European Offshore Wind Deployment Centre

Environmental Statement

Appendix 24.2: In Air Noise EIA Technical Report

A project part-funded by the European Union under the European Economic Plan for Recovery in the field of Energy

1 IN - AIR NOISE IMPACT ASSESSMENT

1 This chapter describes the effects of noise at onshore locations along the shoreline north of Aberdeen from the proposed European Offshore Wind Deployment Centre (EOWDC) due to the construction and operation of the wind turbines.

2 Noise emissions associated with the construction and operation of the wind turbines will also be radiated into the water. The effects upon the marine environment due to noise being transmitted from the wind turbine support structure or pile into the water are dealt with within the underwater noise chapter.

1.1 Information for the Non-Technical Summary

3 The noise impact due to the operation of the proposed European Offshore Wind Deployment Centre on residential properties on land is assessed.

4 The operational noise assessment has been carried out according to ETSU-R-97, *Assessment and Rating of Noise from Wind Farms*, as specified in Scottish Government web based planning advice on onshore wind turbines referred to in PAN 1/2011, *Planning and Noise*, as there is no equivalent guidance for offshore wind farms affecting properties on land. The more stringent Aberdeenshire Council noise limits have also been taken into account.

5 Predictions of the typical noise levels likely to result from the operation of the wind farm were carried out based on generic noise data for a wind turbine with a rated power of up to 10 MW and a hub height of 100 m.

6 The assessment shows that predicted operational noise levels would meet the ETSU-R-97/Aberdeenshire Council night-time noise limits and lower day-time noise limits under all conditions.

7 It is assumed that piling with a hydraulic hammer causes the highest noise levels of all foundation types. The prediction of the construction noise has therefore been carried out for pile driving with assumed sound power level based on piling noise measurements elsewhere.

8 The noise limits for the construction noise have been derived from measurements of existing noise level in accordance with BS5228-1:2009 *Code of practice for noise and vibration control on construction and open sites – Part 1: Noise*. The predictions show exceedance of the night-time noise limits for piling activities. It is proposed that piling activities should be restricted to daytime hours from 07:00 to 19:00 hours only, unless otherwise agreed with Aberdeen City and Aberdeenshire Council or if significant levels of mitigation can be applied during night time hours.

9 A cumulative noise assessment of the operational wind farm noise and the diesel generator located on the potential ocean laboratory platform has been carried out. The additional noise from the diesel generator results in no increase of the predicted operational wind farm noise.

1.2 Introduction

10 An assessment has been carried out that takes into account the predicted noise immissions from the proposed EOWDC wind turbines using a generic worst case sound power level and the existing noise environment at locations along the shoreline north of Aberdeen.

11 The generic wind turbine assumed for the noise predictions has a hub height of 100 m and a maximum sound power level (SWL) of 112 dB(A) at 9 m/s at standardised 10 m height wind speed. The anticipated hub height for the EOWDC is between 100 m and 120 m. Noise predictions have been carried out for a wind turbine with a 100 m hub height as this represents the worst case in terms of source height.

12 As part of the proposed EOWDC development it is possible that an Ocean Laboratory may also be developed which could include a diesel generator for power supply, this development would be subject to a separate consent application. A prediction of the cumulative noise levels due to the combined operation of the generator and the wind turbines has been carried out.

13 An assessment has been performed of the construction noise associated with piling operations for the wind turbine foundations when using a monopile construction.

1.2.1 Methodology Consultation

14 Aberdeen Offshore Wind Farm Limited (AOWFL) submitted a Request for an Environmental Impact Assessment (EIA) Scoping Opinion in August 2010. Chapter 6.9 deals with airborne noise assessment. None of the responses received identified specific requirements for airborne noise assessment for residential properties onshore.

15 The Environmental Health Officers of Aberdeen City Council and Aberdeenshire Council have been consulted regarding the operational noise assessment methodology and the choice of measurement locations for the baseline noise survey:

- Andrew Gilchrist, Aberdeen City Council (110106)
- John Dawson, Aberdeenshire Council (110106)

1.2.2 Key Guidance Documents

16 The following documents have been used in the assessment:

- Scottish Executive (2011). Planning Advice Note PAN 1/2011: Planning and Noise
- Scottish Executive (2010). Web based ‘renewables advice’
- Department of Trade and Industry (1996). The Assessment and Rating of Noise from Wind Farms ETSU-R-97
- Aberdeenshire Council (2005). Use of Wind Energy in Aberdeenshire: Guidance for Developers – Supplementary Planning Guidance Part 1
- Institute of Acoustics Bulletin Vol 34 No 2, March/April 2009 Prediction and Assessment of Wind Turbine Noise

- British Standards Institution (BSI) (2009). BS 5228:2009 Code of practice for noise and vibration control on construction and open sites – Part 1: Noise
- The Scottish Government (2011). Technical Advice Note – Assessment of Noise

17 The documents listed above have all been written for the purpose of assessing onshore developments but have been adopted for this project as providing suitable guidance on assessing background noise and deriving noise limits for the onshore residential properties.

18 Advice on long-range sound propagation over sea has been taken from:

- Mathieu Boué (2007). Report for Swedish Energy Agency: Long-range sound propagation over the sea with application to wind turbine noise.

1.2.3 Data Information and Sources

19 Background noise monitoring was carried out at 6 locations for three weeks. The results of this survey and the derivation of the noise limits is described in the baseline technical report *Measurement of background noise data and rainfall (Hayes McKenzie Partnership Ltd (HMPL), 2011)*.

20 Wind speed was simultaneously measured with a SoDAR (Sound Detection and Ranging) remote sensing device on a field at Easter Hatton, Balmedie, an onshore location near the coastline. This onshore wind data has been translated to the offshore wind farm location as described in (Oldbaum 2011).

- Oldbaum Services Limited (2011a). Wind speed data spatial translation – Method Statement for Aberdeen Offshore Windfarm Limited
- Hayes McKenzie Partnership Ltd. (2011). Measurement of background noise data and rainfall.
- Hayes McKenzie Partnership Ltd. (2011). Baseline Technical Report for European Offshore Wind Deployment Centre.
- Oldbaum Services Limited (2011b). Wind speed data spatial translation – Wind data analysis for Aberdeen Offshore Windfarm Limited

1.2.4 Impact Assessment Methodology

21 Planning Policy Guidance associated with the development of wind farms currently only deals with onshore developments regarding airborne noise. In the absence of detailed Planning Guidance on the development of Offshore Wind Farms and noise immissions, the best current practice for onshore developments as been referred to.

22 When wind speeds are high any noise is masked by wind induced noise effects, particularly that of the trees being blown. Noise from the sea and the traffic noise from the A90 will also contribute to the masking of noise from the proposed EOWDC wind turbines but this will be more significant at lower wind speeds when wind induced background noise may be low. Wind turbine noise increases with wind speed up to rated power with very low levels of noise being generated at lower wind speeds.

23 Noise levels are normally expressed in decibels. Noise in the environment is measured using the dB(A) scale which includes a correction for the response of the human ear to noises with different frequency content. Planning Advice Note PAN 1/2011, *Planning and Noise* (Scottish Executive, 2011) states that:

'For noise of a similar character, a change of 3 dB(A) is the minimum perceptible under normal conditions, and a change of 10 dB(A) corresponds roughly to halving and doubling the loudness of a sound'.

24 It also provides examples of noise levels from certain activities as shown in Table 1 (below).

Table 1: Examples of Indicative Noise Levels*

Source/Activity	**Indicative noise level dB (A)**
Unsilenced pneumatic drill (at 7 m distance)	95
Heavy diesel lorry (40km/h at 7 m distance)	83
Modern twin-engine jet (at take-off at 152 m distance)	81
Passenger car (60 km/h at 7m distance)	70
Office environment	60
Ordinary conversation	50
Quiet bedroom	35

* Based on information in PAN 1/2011, Planning and Noise

1.2.4.1 *Legislative and Planning Context*

***Planning Advice Note PAN1/2011, Planning and Noise* (Scottish Executive, 2011)**

25 PAN1/2011 replaces PAN56 *Planning and Noise*. It 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 renewable technologies for onshore wind turbines.

26 PAN1/2011 states that the Control of Pollution Act 1974 and the Pollution and Prevention Control Act 1999 are suitable to limit noise from temporary construction sites.

***Scottish Executive Web Based Planning Advice, Onshore Wind Turbines* (Scottish Executive, 2010)**

27 The web based Planning Advice, Onshore Wind Turbines refers to ETSU-R-97, *Assessment and Rating of Noise from Wind Farms* (DTI, 1996a), as the document that *'should be followed by applicants and consultees, and used by planning authorities to assess and rate noise from wind energy developments*'. There is no equivalent guidance for offshore wind farms, but there is no reason why the ETSU-R-97 guidance should not apply. ETSU-R-97 contains noise limits designed to protect external amenity during the day and sleep disturbance at night. These limits are derived from baseline noise measurements carried out at potentially affected properties around the proposed development site.

***ETSU-R-97, The Assessment and Rating of Noise from Wind Farms* (DTI, 1996a)**

28 ETSU-R-97, *The Assessment and Rating of Noise from Wind Farms*, 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 wind farm noise assessments. The group comprised independent experts on wind turbine noise, wind farm developers, DTI personnel and local authority EHOs. 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 wind farm noise and contains suggested noise limits, which were derived with reference to existing standards and guidance relating to noise emission from various sources.

29 It is recommended that noise limits should be applied to external locations used for relaxation or where a quiet environment is highly desirable. These limits should be set relative to background noise and should reflect the variation in both wind turbine source noise and background noise with wind speed. It is not, however, necessary to use a margin above background in particularly quiet areas as such low limits are not necessary to offer a reasonable degree of protection to wind farm neighbours.

30 Separate noise limits should apply for day-time and for night-time as during the night the protection of external amenity becomes less important and the emphasis should be on preventing sleep disturbance.

31 The form of the noise limits proposed in ETSU-R-97 is that noise should be limited to X dB L_{A90} or 5 dB above the 'prevailing background noise level', whichever is the greater.

32 The $L_{A90,T}$ is the A-weighted sound pressure level exceeded for 90% of a given time period T. Background noise is commonly measured using this index. The $L_{Aeq,T}$ is the equivalent continuous A-weighted sound pressure level determined as an energetic average during a certain time interval T. The A-weighting curve is based on the inverted 40 phon equal loudness curve and is designed to mimic the human hearing over a certain frequency range.

33 For night-time (2300-0700) the value of 'X' is given as 43, to protect against sleep disturbance indoors with a window open. The 43 dB(A) 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}. The prevailing background noise is that acquired during the same night-time hours.

34 For day-time hours (evenings and week-ends) 'X' is given as 35-40 with the actual value in the range dependant on:

- The number of dwellings in the neighbourhood of the wind farm
- The effect of noise limits on the number of kWh generated
- The duration and level of exposure

The prevailing background noise is that acquired during the quiet day-time hours, as defined in ETSU-R-97.

35 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}. The L_{A90} is the noise level which is exceeded for 90% of the measurement period 't'. It is recommended that at least 1 week's worth of measurements is required.

36 It is stated that the $L_{A90,10min}$ noise descriptor should be adopted for both background and wind farm noise levels and that, for the wind farm 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 wind farm noise allows reliable measurements to be made without corruption from relatively loud, transitory noise events from other sources.

37 ETSU-R-97 also specifies that a penalty should be added to the predicted noise levels, where any tonal component is present. The level of this penalty is described and is related to the level by which any tonal components exceed audibility.

***Use of Wind Energy in Aberdeenshire: Supplementary Planning Guidance Part 1* (Aberdeenshire Council, 2005)**

38 As a variation to the lower fixed noise limits described by ETSU-R-97, (see above), Aberdeenshire Council specifies the lower noise limits at 38 dB $L_{A90,10min}$ during night-time and 35 dB $L_{A90,10min}$ during day-time for very quiet locations. These lower fixed noise limits are valid for measurements carried out externally.

