dominated by local noise sources of wind induced noise (i.e. wind in the trees and foliage), birdsong, farming and forestry activities, road traffic noise from vehicles accessing local roads, and in some cases noise from existing windfarm developments.

85. Baseline noise measurements were not undertaken as operational and construction noise levels have been assessed against a fixed noise limit not related to baseline noise levels.

86. Where baseline noise levels are above 35 dB L_{A90} the derived ETSU-R-97 noise limits would be higher than the assumed 40 dB L_{A90} limit assumed for cumulative noise, but for the purposes of this assessment the fixed limit is assumed, and therefore the assessment remains conservative.

10.6 Potential Effects

10.6.1 Construction Noise

87. The construction of the proposed Development (including construction of the turbines and solar array) will occur at distances that are highly unlikely to breach typical construction noise limits at the closest noise sensitive receptors prescribed within relevant guidance such as BS 5228 *Code of Practice for Noise and Vibration Control on Construction & Open Sites* (see **Paragraphs 23** to **25**). 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 89**).

88. An additional construction noise impact would be blasting associated with the proposed stone extraction from the two borrow pit areas (marked as BP01 and BP02 on **Figure 4.1a**) in order to obtain materials for the construction of internal access tracks. 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 likely that blasting noise would 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** below.

89. Where highways upgrades are 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 is considered to be not significant. Further to this, it should be noted that any required upgrades to highways were carried out for the purposes of installing the existing Kilgallioch turbines and most of the construction noise will be limited to building tracks from the existing site to the extension (details of track construction are provided in Chapter 4). Construction activities associated with building tracks to the turbines will be a sufficient distance from residential receptors that it can be considered to be not significant.

10.6.2 Operational Noise

90. The results of the noise predictions are shown at **Table 10.6.1** for the nearest residential receptors to the proposed Development. The results area valid for wind speeds of 7-12 m/s when the turbines have reached their maximum sound power level. For lower wind speeds and propagation conditions other than downwind, predicted noise levels will be lower. 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 results are also shown as noise contours on **Figure 10.1** which also shows the locations of the assessed noise receptors.

Location Name	Easting	Northing	Distance to Nearest Turbine (km)	Predicted Noise Level (dB L_{A90})	Margin to 30 dB L_{A90} limit
High Eldrig[4]	224984	569177	0.5	-	-
Low Airies	226131	566535	3.2	26	4
Artfield	223682	566123	3.3	26	4
Quarter Farm	218645	568273	4.6	22	8
Glewhilly	217237	571345	5.7	20	10
Dirniemow	217448	570847	5.5	20	10
Pultadie	218253	570027	4.7	22	8
Miltonise	218968	573422	4.9	22	9
Derry	226063	573413	6.4	27	3
Tannielaggie	228748	572073	3.0	23	7
Darloskine Bridge	227995	572901	4.3	24	6
Waterside	229434	571817	4.0	22	8
Urrall	229268	569560	4.8	23	7
Kilquhockadale	229256	567802	4.4	22	8
The Old Schoolhouse	228680	566394	4.8	21	9
Polbae	227923	572984	5.1	24	6
Balminnoch Cottage	226843	565396	4.0	22	8
Kilmacfadzean	220363	567523	4.5	25	5

Table 10.6.1 Predicted Proposed Development Noise Levels, dB L_{A90}

[4] High Eldrig is a derelict property and therefore does not require assessment, but its location is shown as it was considered as a potential sensitive receptor.

91. The results of the predictions indicate that operational noise levels are at least 3 dB below the adopted 30 dB L_{A90} noise limit, and therefore no significant operational effects are predicted.

92. All other residential properties are further from the proposed Development and therefore predicted operational noise levels are lower and therefore would also be below the adopted noise limit and no significant effects predicted.

10.7 Cumulative Assessment

10.7.1 Construction Noise

93. Construction noise effects are likely to be significantly below the adopted construction noise limit such that if any concurrent construction actives occur that are audible at nearby sensitive receptors construction noise from the proposed Development would be not significant.

10.7.2 Operational Noise

94. The operational noise limit, for the proposed Development acting alone, of 30 dB L_{A90} ensures that even if operational noise from other windfarm developments resulted in noise at receptor locations at 40 dB L_{A90}, the addition of the proposed Development would not add significantly to overall noise levels. As such, and as agreed with DGC, detailed cumulative noise predictions are not required, and the cumulative operational noise is determined to be not significant.

10.8 Mitigation

10.8.1 Construction Noise

95. While no significant noise effects are anticipated during construction there would a commitment to adhere to best practice means of controlling noise from construction activities, as advocated by BS 5228. This would be detailed within the proposed Development Construction Environmental Management Plan (CEMP).

96. 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.

97. Noise during construction works would be controlled by generally restricting works to standard working hours, unless specifically agreed otherwise. This usually means 07:00 to 19:00 during the week and 07:00 to 16:00 on weekends or as agreed with the EHO.

98. The construction works onsite 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: 2014; and
- Section 61 of the Control of Pollution Act 1974 and Section 80 of the Environmental Protection Act.

99. Where construction activities relating to highways improvements are within 200 m of a residential property, contractors would be required to assess noise impacts during the construction phase and 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 proposed Development.

100. With regards to blasting in stone extraction areas, the most appropriate way to address blasting noise 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.

10.8.2 Operational Noise

101. The adopted noise limit is met with candidate turbine assumed, and no specific mitigation is required to ensure that the limits are met. Operational noise would be controlled via planning conditions which set out noise limits for the proposed Development

10.9 Residual Effects

10.9.1 Operational Noise

102. No significant residual operational effects are predicted. Operational noise levels (including cumulative noise) meet the relevant derived noise limits.

10.9.2 Construction Noise

103. While some noise from construction activities could be audible at receptor locations at times, no significant residual construction effects are anticipated given the proposed construction best practice measures outline above and implemented with the CEMP.

10.10 Summary

104. A noise assessment was carried out in order to determine whether the proposed Development meets planning requirements in respect of operational noise from wind turbines. The assessment takes in to account the methodologies set out within ETSU-R-97, T*he 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*.

105. A noise limit of 30 dB L_{A90} was derived for the proposed Development which would ensure noise from the proposed Development does not add significantly to cumulative noise from other consented windfarms in the area, and to ensure that cumulative noise levels remain within relevant ETSU-R-97 noise limits.

106. The results of the operational noise assessment indicate that 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. The noise limit was derived to ensure that cumulative noise would also be within the relevant noise limits, and therefore cumulative noise from the proposed Development in conjunction with other windfarms is also determined to be not significant.

107. 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.

108. A summary of the noise impacts is also presented in **Table 10.10.1** below.

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	Not Applicable	Adherence to best practise guidance during construction via the implementation of a CEMP.	Not Significant	Not Applicable
During Operation					
Operational noise	Not Significant	Not Applicable	None required.	Not Significant	Not Applicable
Cumulative Effects					
Cumulative operational noise	Not Significant	Not Applicable	None required.	Not Significant	Not Applicable

Table 10.10.1 Summary Table

10.11 References

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