

9 NOISE AND VIBRATION

9.1 Introduction

- 9.1.1 This chapter presents an assessment of the likely significant noise and vibration effects of the Proposed Scheme, as described in **Chapter 3: Proposed Scheme**.
- 9.1.2 The effects of the Proposed Scheme are considered for the decommissioning and construction, and operational phases.
- 9.1.3 Noise and vibration can have an effect on the environment and the quality of life enjoyed by individuals and communities. Noise and vibration is often therefore an important consideration in the determination of planning applications.
- 9.1.4 Construction noise effects are normally of a temporary nature and result from both moving and static sources. Assessment allows the temporary impact of construction noise to be understood and for suitable mitigation measures to be identified to minimise any potential adverse effects.
- 9.1.5 When operational, wind turbines emit two types of noise, mechanical and aerodynamic. The main sources of mechanical noise are from internal components housed within the nacelle, such as the gearbox and generator. Mechanical noise from a modern wind turbine is negligible, as the nacelles are insulated to reduce noise emissions and the various mechanical components housed within the nacelle are acoustically isolated to prevent structure borne noise. Aerodynamic noise occurs from the movement of the blades passing through the air. At higher wind speeds aerodynamic noise is usually masked by the increasing sound of wind blowing through trees ('psithurism') and around buildings. The level of masking noise determines the perceived audibility of the wind farm. This assessment establishes the relationship between wind turbine noise from the Proposed Scheme and the natural masking noise and assesses levels against established standards.

9.2 Statutory and planning context

- 9.2.1 The assessment of noise and vibration effects of the Proposed Scheme has been carried out with reference to relevant national, regional and local planning policy, and guidance, as summarised in **Table 9.1**.

Table 9.1: Legislation and guidance relevant to noise and vibration

Document	Summary
Legislation	
Environmental Protection Act 1990, Part III (as amended by the Noise and	The Environmental Protection Act 1990 sets out the duty for local authorities to investigate and, where identified, take abatement action against noise nuisance. The Act provides the definition of Best Practicable Means (BPM) to minimise

Document	Summary
Statutory Nuisance Act 1993	noise (including vibration), the basis for defence against noise abatement action taken by a local authority (section 80). The Act also provides for individuals to seek for abatement action to be taken by a magistrate's court against noise nuisance (section 82).
Control of Pollution Act 1974	The Control of Pollution Act 1974 provides the definition of Best Practicable Means (BPM) to minimise noise (including vibration), the basis for defence against noise abatement action taken by a local authority (section 60). The Act also provides for i) persons responsible to seek prior consent for works on construction sites including BPM steps to minimise noise and ii) the basis for defining codes of practice (applies to BS 5228:2009+A1:2014 ' <i>Code of practice for noise and vibration control on construction and open sites, Part 1: Noise and Part 2: Vibration</i> ').
National Planning Policy	
Future Wales – The National Plan 2040 (2021)	A framework development plan for Wales, including policies supporting the principle of developing renewable energy where they can be demonstrated to not have an unacceptable adverse impact on the environment.
Planning Policy Wales (ed. 11. 2021)	PPW (2021) sets out the land use and planning policies of the Welsh Government. PPW (2021) contains the planning policy framework for addressing noise, namely Technical Advice Note (TAN) 11: Noise
Technical Advice Note (TAN, Wales) 11: Noise (1997) & CL-01-15 Updates to Tan 11 Noise – Noise Action Plan (2013-18) Commitments (2015)	TAN 11 (1997) provides advice on how the planning system can be used to minimise the adverse impact of noise without placing unreasonable restrictions on development. TAN 11 (1997) makes reference to TAN 8 Planning for Renewable Energy (2005) (now revoked) which references the ETSU Guidance as the relevant guidance when considering operational noise from wind farm. Even though TAN 8 has been revoked it remains as relevant guidance (via TAN 11) when considering operational noise from wind farms. TAN 11 (2015) endorses the A Good Practice Guide to the Application of ETSU-R-97 for the Assessment and Rating of Wind Turbine Noise, Institute of Acoustics (IOA), May 2013, (IOA GPG), and its six supplementary guidance notes.
Local and Regional Policy	
Caerphilly County Borough Council - Local Development Plan up to 2021 (2020)	The key objectives of the CCBC LDP include a requirement to: <i>'improve energy, waste and water efficiency while promoting environmentally acceptable renewable energy to maintain a</i>