Institute of Acoustics Bulletin Article, Prediction and Assessment of Wind Turbine Noise, March/April (IoA Bulletin 34, 2009

39 Institute of Acoustics (IoA) Bulletin Vol 34 no. 2 contains an agreement, jointly authored by a number of consultants working in the wind turbine sector for both developers, local authorities and third parties, on an agreed methodology for addressing issues not covered by ETSU-R-97. This includes a methodology for dealing with wind shear.

40 It should be noted that this article is written in the context of onshore wind farms, but the recommendation for dealing with wind shear is also applicable for offshore wind farms.

Blade Swish (Aerodynamic Modulation)

41 The noise limits prescribed in ETSU-R-97 take into account the fact that all wind turbines exhibit the character of noise described as blade swish, to a certain extent. *The Measurement of Low Frequency Noise at Three UK Wind Farms* (DTI, 2006), concluded that *'the common cause of complaints associated with noise at all three wind farms is not associated with low frequency noise, but is the audible modulation of the aerodynamic noise, especially at night'*. It suggests that *'it may be appropriate to re-visit the issue of aerodynamic modulation (AM) and the means by which it should be assessed'*.

42 As a result, Salford University carried out a study, jointly commissioned by the Department for Food, Environment and Rural Affairs (Defra), Department for Business, Enterprise and Regulatory Reform (BERR, formerly the DTI) and the Department for Communities and Local Government (DCLG), to investigate AM of wind turbine noise. The results were published by way of report NANR233 *Research into Aerodynamic Modulation of Wind Turbine Noise*, which concluded that AM was only considered to be a definite factor at four, and a possible factor at eight, out of the 133 sites (all the sites in the UK operational at the time of the study) considered. At the four sites, it was considered that conditions associated with AM might occur between about 7% and 15% of the time.

43 In a statement accompanying the published report, BERR states that it *'continues to support the approach set out in Planning Policy Statement (PPS) 22 – Renewable Energy. This approach for local planning authorities to ensure that renewable energy*

developments have been located and designed in such a way to minimise increases in ambient noise levels, through the use of the 1996 report by ETSU to assess and rate noise from wind energy developments.' PPS 22 is the relevant English planning advice covering onshore wind turbines, equivalent to the Scottish PAN 45.

44 Renewable UK, the trade body representing the wind and marine energy industry, has recently commissioned a research project involving two university departments specialising in noise issues, two independent UK consultancy practices and a well respected researcher in the field of source localisation on wind turbine blades to carry out further research into this issue.

45 The above effects are described for onshore wind farms. It has yet to be determined whether these affects arise for offshore wind farms.

Infrasound

46 Infrasound is defined as noise occurring at frequencies below that at which sound is normally audible, i.e. at less than 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 at a very high amplitude and it is generally considered that when such sounds are perceptible then they can cause considerable annoyance.

47 Wind turbines have been cited as significant producers of infrasound. This has, however, been due to the high levels of such noise, as well as audible low frequency thumping noise, occurring on older 'downwind' wind turbines of which many were installed in the USA prior to the large scale take up of wind power production in the UK. Downwind wind 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 infrasonic components, each time a blade passes the tower. Virtually all wind turbines which have been installed in the UK, however, have been of the upwind design; that is with the blades up wind of the tower, such that this effect is eliminated.

48 The DTI (2006) report 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 that '*there is no reliable evidence that infrasounds below the hearing threshold produce physiological or psychological effects'* it may 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'*.

Low Frequency Noise

49 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 wind farm site increases the noise level decreases as a result of the spreading out of the sound energy but also due to air absorption which increases with increasing 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 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. The DTI study showed that low frequency noise could be measurable on occasion but was below

the low frequency noise criterion published in DEFRA Project Report NANR45, Proposed Criteria for the Assessment of Low Frequency Noise Disturbance.

1.2.4.2 Construction Site Noise Planning Policy Guidance

BS 5228, Code of Practice for Noise and Vibration Control on Construction and Open Sites **(British Standards Institution, 2009)**

50 British Standard BS5228 was re-issued in 2009 as BS5228: 2009, *Code of Practice for Noise and Vibration Control on Construction and Open Sites*.

51 The Control of Pollution Act 1974 provides a legal framework for the control of construction noise. Example criteria for the assessment of construction noise effects and a method for prediction of noise levels from construction activities are given in BS5228. Two example methods are provided for assessing the impact of construction activities.

52 The first is based on the use of criteria defined in Department of the Environment (DoE) 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 and 75 dB(A) in urban areas near main roads in heavy industrial areas. 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} and 72 dB(A) respectively.

53 The second is based on noise change but applies minimum criteria of:

- 45 dB L_{Aeq}: night-time (2300-0700)
- 55 dB L_{Aeq}: evening and weekends (1900-2300 weekdays, 1300-2300 Saturdays and 0700-2300 Sundays)
- 65 dB L_{Aeq}: daytime (0700-1900) including Saturdays (0700-1300)

These criteria are applicable when existing noise levels are low, and subject to a construction period of one month or more. The threshold values are based on measured background data and give limits in three categories A, B and C, depending on the magnitude of the background noise levels. It should be noted that the time period to which each limit applies also defines the time averaging period for the calculated L_{Aeq}.

1.2.4.3 Sleep Disturbance Criteria

54 International Guidance concerning the effects of noise upon sleep are covered in a number of documents discussed within ETSU-R-97. In general, if internal noise levels are limited to a range of no more than 30 - 35 dB L_{Aeq}, then sleep disturbance and any adverse effects of noise upon sleep will be minimised. Since the issue of ETSU-R-97 further guidance has been issued by the World Health Organisation (WHO): *Guidelines for Community Noise* in March 2000 and *Night Noise Guidelines for Europe* in 2009.

55 The Guidance within BS 8233: 1999 *Sound Insulation and Noise Reductions for Buildings – Code of Practice* (BSI, 1999) follows the advice contained within the WHO (2000) Report on Community Noise which states that unoccupied indoor ambient noise levels within bedrooms are a "good " design when in the range of

around 30 dB L_{Aeq} and “reasonable” when around 35 dB L_{Aeq}. Individual noise events should also be limited to no more than 45 dB L_{Amax}. This internal noise level criterion is not relevant for operational wind turbine noise as it refers to individual, discrete noise events, but is applicable for driving piles into the seabed for wind turbine foundations.

56 The WHO World Health Organisation (WHO) *Night Noise Guidelines for Europe* advises as to what is an acceptable external noise level to a bedroom and gives a value of $L_{night,outside}$ = 40 dB below which no effect harmful to health has been observed and this level is therefore recommended as night noise guideline. It should be noted that this is an average noise level over a period of 8 hours per night over a whole year. Due to the nature of the averaging, events with higher and lower short-term noise level can occur during this period.

1.2.4.4 Prediction of Wind Turbine Noise Levels

57 Noise predictions were carried out using International Standard ISO 9613, Acoustics – Attenuation of Sound During Propagation Outdoors (International Organization for Standardization, 1996) but with an adjustment added to allow for long distance propagation over the sea surface. The propagation model described in Part 2 of this standard provides for the prediction of sound pressure levels based on either short-term downwind (i.e. worst case) conditions or long term overall averages up to 1000 m. Only the downwind condition has been considered in this assessment, that is for wind blowing from the proposed development site towards the nearby houses. When the wind is blowing in the opposite direction noise levels will be significantly lower, especially if there is any shielding between the site and the houses. Therefore, the results of the assessment should be considered as the ‘worst case’ in that they any impacts identified will only be present for a limited duration when winds are blowing onshore.

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

Predicted Octave Band Noise Level = $L_w + D – A_{geo} - A_{atm} – A_{gr} - A_{bar} - A_{misc}$

59 The predicted octave band levels from each of the wind turbines are summed together to give the overall ‘A’ weighted predicted sound level from all the wind turbines acting together. These factors are discussed in detail below.

L_W - Source Sound Power Level

60 The sound power level of a noise source is normally expressed in dB re: 1pW (10^{-12} Watt). Noise predictions have been based on source sound power levels of a typical 3 MW class offshore wind turbine with a 4 dB margin added to represent a generic 10 MW wind turbine. This approach has been adopted so that predictions are higher than the sound power level of currently operational offshore wind turbines and therefore assumed to be worst case. The noise levels for different wind speeds are shown in Table 2.

Table 2: **Wind Turbine Source Sound Power Levels for a Generic 10 MW Wind Turbine with 100 m Hub Height**

Standardised Wind Speed at 10 m height (m/s)	Sound Power Level (dB L_{Aeq} re 1 pW)
4	99.5
5	109.6
6	111.5
7	112.0
8	112.0
9	112.0
10	112.0

61 The noise spectrum used is shown in Table 3. This data is based on typical octave band spectra of a 3 MW class wind turbine for 8 m/s (referenced to 10 m height) and has then been normalised to the overall sound power level at each integer wind speed.

Table 3: **Normalised Noise Spectrum for Maximum Sound Power Level for a Generic 10 MW Wind Turbine with Hub Height 100 m**

Octave Band Centre Frequency (Hz)	Normalised Octave Band Sound Power Level (dB L_{Aeq} re 1 pW)
63	91.6
125	100.9
250	105.9
500	107.0
1k	106.6
2k	99.9
4k	89.7
8k	76.8

D – Directivity Factor

62 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 down wind direction, corresponding to the worst case propagation conditions considered here and needs no further adjustment.

A_{geo} – Geometrical Divergence

63 The geometrical divergence accounts for spherical spreading in the free-field from a point sound source resulting in attenuation depending on distance. It has been found

in various publications (e.g. Boué, 2007 and Søndergaard, 2005) that for sound propagation at sea, spherical spreading is only applicable up to a certain distance. Measurements of piling activities carried out by Hayes McKenzie Partnership Ltd have found that the prediction correlates well with a distance of 800 m for the spherical spreading term:

$A_{geo} = 20 \cdot \log(800) + 11$

64 At distances beyond 800 m the propagation is modelled with cylindrical spreading:

$A_{geo} = 10 \cdot \log(d/800)$

where d = distance from the wind turbine.

65 Each of the wind turbines may be considered as a point source beyond distances corresponding to one rotor diameter.

***A_{atm}* - Atmospheric Absorption**

66 Sound propagation through the atmosphere is attenuated by the conversion of the sound energy into heat. This attenuation is dependent on the temperature and relative humidity of the air through which the sound is travelling and is frequency dependent with increasing attenuation towards higher frequencies. The attenuation depends on distance according to:

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

where d = distance from the wind turbine
α = atmospheric absorption coefficient in dB/m.

67 Published values of 'α' from ISO 9613 Part 1 (International Organization for Standardization, 1992), corresponding to a temperature of 10ºC and a relative humidity of 70% have been used for these predictions. These are the values specified in the Acoustics Bulletin article *Prediction and Assessment of Wind Turbine Noise* (IoA, 2009), which give relatively low levels of atmospheric attenuation, and subsequently worst case noise predictions as shown in Table 4.

Table 4: **Frequency dependent Atmospherical Absorption Coefficients (10℃ and 70% Humidity)**

Octave Band Centre Frequency (Hz)	Atmospheric Absorption Coefficient (dB/m)
63	0.00012
125	0.00041
250	0.00104
500	0.00193
1k	0.00366
2k	0.00966
4k	0.0328
8k	0.117

***A_{gr}* - Ground Effect**

68 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 is inherently complex and depends 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 predictions have been carried out using a source height corresponding to the proposed height of the wind turbine nacelle, a receiver height of 4 m and an assumed ground factor G = 0 for the water surface.

***A_{bar}* - Barrier Attenuation**

69 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 down wind conditions. The results of a study of propagation of noise from wind farm sites carried out for ETSU (DTI, 2000) concludes that an attenuation of just 2 dB should be allowed where the direct line of site between the source and receiver is just interrupted and that 10 dB should be allowed where a barrier lies within 5 m of a receiver and provides a significant interruption to the line of site. It should be noted that no barrier attenuation has been used in any of the noise predictions carried out here.

***A_{misc}* – Miscellaneous Other Effects**

70 ISO 9613 includes effects of propagation through foliage, industrial plants and housing as additional attenuation effects. These have not been included here and any such effects are unlikely to significantly reduce noise levels below those predicted.

Tonality

71 No allowance has been made for the character of the noise emitted by the wind turbines. In general, wind turbines exhibit little tonality within the radiated noise. However, an appropriate method to control such a character is through the imposition of a Planning Condition which limits the level of tonality that a site may emit. ETSU-R-97 defines a method by which tonality may be assessed and proposes a penalty system for any tonality which might be measured.

Wind Shear

72 It is now well established that wind speed experienced by a wind turbine cannot be correctly predicted from 10 m height wind speed measurements and ground roughness conditions alone. Hub height wind speed, and hence the wind speed experienced by the wind turbine, may be under-predicted under these conditions and hence the output noise level may be under-predicted. To correctly account for this in the assessment methodology, background noise is referenced to hub height wind speed, as described in the agreement published in the IoA Bulletin (IoA, 2009).

73 Wind speed and direction was measured with an AQ500 SoDAR remote sensing device at Easter Hatton, Balmedie, an onshore location near the coastline. The data was recorded in 5 m steps from 50 m to 200 m. This data has been translated to the location of the proposed EOWDC as described in (Oldbaum 2011b). For the assessment, the measured data correlating to hub height wind speed is used.

74 This translated hub height wind speed has then been corrected to 'standardised' 10 m height wind speed, as required by the method described in (IoA, 2009) using the same methodology as is used by the manufacturers to produce noise data for 'standardised' 10 m height wind speed, i.e.:

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

75 Where V_{10} and V_h are the 'standardised' 10 m height (h_{10}) and hub height (h_h) wind speeds respectively, and z_0 is the standardised ground roughness length (= 0.05 m).

76 This standardisation is not intended to reflect actual 10 m height wind speed conditions and does not affect the relationship between wind turbine noise, background noise, and the derived noise limits.

1.2.4.5 Prediction of Construction Noise Associated with Wind Turbine Erection

77 Noise associated with the construction of the wind turbines will be caused by the following sources:

- Noise associated with the insertion of the wind turbine tower foundation
- Noise associated with the erection of the wind turbine tower and nacelle/rotor assembly
- Noise associated with boat movements to and from shore
- Noise associated with onsite activities such as cable laying at the point the cable comes ashore.

78 The potentially noisiest activity associated with these potential sources is related to the installation of the wind turbine foundation. The method of foundation construction that will generate the greatest level of noise is associated with a monopile foundation system.

79 Drilling of the monopile would minimise the noise emissions from this construction operation, however, it may be necessary to drive the pile into the seabed. If this is the case, then there is the potential for impulsive piling noise to occur.

80 Specifically, if the monopile is driven into the sea bed, levels associated with this method of pile insertion can generate measured sound pressure levels as high as 105 dB L_{Amax} and 93 dB $L_{Aeq,1\ minute}$ measured at a distance of 55 metres from the pile. This is equivalent to a source noise level of L_{WAmax}=151 dB re: 1 pW and L_{WA}=139 dB re: 1 pW respectively.

1.2.4.6 Spatial Extent of Effect

81 The construction of the proposed EOWDC will have a regional effect. The piling noise levels will be greater than 65 dB $L_{Aeq,1minute}$ for up to 1.6 km distance from the piling location. The piling will still be audible at a greater distance further inland especially when background noise is low and the influence of the surf and the A90 traffic noise decrease.

82 The operational noise will have a local effect on the nearest properties along the shore in the vicinity of the proposed EOWDC.

1.2.4.7 Duration of Effect

83 The highest construction noise due to the piling process is expected to last 24 hours per location at a maximum, i.e. 11x 24 hours. It is expected that there are breaks inbetween, when the vessel is relocated and the next monopile lifted in position. Therefore this will have a temporary effect on the residents.

84 The Crown Estate lease for the proposed EOWDC is 22 years, the project will therefore have a long-term effect. It is assumed that the wind farm will be decommissioned after its operational span of life has been reached so that the effect is not considered permanent.

1.2.4.8 Scale of Effect

85 Table 5 is taken from the Technical Advice Note (TAN Noise) on the Assessment of Noise issued by The Scottish Government in association with PAN 01/2011.

Table 5: Classification of Magnitude on Noise Impacts according to TAN *Assessment of Noise* (Table 2.2)

Descriptor for Magnitude of Impact	Generic Criteria of Descriptor
Major adverse	Loss of resource and/or quality of resource; severe damage to key characteristics, features or elements
Moderate adverse	Loss of resource, but not adversely affecting the integrity; partial loss of/damage to key characteristics, features or elements
Minor adverse	Some measurable change in attributes, quality or vulnerability; minor loss of, or alteration to, one (maybe more) key characteristics, features or elements
Negligible adverse	Very minor loss or detrimental alteration to one or more characteristics, features or elements
No change	No loss or alteration of characteristics, features or elements; no observable impact

1.2.4.9 Recoverability of the Receptor

86 Due to the limited time of 11 days with high noise levels from the piling noise, it is expected that the receptor, i.e. the residents in the affected area, will fully recover from any effects.

1.2.4.10 Importance of the Receptor

87 The receptor, i.e. the affected residents near the shore, is considered of high importance.

1.2.5 Implications of Significance

88 The receptors closest to the shore and the A90 are considered of medium sensitivity as background noise is relatively high. Further inland with fewer other noise sources, the sensitivity increases.

89 Schools, hospitals/residential care homes, residential properties with low background noise, conference facilities and quiet outdoor areas used for recreation are considered to have a high sensitivity to noise.

1.2.6 Cumulative Impact Assessment Methodology

90 Cumulative impact assessments have been undertaken on all existing and any reasonably foreseeable project/development activities. The possible development of an Ocean Laboratory has been considered as having the potential to contribute to cumulative impacts and has been assessed.

1.2.7 Worst Case

91 At this stage of the project, no decision has been made on which wind turbine foundation type will be adopted. The noise associated with a hydraulic hammer driving monopiles into the seabed is assumed to be the loudest of all foundation types. It is also the loudest activity of the construction process itself. The prediction of construction noise from piling 8.5 m diameter monopiles is therefore considered worst case.

92 There is no information available about the sound power level of potential candidate wind turbines. Some of the wind turbine types in the offshore market are still in the development stage and the manufacturer can therefore not yet issue information about the sound power level. Generic sound power level data has been assumed based on source sound power levels of a typical 3 MW class offshore wind turbine with an added margin of 4 dB which is considered worst case for currently available offshore wind turbine models. The anticipated hub height for the EOWDC is between 100 m and 120 m. Noise predictions have been carried out for a wind turbine with a 100 m hub height as this represents the worst case in terms of source height.

93 A worst case cumulative noise assessment that considers a possible ocean laboratory has been carried out for the construction and operational phases of the proposed EOWDC. This includes the possible installation of an additional 8.5 m diameter monopile and a diesel generator during the operational phase. It is possible that if the ocean laboratory is developed a diesel generator may not be required.

1.3 Impact Assessment

1.3.1 Deployment of 11 Wind Turbines

1.3.1.1 Construction Phase

Potential Impacts

94 The noise limits for the construction period are based on Table E.1 in BS5228 – Part 1 (BSI, 2009), derived from the average measured LAeq from the background noise survey as displayed Table 6. Sound pressure levels measured at wind speeds >5m/s have been removed from further assessment. This is in accordance with BS4142:1997 Method for Rating industrial noise affecting mixed residential and industrial areas and BS7445 Description and measurement of environmental noise (BSI, 1991).

95 For the purpose of assessing the noise generated by the construction of the proposed EOWDC, hours are defined as follows:

- daytime: 07:00-19:00 weekdays
  07:00-13:00 Saturdays
- evenings and weekends: 19:00-23:00 weekdays
  13:00-23:00 Saturdays
  07:00-23:00 Sundays
- night-time: 23:00-07:00

Table 6: Arithmetic averaged measured Sound Pressure Level at Measurement Locations

Location	Easting	Northing	Average Measured Day L_{Aeq}, dB	Average Measured Evenings and Weekends L_{Aeq}, dB	Average Measured Night L_{Aeq}, dB
Four Winds	395191	814956	54	53	44
16 Chapelwell Wynd	396968	817138	49	45	40
Easter Hatton	396245	816102	61	57	52
Hareburn House*	396294	813979	57	55	53
3 Tarbothill Farm Cottages	395696	813430	56	51	48
16 Dubford Gardens	393913	812139	49	41	32

*data only available for 3 days

96 Table 7 shows the suggested noise limits for the construction activities based on the average measured background at each property. BS5228 (BSI, 2009) gives threshold values for a whole period, e.g. an $L_{Aeq,day}$ for a period of 12 hours.

Table 7: Noise Limits derived from Table E.2 in BS 5228 – Part 1 at the Measurement Locations.

Location	Easting	Northing	Noise Limit Day L_{Aeq}, dB	Noise Limit Evenings and Weekends L_{Aeq}, dB	Noise Limit Night L_{Aeq}, dB
Four Winds	395191	814956	65	60	45
16 Chapelwell Wynd	396968	817138	65	55	45
Easter Hatton	396245	816102	65	60	55
Hareburn House*	396294	813979	65	60	55
3 Tarbothill Farm Cottages	395696	813430	65	55	55
16 Dubford Gardens	393913	812139	65	55	45

*data only available for 3 days

97 Predictions of the incident noise levels at the shore-line have been performed using the same method as for noise from an operational wind farm. The noise spectrum was taken from a measurement during piling activity carried out by HMPL. The highest equivalent sound pressure level measured at a distance of 55 metres from the pile was 93 dB $L_{Aeq,1minute}$. This is equivalent to a source noise level of L_{WA}=139 dB re: 1 pW. The predicted noise levels for the same six locations as for the operational wind farm assessment are detailed in Table 8 below.

Table 8: Predicted Noise Levels $L_{Aeq,1minute}$ associated with driven Monopile Activity at Wind Turbine Locations and potential Ocean Laboratory

Location	WT location											
	1	2	3	4	5	6	7	8	9	10	11	Ocean Lab
Four Winds	63	64	64	62	63	63	62	62	62	61	61	63
16 Chapelwell Wynd	63	64	66	63	64	65	63	64	65	63	63	63
Easter Hatton	64	65	66	63	64	65	63	63	64	62	62	64
Hareburn House	66	66	66	65	65	65	63	63	63	62	62	66
3 Tarbothill Farm Cottages	65	65	65	64	64	63	62	62	62	61	61	65
16 Dubford Gardens	62	62	61	61	62	60	60	60	59	59	58	62

98 As it is proposed that pile insertion for the tower support structures may occur during any period of the day or night, it is appropriate to consider the worst-case noise impact that may occur, i.e. the potential for sleep disturbance of residents within dwellings facing the site. Therefore, the potential for construction noise is evaluated against the criterion of 45 dB $L_{Amax,inside}$ for night time operations. Assuming an attenuation of 10 dB, the outside level above which sleep of the residents is likely to be disturbed is 55 dB L_{Amax}.

99 Table 9 shows the predicted $L_{Amax,outside}$ based on the maximum sound power level determined during a measurement of a 30 minute piling operation carried out by HMPL.

100 The maximum sound pressure level measured at a distance of 55 metres from the pile was 105 dB L_{Amax}. This is equivalent to a source noise level of L_{WAmax}=151 dB re: 1 pW.