Document	Summary
	<i>cleaner environment and help reduce our impact on climate change'</i>
Merthyr Tydfil County Borough Council - Replacement Local Development Plan (2016–2031) (2020)	Policy EnW4: Environmental Protection <i>Development proposals will be required to demonstrate they will not result in an unacceptable impact on people, residential amenity, property and / or the natural environment from either: ..</i> - Noise, vibration, dust, odour nuisance and light pollution; or - Any other identified risk to public health and safety. Policy EcW8: Renewable Energy <i>We will support the use of renewable energy as a tangible means of reducing our local carbon footprint, where appropriate to do so. Development proposals for renewable energy will be permitted where:</i> ... - There would be no unacceptable cumulative impacts in combination with existing or consented development. - Satisfactory mitigation can be put in place to minimise the impacts of the renewable energy proposal and its associated infrastructure.
Blaenau Gwent County Borough Council - Local Development Plan up to 2021 (2012)	Local Development Plan up to 2021 (November 2012) Policy DM1 New Development <i>Development proposals will be permitted provided:</i> <i>h. There would be no unacceptable risk of harm to health and/ or local amenity from unacceptably high levels of noise, vibration, odour or light pollution;..</i> Policy DM4 Low and Zero Carbon Energy <i>The Council will encourage major development proposals to incorporate schemes which generate energy from renewable and low/zero carbon technologies. These technologies include onshore wind; landfill gas; energy crops; energy from waste; anaerobic digestion; sewage gas; hydropower; biomass; combined heat and power; and solar.</i> <i>These technologies will be permitted provided that:</i> ... <i>d. They will not have an unacceptable adverse impact on local amenity by reason of noise emission, visual dominance, shadow flicker, reflected light, the emission of smoke, fumes, harmful gases, dust, nor otherwise cause pollution to the local environment;</i>

Document	Summary
Guidance	
British Standard BS 5228 (2009+A1:2014), Code of practice for noise and vibration control on construction and open sites, parts 1 and 2	Part 1 of BS 5228 (2014) relates to the potential effects of existing noise sensitive human receptors as a result of noise arising from construction activities. This includes construction vehicles travelling on haulage routes to and from the construction site. Part 2 of BS 5228 (2014) relates to the potential effects of existing noise sensitive human receptors as a result of vibration arising from construction activities. This includes construction vehicles travelling on haulage routes to and from the construction site
The assessment and rating of noise from wind farms (ETSU-R-97) 1996 (ETSU Guidance)	The ETSU Guidance provides a framework for the assessment and rating of noise from wind turbine installations.
A Good Practice Guide to the Application of ETSU-R-97 for the Assessment and Rating of Wind Turbine Noise, Institute of Acoustics (IOA), May 2013, (IOA GPG)	The IOA GPG (2013) was published by the Institute of Acoustics (IOA) in 2013, and presents good practice in the application of the ETSU Guidance methodology.
ISO 9613-2 Acoustics – Attenuation of sound during propagation outdoors – Part 2: General method of calculation	ISO 9613-2 (1996) is a method for calculating the attenuation of sound during propagation outdoors. The ISO 9613-2 (1996) methodology is advocated by the IOA GPG (2013)

9.3 Consultation undertaken

- 9.3.1 The consultation spatial extents for the noise and vibration assessment have been informed by a calculation of the 35 dB L_{A90} operational noise contour. This is the study area as advocated by the IOA GPG (2013). The operational noise contour is based on the candidate wind turbine for the Proposed Scheme, the Nordex N149 (105 m hub height) without serrated trailing edges, and is shown in **Figure 9.1**. The referenced noise monitoring locations, and receptors are discussed further in Section 9.5, and summarised in **Table 9.5** and **Table 9.6**.