Table 9: Predicted Noise Levels $L_{Amax,outside}$ associated with Driven Monopile Activity at Wind Turbine Locations and potential Ocean Laboratory

Location	WT location											
	1	2	3	4	5	6	7	8	9	10	11	Ocean Lab
Four Winds	75	76	76	74	75	75	74	74	74	73	73	76
16 Chapelwell Wynd	75	76	78	75	76	77	75	76	77	75	75	75
Easter Hatton	76	77	78	75	76	77	75	75	76	74	71	76
Hareburn House	78	78	78	77	77	77	75	75	75	74	74	78
3 Tarbothill Farm Cottages	77	77	77	76	76	75	74	74	74	73	73	77
16 Dubford Gardens	74	74	73	73	73	72	72	72	71	71	70	74

101 As there is only limited information available about the foundation type(s) that could be used for the proposed EOWDC it has not yet been decided which equipment will be used for the construction period, the relevant sound power level has had to be assumed for this assessment. The predicted piling noise is based on measurements previously carried out by HMPL for an offshore piling noise assessment.

102 The predicted $L_{Aeq,1minute}$ in Table 8 exceeds the suggested daytime noise limits in Table 7 by 1 dB at the three closest locations to the development. At Chapelwell Wynd and Easter Hatton this would only be the case for the piling at location 3. At Hareburn House this would be the case for turbine location 1-3 and at the potential ocean laboratory location.

103 The predicted $L_{Aeq,1minute}$ would, however, comply with the noise criterion of proposed noise limit of 67 dB L_{Aeq} for rural and suburban areas as suggested in the Environment Advisory Leaflet 72, *Noise Control On Building Sites* (DoE, 1976).

104 Comparing the predicted noise levels in Table 8 with the evening and weekend noise limits in Table 7 shows that the noise limits are exceeded at all locations by a minimum margin of 4 dB at Four Winds and a maximum margin of 11 dB at 16 Chapelwell Wynd.

105 The night-time noise limits in Table 7 are exceeded at all locations by a minimum margin of 10 dB at 3 Tarbothill Farm Cottages and by a maximum margin of 21 dB at 16 Chapewell Wynd.

106 Table 10 shows the highest predicted $L_{Aeq,1minute}$ for each property and a comparison with the adopted criterion.

Table 10: Comparison of highest Predicted Noise Level $L_{Aeq,1minute}$ at each Property with adopted Noise Limits, yes / no indicate if value is within the noise limit, values in brackets indicate exceedance above the noise limit.

Location	Highest predicted $L_{Aeq,1minute}$, dB	DoE AL 72 Noise Limit (67 dB L_{Aeq})	BS 5228 – Part 1 Noise Limits (see Table 7)		
			Day L_{Aeq}, dB	Evenings/ Weekends L_{Aeq}, dB	Night L_{Aeq}, dB
Four Winds	64	Yes	Yes	No (+4 dB)	No (+19 dB)
16 Chapelwell Wynd	66	Yes	No (+1 dB)	No (+11 dB)	No (+21 dB)
Easter Hatton	66	Yes	No (+1 dB)	No (+6 dB)	No (+11 dB)
Hareburn House*	66	Yes	No (+1 dB)	No (+6 dB)	No (+11 dB)
3 Tarbothill Farm Cottages	65	Yes	Yes	No (+10 dB)	No (+10 dB)
16 Dubford Gardens	62	Yes	Yes	No (+7 dB)	No (+17 dB)

107 It should be noted that the noise levels measured by HMPL decreased during the piling operation by 8 dB within half an hour due to the immersion of the hydraulic hammer into the water.

108 The maximum sound pressure levels are considerably higher due to the impulsive nature of the piling operation with a hammer. Comparing the highest predicted maximum sound pressure level of 78 dB L_{Amax} in Table 9 with the WHO noise level for sleep disturbance of 55 dB L_{Amax} for outside the bedroom window shows that the sleep disturbance criterion is exceeded by up to 23 dB at the closest locations.

109 With regard to the impact from piling noise during the daytime it is expected that the noise from driving a pile into the seabed has a minor adverse impact on the residents during the daytime at those properties where background noise is already high due to the noise from the surf and the A90. It is assumed that due to the repetitive nature of the piling noise and slight exceedance of the daytime noise limits, the noise will be noticeable (mildly intrusive) and may cause small changes in behaviour such as closing the windows or turning up the volume of the TV/radio (see Table 5 above and Table 2.5 in (TAN Noise)). At properties further away from the A90 and the coast and therefore with lower background noise, effects may increase and have a minor to moderate adverse impact for a limited time as the piling noise will be more noticeable and may be perceived as disruptive.

110 Due to the limited period of time it is expected that the residents will fully recover from any disturbance during the day-time. The recovery period after disturbed sleep for up to 12 nights would, in all likelihood, be longer. A full recovery is expected once the construction phase is completed. The impact on the closest neighbours of the proposed EOWDC due to piling noise during evenings/weekends is expected to be between minor and major adverse depending on the prevailing background noise and the distance to the development. The repetitive nature and the magnitude may be perceived as mildly intrusive up to very disruptive if the noise impact requires a significant change in behaviour such as keeping windows closed at all times, or not being able to use the garden in the evenings.

111 The impact from piling noise during the night-time, the impact is expected to be between minor and major adverse for the L_{Aeq}, depending on the location, i.e. distance to the development, and the prevailing background noise. For the closest properties it may result in loss of regular sleep and increased stress due to the magnitude of the noise levels and the nature of the noise (repetitive). It is considered to be major adverse impact for these properties. Depending on prevailing background noise and increasing distance to the piling activity, the impact will be reduced.

112 The impact on undisturbed sleep will be major adverse for the closest properties but would also affect a wider area when assessing the maximum sound pressure level against the adopted sleep disturbance criteria due to the magnitude of the noise levels. The generated noise levels will be well above the recommended criterion for undisturbed sleep and therefore prevent regular sleep.

113 The predicted piling noise will have a major and thus significant impact on the residents during evenings/weekends and during the night through temporary loss of amenity and likelihood of disturbed sleep during the driving of the monopiles.

114 Due to the limited period of the piling operation to 12 days, the effect on the surrounding properties during the day is regarded to be less significant than for the evening/weekend or night-time. BS 5228-1:2009 (BSI, 2009) states in Appendix E.3.2 that '*if the total noise level exceeds the appropriate category value* (i.e. noise limit), *then a significant effect is deemed to occur*.' The exceedance of the noise limits occurs only during a very limited period at the beginning of the piling process and a limited number of properties on a limited number of days (i.e. when piling the closest locations). This is a potential significant effect but is considered reversible and only of limited duration. Therefore the effect is expected to be acceptable.

Mitigation

115 It is impossible to calculate the reduction of noise levels due to proposed noise mitigation measures as very little data is available for airborne noise reduction of offshore piling operation and currently it is uncertain which machinery will be used.

116 Suggestions for the noise reduction of onshore building construction sites is available but it should be noted that those piles are much smaller in diameter and therefore much less energy is needed to drive them and thus a lower noise emission is produced. It is possible that suggested measures might not be practically feasible at sea.

117 Potential mitigation measures at the source could include enclosing the hammer head and the top of the pile in an acoustic screening or using a resilient pad between hammer head and pile to prolong the impulse/contact time and thus reduce the peak sound power level. If hammer driver monopiles are to be installed, consideration will be given to the selection of the hammer and potential dampening techniques to abate in-air emissions.

118 Using vibration pile driving reduces the sound power level compared to impulse pile driving, especially the peak level. This technique, however, is normally only used for small piles and is limited to a certain type of soil. It therefore may not be suitable for the proposed EOWDC.

119 The duration of high noise levels can be reduced when pile driving is limited to the necessary amount to achieve necessary penetration depth and mechanical boring is used when applicable.

120 It is recommended that a stringent noise management policy is designed to ensure the noise levels at nearby dwellings are kept to a minimum at all times. It is recommended that regular meetings are held with one or more elected resident's representatives to ensure noise levels do not become excessive. A 24hr contact telephone number should be made available and publicised for surrounding receptors in case noise levels become excessive.

121 To reduce annoyance and hostility, potentially affected residential areas should be notified well before the piling operations start and be informed about the expected impacts and the duration of the construction phase. A neighbourhood comment and complaint system should be developed to record and deal with complaints.

122 In order to mitigate the effects on sleep disturbance during the night and periods used for relaxation at the weekends, it is proposed to restrict the pile driving operation to the following periods:

- Mondays – Fridays 07:00 until 19:00
- Saturdays 07:00 until 13:00
- Sundays and bank holidays no noisy equipment should operate

Residual Impacts

123 If piling is not carried out during the night there will be no noise impact on the residents during this time and the impact will be negligible.

124 By introducing a noise management policy that includes regular meetings with local resident representatives and facilitates the dissemination of information on the expected timing and duration of piling it is expected that the impact during daytime hours will be minor. As the construction period associated with high noise levels is only for a limited time and as methods to screen the sound at source could potentially be employed this impact could be reduced even further.

125 By following the same mitigation as is proposed for daytime hours above it is felt that the impacts during evenings and weekends will also be moderate adverse.

Cumulative Impacts

126 The installation of the potential Ocean Laboratory has been assessed as a cumulative impact. Table 9 highlights that the worst case predicted noise levels associated with installing the potential Ocean Laboratory will be similar to those associated with installing the worst case wind turbine on the site. Additional time spent installing the structure would increase the time local residents could be exposed to noise. However, as the additional time that noise will be generated will only be of a short, temporary duration the cumulative impact is assessed as being of minor significance.

Monitoring

127 It is vital to monitor the construction noise at least at the beginning of the pile driving phase. This is essential to establish the real sound power level of the pile driving activity, verify the propagation calculation and check the efficiency of the mitigation measures.

128 It is suggested to measure the sound pressure level as close to the piling operation as possible to calculate the sound power level of this noise source.

129 Further monitoring should be carried out at the locations where the background noise monitoring has been done. It might be advisable to choose one location at a greater distance inland (2-3 km) to establish how far inland the noise could cause complaints, especially in areas where there is not much road traffic and surf noise.

130 During the monitoring noise mitigation measures could also be tested and it could be established whether sufficient mitigation is in place to allow for night-time piling as well.

1.3.1.2 Operational Phase

131 To determine the potential impact of the proposed development when operating, wind turbine noise has been assessed in accordance with the guidance contained within ETSU-R-97.

132 Following discussions with the relevant EHOs noise predictions were carried out for the four locations representing the closest residential properties to the proposed EOWDC and two locations further inland. The predictions assume down wind propagation from all sources simultaneously, which cannot occur in practice. The predicted noise levels are summarised in Table 11 below.

Table 11: Highest predicted Wind Farm Noise Level at the assessed Properties

Location	**Highest predicted wind farm noise level L_{A90}, dB**
Four Winds	39.5
16 Chapelwell Wynd	40.9
Easter Hatton	40.7
Hareburn House	41.3
3 Tarbothill Farm Cottages	40.2
16 Dubford Gardens	37.2

Potential Impacts

133 Plots have been produced of the measured L_{A90} background noise levels against wind speed at six locations representing the closest residential properties to the proposed EOWDC site. The derived noise limits are based on the lower ETSU-R-97 daytime limit and the Aberdeenshire night-time limit of 38 dB L_{A90} or background noise level plus 5 dB, whichever is the greater. The plots for these locations also show the upper ETSU-R-97 day time limit for completeness.

134 All the data points corresponding with recorded incidences of rainfall were removed.

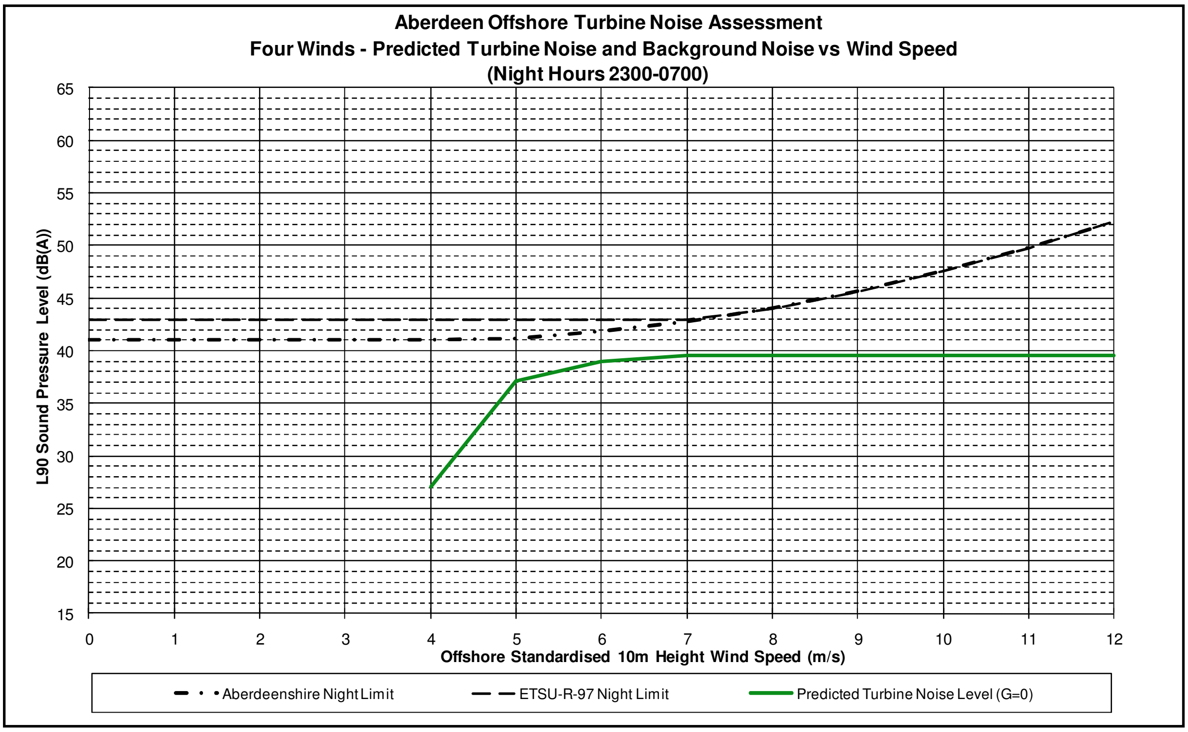
135 The assessment plots are shown in Chart 1 to 12 for the night hours and daytime hours for the representative residential locations.

136 Due to a technical error, the sound level meter at Hareburn House only recorded data for 3 days. During that period background noise levels were between 40 and 58 dB L_{A90} at 3 m/s and 52 and 59 dB L_{A90} at higher wind speeds during amenity hours and 42 and 55 dB L_{A90} at 3 m/s and 52 and 55 dB L_{A90} at higher wind speeds during night hours. Comparing the measured noise level of Hareburn House with the noise levels obtained at 3 Tarbothill Farm and 16 Chapelwell Wynd leads to the conclusion that background noise levels are generally higher at Hareburn House due to the proximity of the sea. The approach taken to use the noise limits derived from the measurement at Chapelwell Wynd as a substitute for Hareburn House is considered conservative as lower noise levels were recorded at this property compared to Tarbothill Farm. It is also assumed that using those noise limits is more representative for the houses in Blackdog which are further back from the shoreline as Hareburn House and would therefore receive less sea noise than Hareburn House.

137 The ETSU-R-97 noise limits 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 recommended limits. The audibility of any tones can be assessed by comparing the narrow band level of such tones with the masking level contained in a band of frequencies around the tone called the critical band. The ETSU-R-97 recommendations suggest a tone correction, which depends on the amount by which the tone exceeds the audibility threshold. A warranty will be sought from the manufacturer of the wind turbines for this site, once the model has been chosen, that the noise output will not require a correction under the ETSU-R-97 scheme.

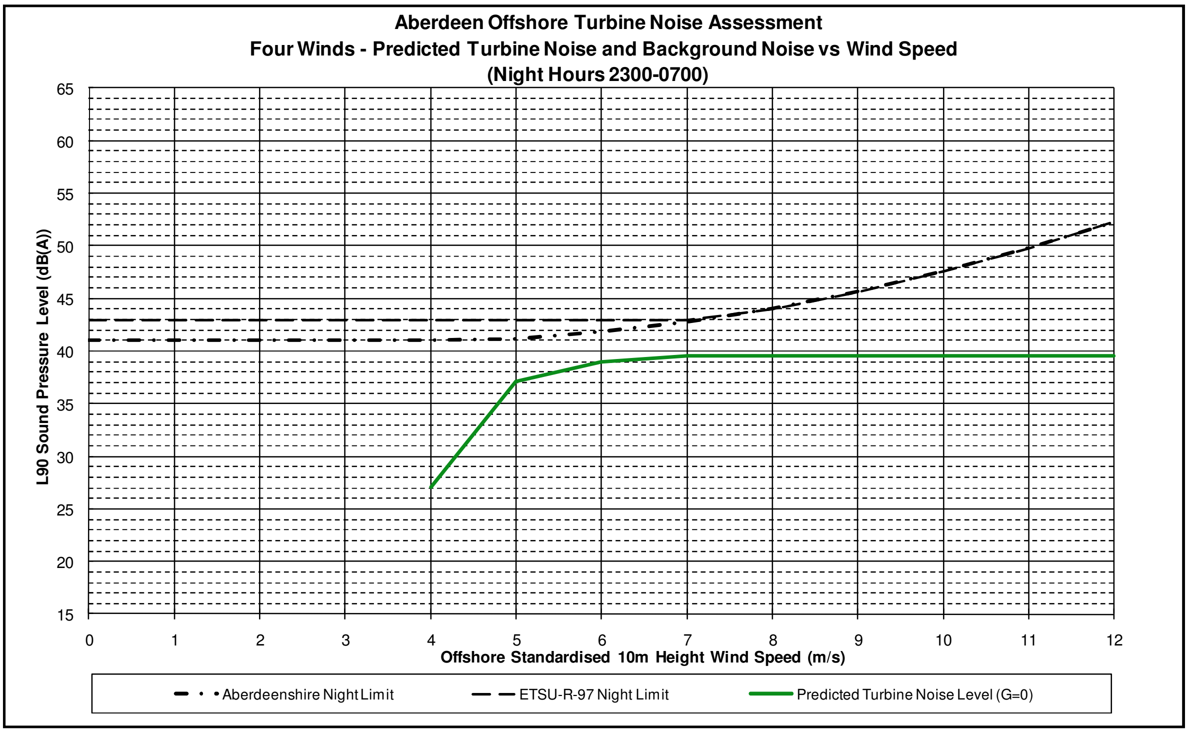
Four Winds

Chart. 1



138 Chart 1 shows that at Four Winds, the typical predicted wind turbine noise level meets the night noise limit by a minimum margin of 2.8 dB. The typical predicted wind farm noise level is below the prevailing background noise for wind speeds above 8.5 m/s.

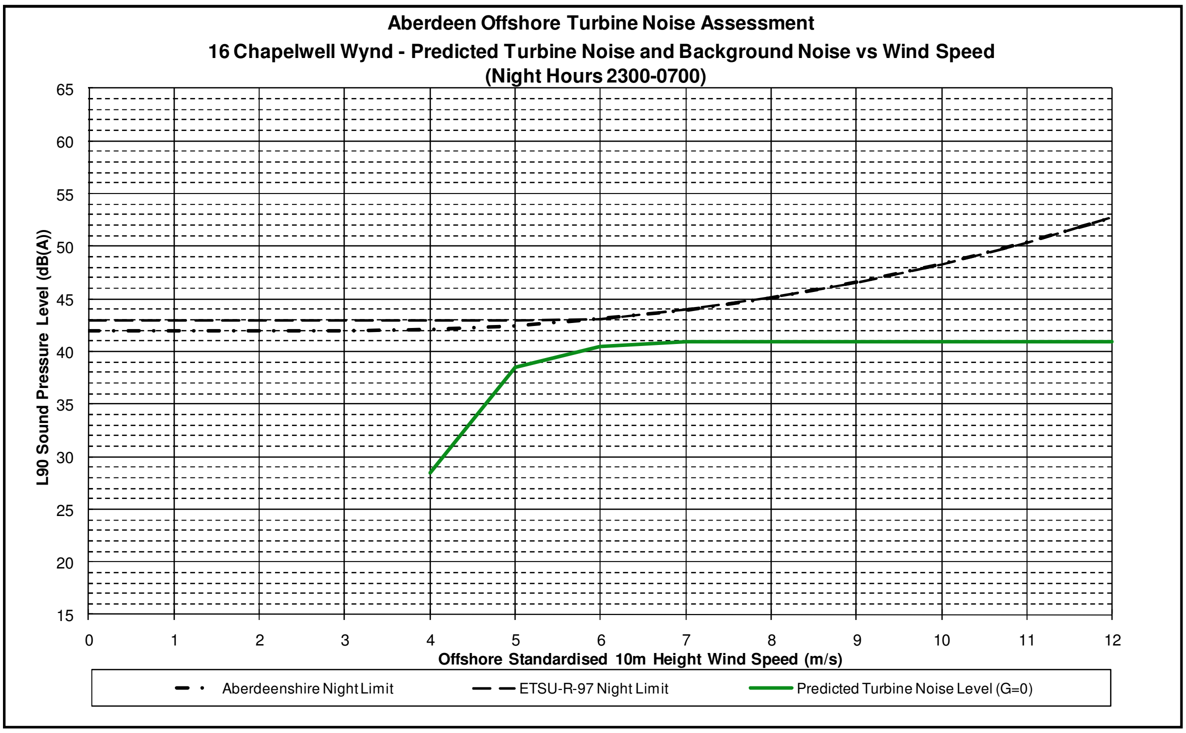
Chart. 2



139 Chart 2 shows that at Four Winds, the typical predicted wind turbine noise level meets the ETSU-R-97 day-time noise limit by a minimum margin of 14.2 dB. The typical predicted wind farm noise is below the prevailing background noise for all wind speeds.

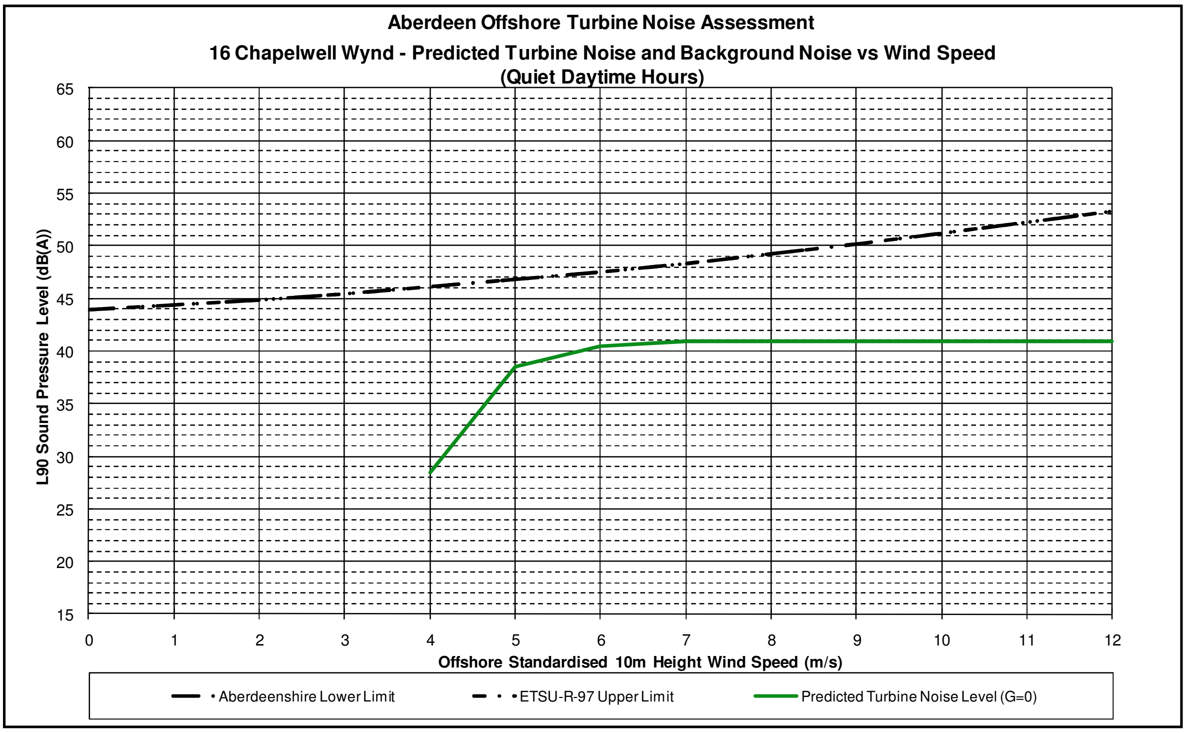
16 Chapelwell Wynd

Chart. 3



140 Chart 3 shows that at 16 Chapelwell Wynd, the typical predicted wind turbine noise level meets the night noise limit by a minimum margin of 2.7 dB. The typical predicted wind farm noise level is below the prevailing background noise for all wind speeds above 8.5 m/s.

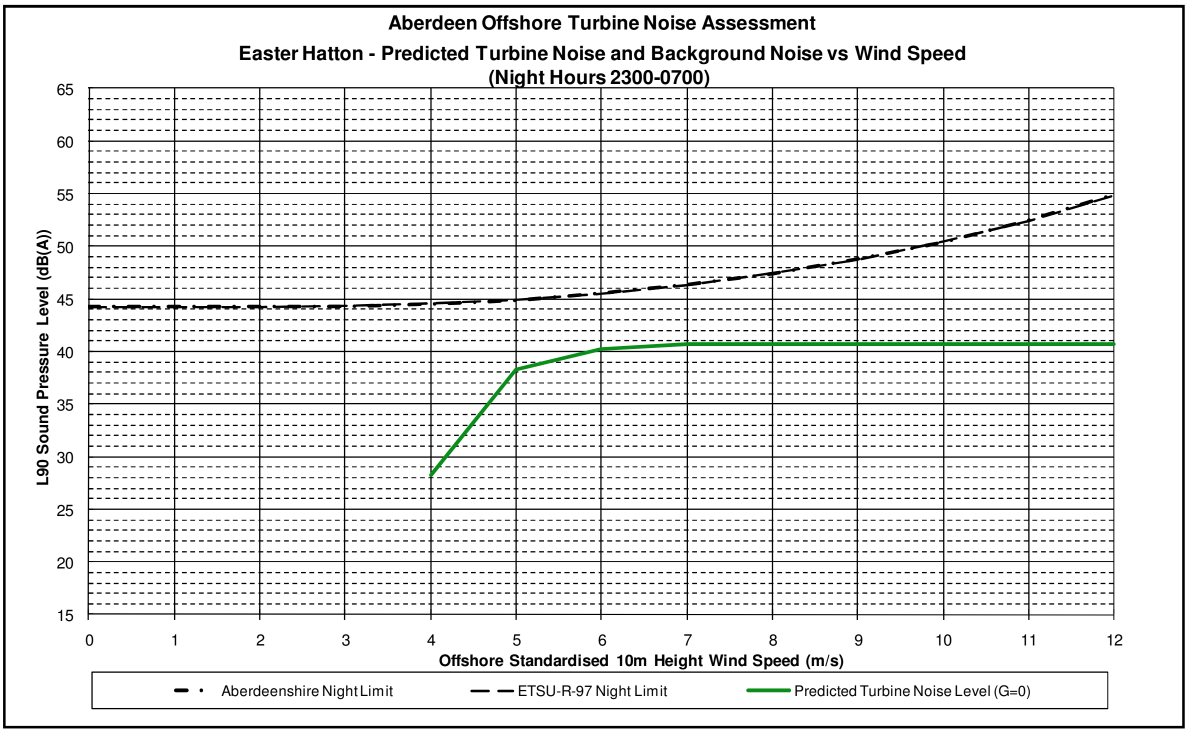
Chart. 4



141 Chart 4 shows that at 16 Chapelwell Wynd, the typical predicted wind turbine noise level meets the ETSU-R-97 day-time noise limit by a minimum margin of 7.1 dB. The typical predicted wind farm noise is below the prevailing background noise for all wind speeds.

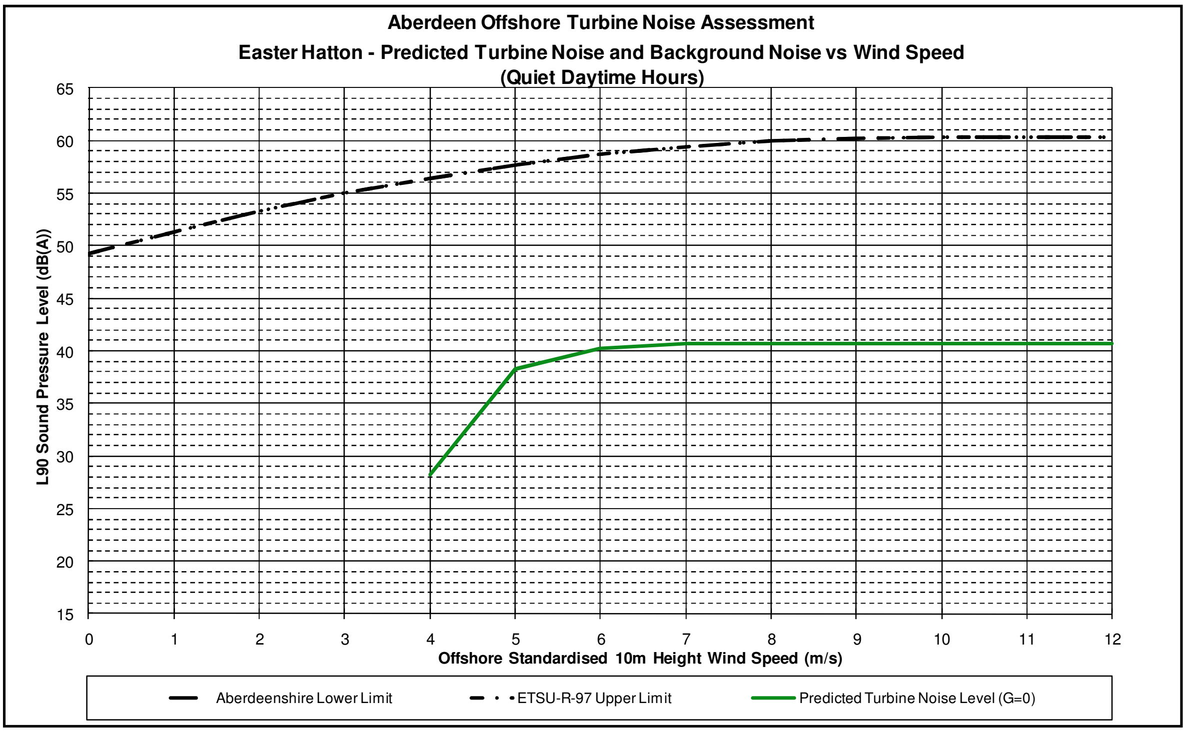
Easter Hatton

Chart. 5



142 Chart 5 shows that at Easter Hatton, the typical predicted wind turbine noise level meets the night noise limit by a minimum margin of 5.3 dB. The typical predicted wind farm noise level is below the prevailing background noise for all wind speeds.

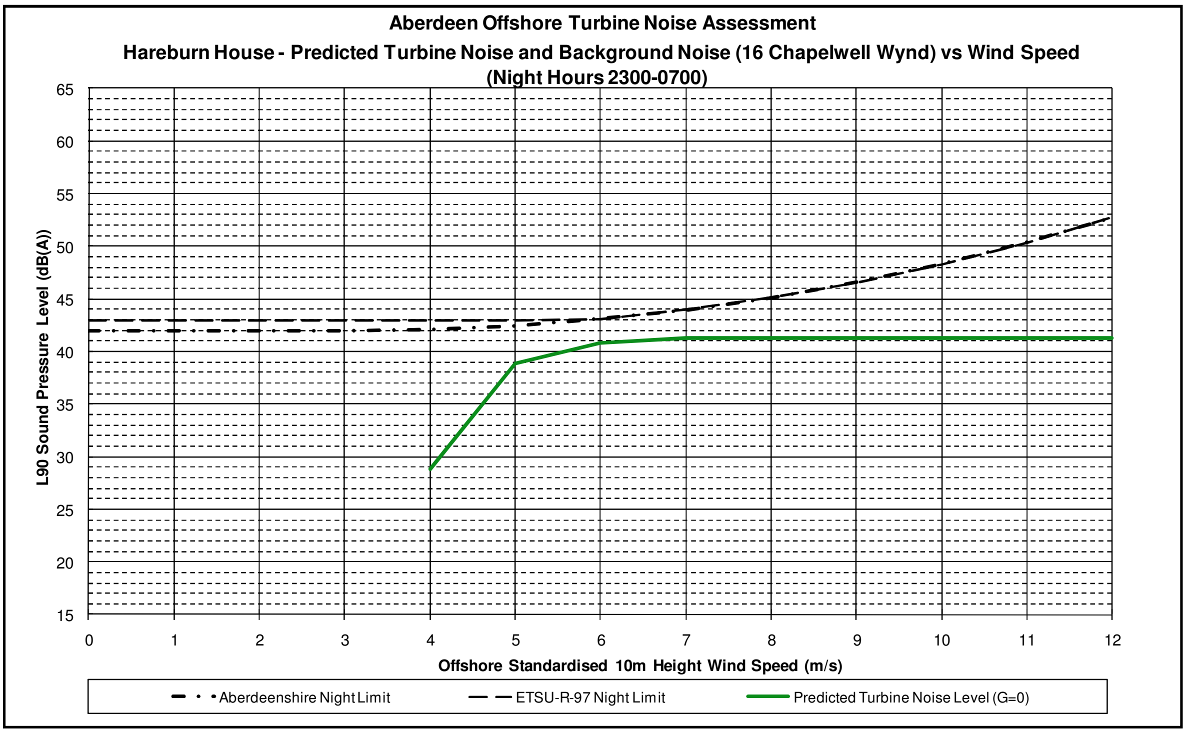
Chart. 6



143 Chart 6 shows that at Easter Hatton, the typical predicted wind turbine noise level meets the ETSU-R-97 day-time noise limit by a minimum margin of 18.5 dB. The typical predicted wind farm noise is below the prevailing background noise for all wind speeds.

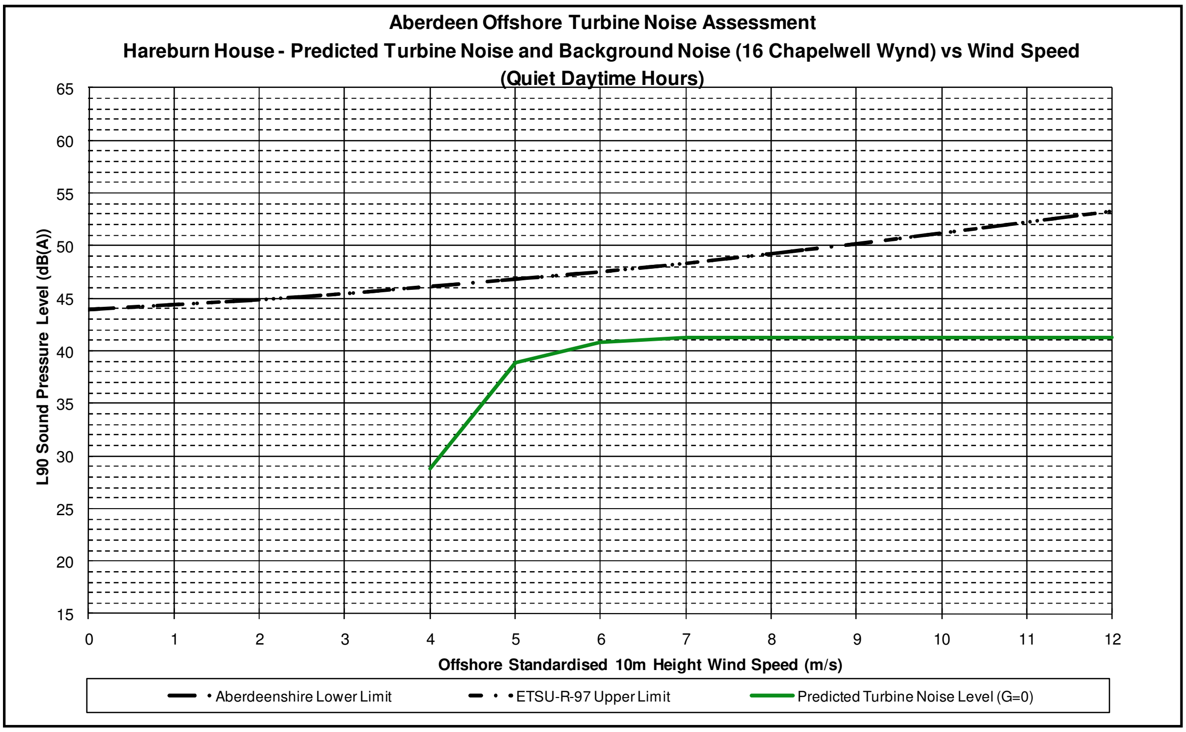
Hareburn House

Chart. 7



144 Chart 7 shows that at Hareburn House, the typical predicted wind turbine noise level meets the night noise limit, based on the background noise measurements at 16 Chapelwell Wynd, by a minimum margin of 2.3 dB.

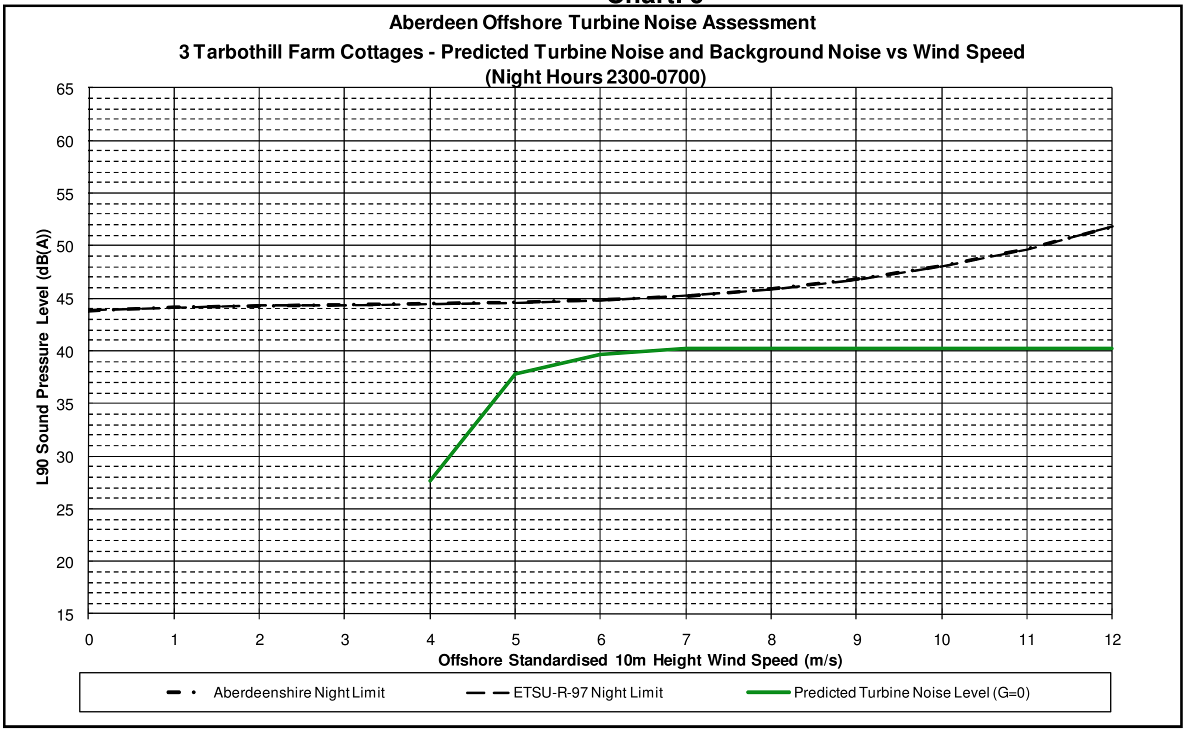
Chart. 8



145 Chart 8 shows that at Hareburn House, the typical predicted wind turbine noise level meets the ETSU-R-97 day-time noise limit assigned from 16 Chapelwell Wynd by a minimum margin of 6.7 dB.

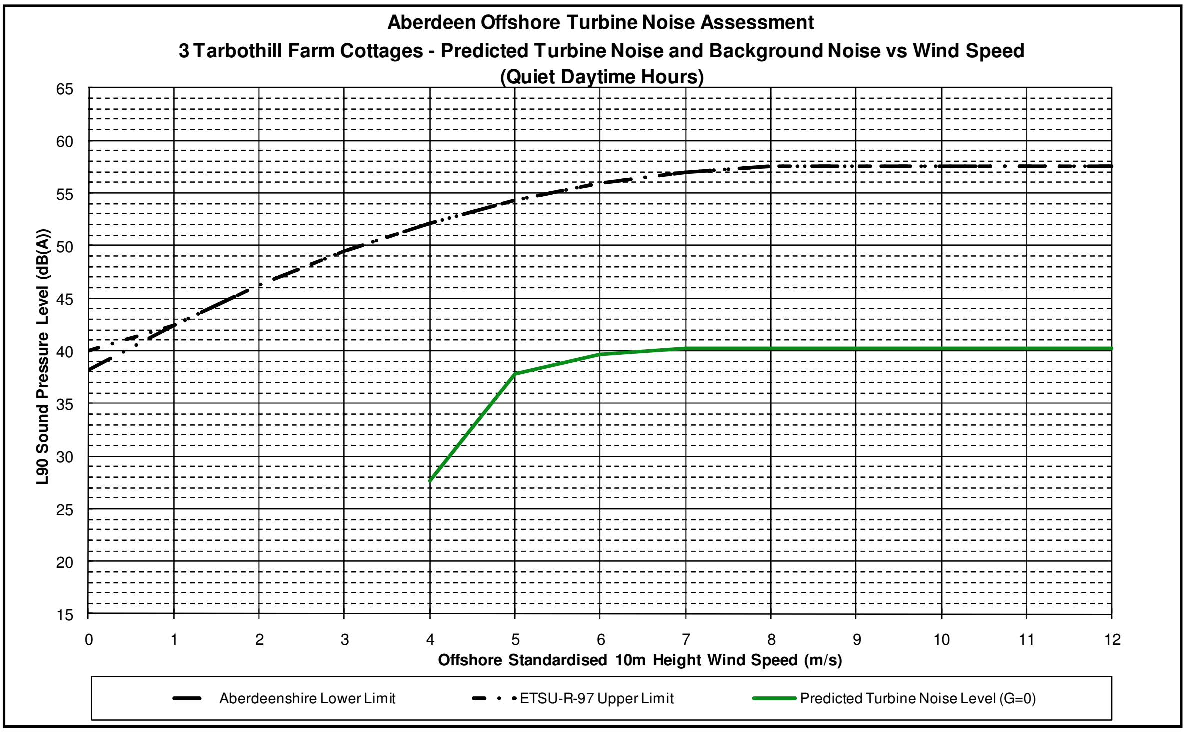
3 Tarbothill Farm Cottages

Chart. 9



146 Chart 9 shows that at 3 Tarbothill Farm Cottages, the typical predicted wind turbine noise level meets the night noise limit by a minimum margin of 5 dB. The typical predicted wind farm noise level is below the prevailing background noise for all wind speeds.

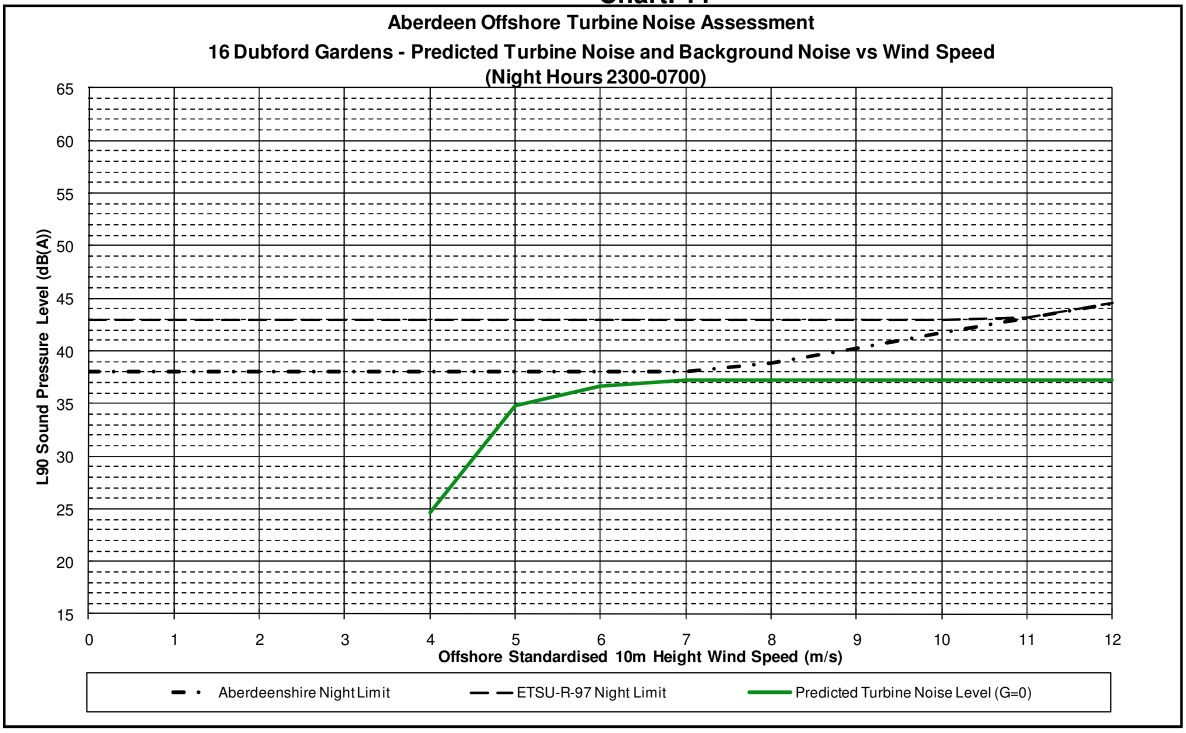
Chart. 10



147 Chart 10 shows that at 3 Tarbothill Farm Cottages, the typical predicted wind turbine noise level meets the ETSU-R-97 day-time noise limit by a minimum margin of 16.2 dB. The typical predicted wind farm noise is below the prevailing background noise for all wind speeds.

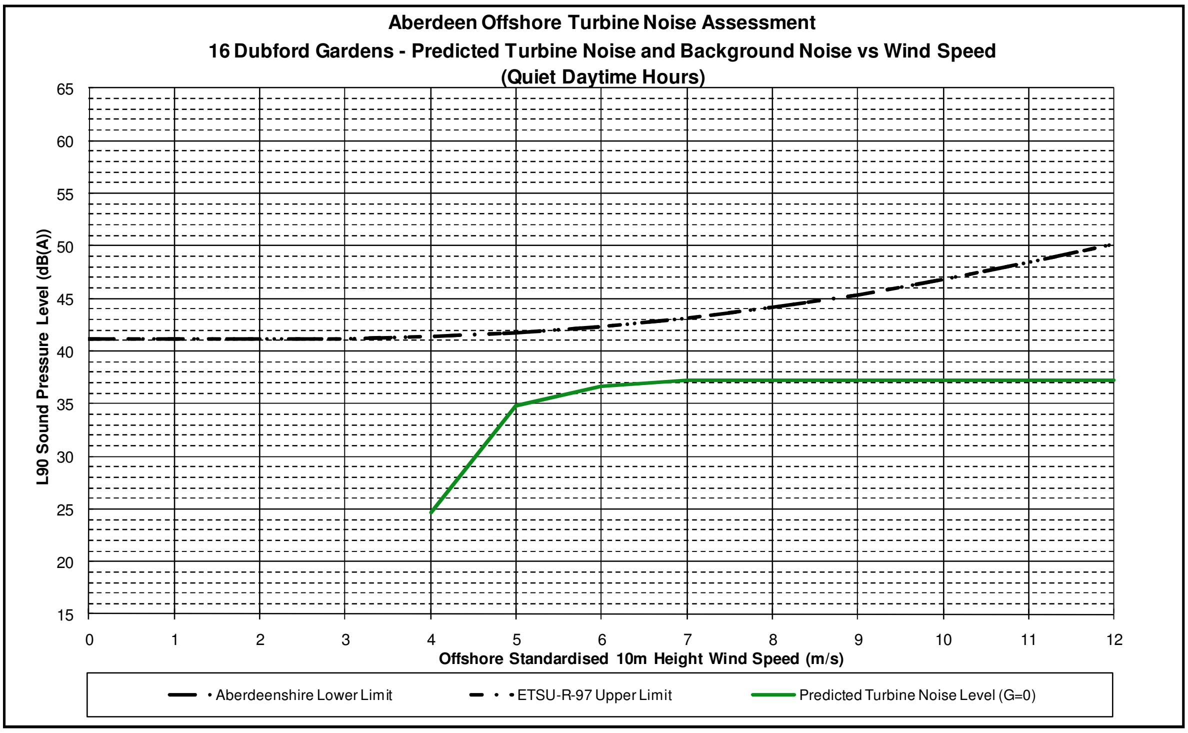
16 Dubford Gardens

Chart. 11



148 Chart 11 shows that at 16 Dubford Gardens, the typical predicted wind turbine noise level meets the night noise limit by a minimum margin of 0.8 dB. The typical predicted wind farm noise level is below the prevailing background noise for wind speeds above 10.5 m/s.

Chart. 12



149 Chart 12 shows that at 16 Dubford Gardens, the typical predicted wind turbine noise level meets the ETSU-R-97 lower day-time noise limit by a minimum margin of 5.7 dB. The typical predicted wind farm noise is below the prevailing background noise for all wind speeds.

1.3.1.3 Other Residential Properties

150 The assessments carried out for the background noise measurement locations are generally representative of the most affected properties in each area. This has been determined by considering distance from the sea, distance from the A90, and the type of residential area. Generally all other properties in the area being represented receive a lower predicted noise level and, assuming background noise is similar, will receive a lower impact than the assessed location.

151 The only area to which this doesn't apply is 16 Dubford Gardens. This is due to the measurement being chosen being both further from the A90, and on the edge of the Aberdeen suburb of Bridge of Don. Although there are properties closer to the proposed EOWDC site, which will therefore have a higher predicted noise level from the wind farm, these properties will equally have a higher background noise than that of 16 Dubford Gardens, due to their proximity to the A90, sea and being in a more built-up region. 16 Dubford Gardens was therefore chosen to represent this area due to its location balancing these factors.

152 The operational wind farm is predicted to be within the noise limits set by ETSU-R-97, the accepted guideline for onshore wind farm noise which has been adopted in this assessment and is therefore considered to have a negligible impact in terms of ETSU-R-97 noise limits.

Mitigation

153 None required

Residual Impacts

154 As no mitigation is required the residual impact will be negligible.

Cumulative Impacts

155 The proposed EOWDC may be supplemented by the installation of a diesel generator on the potential Ocean Laboratory Platform for electricity generation for the laboratory. The operational wind farm noise has been assessed together with the operation of the diesel generator of the potential ocean laboratory as a cumulative impact.

156 The height of the ocean laboratory is proposed to be 18 – 20 m above sea level. This has been assumed as source height. The source noise level of 90 dB(A) at 1 m distance for the diesel generator has been given in chapter 3, Description of the Proposed Development. Table 12 shows the assumed octave band sound power level based on octave band information from BS5228:2009 Appendix C, Table C.4 normalised to 90 dB(A).

Table 12: Normalised Noise Spectrum for a Diesel Generator at 1 m

Octave Band Centre Frequency (Hz)	Normalised Octave Band Sound Power Level (dB L_{Aeq})
63	88.8
125	81.8
250	76.8
500	72.8
1k	69.8
2k	65.8
4k	66.8
8k	59.8

157 The results of the cumulative assessment showed no change in predicted noise levels at all. The operation of the diesel generator has no effect on the predicted noise levels of the operational EOWDC, the cumulative impact has therefore been assessed as negligible.

Monitoring

158 Due to the magnitude of the prevailing background noise compared to the predicted EOWDC noise especially during the daytime, it might be difficult or impossible to distinguish between the two during a measurement especially if the wind turbines cannot be stopped for an additional background noise measurement during the survey.

159 If the Planning Permission requires a compliance test nevertheless, it is proposed to carry out the measurement at the same locations as previously, according to the methodology proposed in ETSU-R-97, measuring the $L_{A90,10minute}$ of the total noise and background noise with the wind turbines stopped if possible, and compare the measured sound pressure level with the noise limits proposed in this EIA chapter.

160 Should complaints arise due to the operational noise of the EOWDC, it is suggested that monitoring should be carried out at the affected properties with the results compared to the limits derived for the nearest relevant property where background noise monitoring was carried out.

1.3.1.4 Decommissioning Phase

Potential Impacts

161 The decommissioning phase is not expected to cause any significant effect as noise levels from shipping and taking down the wind turbine parts will be significantly lower than the piling noise from the construction phase.

1.3.2 **Additional Potential Noise Generating Activities**

1.3.2.1 Construction Phase

Potential Impacts

162 Noise from shipping activities is not considered significant and has not been assessed here.

163 The main noise source of the cable laying process is assumed to be from the activity of ploughing, trenching or jetting. Neither the machinery nor the exact cable route is known at this stage and therefore no accurate assessment could be carried out. It is expected that the effect, if at all, would be where the cable route comes to shore but due to the duration of the activity and the machinery potentially under water for most of the works, a negligible impact on the closest residential properties is expected. No further assessment has been carried out here.

164 To ensure compliance with the noise limits adopted from BS5228-1:2009 it is suggested to carry out measurements during the period, when the cable lying activity is closest to the nearest properties. For any other times, noise levels would be lower and thus comply with the noise limits.

Mitigation

165 None required.

Residual Impact

166 As no mitigation is required the residual impact will be negligible.

1.3.2.2 Operational Phase

Potential Impacts

Additional noise generated from ongoing operation and maintenance (for example vessel movements) is not considered significant and has not been assessed here.

Mitigation

167 None required.

Residual Impact

168 None.

1.3.3 EOWDC Future Research and Monitoring Opportunities

1.3.3.1 Offshore Piling

169 As only limited noise data is available for the offshore piling activity it is suggested to carry out sound measurements at the source and simultaneously at two receiver locations, one near the shore and one further inland. The sound source measurements would provide sound power level for future offshore projects which involve piling and would also be useful to verify the data that has been used for this assessment.

170 The noise measurements onshore in combination with the simultaneous sound source measurements can be used to verify the propagation model for long-range propagation at sea and also to verify the noise reduction measures for local residents during the construction phase. Those measurements are also essential to show compliance with the construction noise limits.

171 Furthermore, the measurements can also be used to refine the sound propagation model especially to investigate the influence of ground absorption for locations further inland.

1.3.3.2 Offshore Wind Turbines

172 Many new offshore wind turbine types have been developed in the last few years but there is still not much noise data available, partly because some of the wind turbine types are still in the development state. Sound source measurements at the offshore wind turbines can fill this gap and provide essential information for a correct sound propagation calculation.

173 Simultaneous noise measurements at the same receptors for which background noise measurements have been carried out can be used to verify the propagation model and also show compliance with the derived noise limits.

174 Long-term noise measurement onshore could be used to investigate the effects certain weather conditions on the propagation and audibility of offshore wind farm noise at onshore receptor locations. This could result in a study where measured noise level are compared with the perception of local residents to get a better understanding of the effects of offshore wind farm noise on residents living near the coast and further inland where the masking noise of the sea noise will be less.

1.4 Summary

175 An assessment of the potential noise impact from the European Offshore Wind Deployment Centre has been performed. The guidance contained within ETSU-R-97 has been used to assess the potential noise impact of the proposed development, as specified in Scottish Government web based planning advice on onshore wind turbines as referred to in PAN 1/2011 (Scottish Executive, 2011), *Planning and Noise*.

176 Background noise measurements were taken at six locations neighbouring the proposed EOWDC. These locations were agreed with the Environmental Health Officers (EHO) for the Local Planning Authorities of Aberdeen City and Aberdeenshire Council.

177 Analysis of the measured data has been performed in accordance with ETSU-R-97 to determine the pre-existing background noise environment at these six locations.

178 Predictions of wind turbine noise have been made, based upon a generic sound power level typical for a 10 MW generating capacity wind turbine. The calculation procedure adopted is considered to be worst-case.

179 A warranty will be sought from the manufacturer of the wind turbine for this site such that any tonal noise output from the wind turbines will not require a correction under the ETSU-R-97 scheme.

180 The predicted levels and measured background noise levels indicate that for all dwellings located onshore, wind turbine noise will meet the amenity and night-time noise criteria proposed within ETSU-R-97.

181 Predictions of noise associated with the possible diesel generator, associated with the potential ocean laboratory indicate that this noise source will result in no audible noise at onshore receptor locations and the sleep disturbance due to this noise source will not occur.

182 Cumulative assessment of the operational EOWDC noise and the possible diesel generator resulted in no change of the operational EOWDC noise.

183 Prediction of the pile driving noise during the construction phase shows exceedance of the night-time noise limits adopted from BS5228:2009 Part 1 (BSI, 2009) at all properties. It has therefore been proposed that construction times should be limited to daytime hours unless suitable noise mitigation can be found and verified by measurements.

184 Prediction of the pile driving noise during daytime shows exceedance of the L_{Aeq} daytime noise limits adopted from BS5228:2009 Part 1 (BSI, 2009) at three assessed properties by 1 dB. With a suitable noise management policy it is expected that the impact during daytime hours will be minor adverse. As the construction period with high noise levels is only for a limited time and as methods to screen the sound at source could potentially be employed this impact could be reduced even further.

185 A summary of the impacts is provided in Table 13.

Table 13: Impact Assessment Summary Table

Potential Impact	Significance Level	Mitigation	Residual Significance	Monitoring
Sleep disturbance during piling night	Major	No piling during night	Negligible	No
Stress, annoyance during piling daytime	Minor to Moderate	Screens and good information policy	Minor	Yes, to determine real sound levels and check efficiency of potential mitigation measures.
Exceedance of noise limits during operation day	Negligible	Not required	Negligible	No
Exceedance noise limits operation night,	Negligible	Not required	Negligible	No
Construction noise from other machinery	Negligible	Not required	Negligible	No
Operational noise from diesel generator	Negligible	Not required	Negligible	No

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