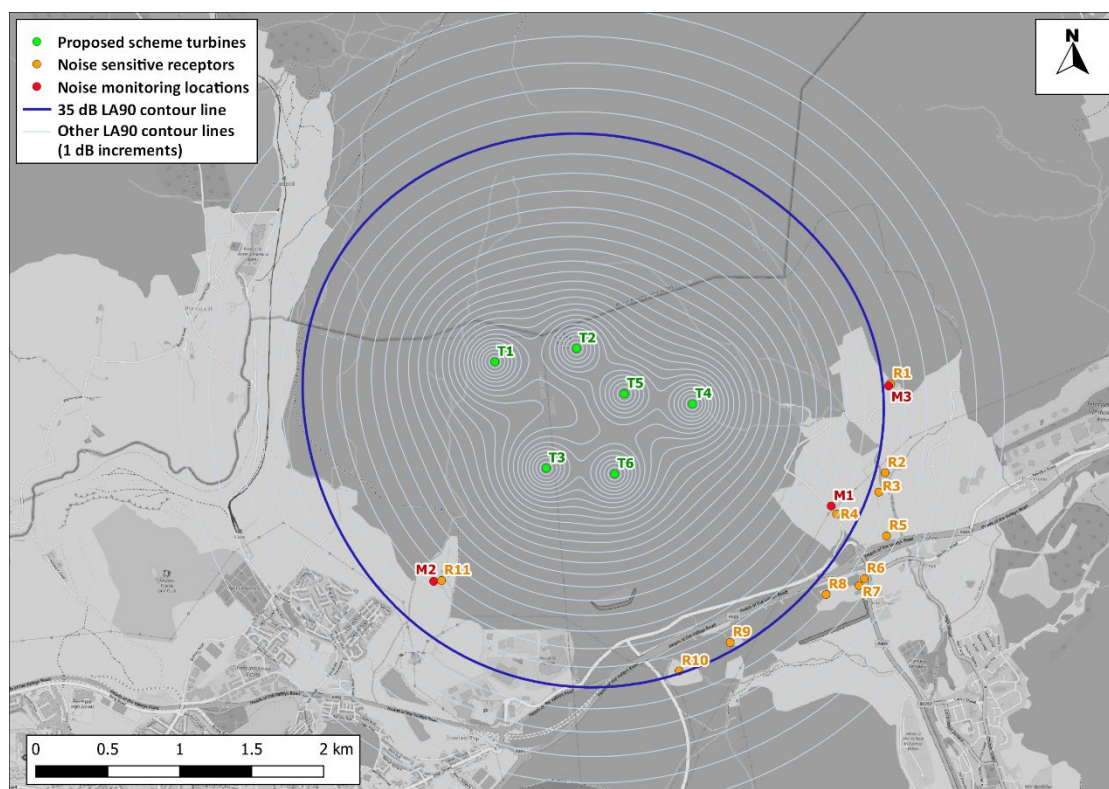


Figure 9.1: Proposed Scheme – 35 dB LA₉₀ Study Area

9.3.2 The spatial scope of the noise contour has identified the potential for noise sensitive receptors within the administrative areas of:

- Caerphilly County Borough Council (CCBC);
- Merthyr Tydfil County Borough Council (MTCBC); and
- Blaenau Gwent County Borough Council (BGCBC).

9.3.3 **Table 9.2** and **Table 9.3** summarises key comments and assessment responses to EIA Scoping consultees and Local Authority engagements, respectively.

Table 9.2: Consultation responses summary

Consultation	Comment Summary	Response
Pen March Wind Farm – EIA Scoping Report (May 2020)	Effects scoped in: noise from the operation of the proposed development; and cumulative operational noise impacts Effects scoped out: noise and vibration associated with on-site construction and decommissioning activities; vibration associated with construction	Scope adopted within this ES chapter.

Consultation	Comment Summary	Response
	traffic; and vibration effects during operation.	
Planning Inspectorate (PINS) DNS: EIA Scoping Direction – Pen March Wind Farm (DNS/3253 147, July 2020)	ID.32 Methodology <i>The Applicant should consider that the noise limits set in ETSU-R-97 are not a definition of significance. The Applicant should have regard to paragraph 3.2.8 of the Institute of Acoustic Good Practice Guide on the application of ETSU-R-97 (2013) which states that single lower fixed limits can be used where background noise levels do not vary significantly between amenity periods and night-time periods, with the agreement of the relevant authorities. The ES should demonstrate compliance with ETSU-R-97 and clearly explain how significant impacts are identified.</i>	Planning policy in Wales advocates the use of the ETSU Guidance to assess operational noise from wind farm developments. The ETSU Guidance sets out noise limits, and consequently the design of the Proposed Scheme will be that these noise limits will not be breached. The determination of impact significance is based upon compliance with these limits i.e. a breach of the noise limits is considered unacceptable and indicates a 'significant' effect, whereas compliance with noise limits indicates a 'not significant' effect. Consideration of single fixed limits will be given where appropriate.
PINS DNS: EIA Scoping Direction – Pen March Wind Farm (DNS/3253 147, July 2020)	ID. 33 Cumulative Impacts <i>The Applicant should comply with the detailed methodology set by section 5 the Institute of Acoustic Good Practice Guide to the application of ETSU-R-97 (2013) regarding the derivation of the appropriate lower fixed limits in the cumulative impact assessment. The ES should clearly identify all the relevant wind farms affecting the same receptors and the correct noise limits the proposal should comply with as part of the cumulative assessment, in agreement with the relevant authorities.</i>	A cumulative noise assessment will be undertaken in compliance with methodologies advocated in the IOA GPG (2013).
PINS DNS: EIA Scoping Direction – Pen March	ID.34 Elements of the Noise assessment to be scoped out	Noted.

Consultation	Comment Summary	Response
Wind Farm (DNS/3253 147, July 2020)	<i>The Planning Inspectorate agrees to scope these elements out.</i>	

Table 9.3: Consultation responses summary (Local Authority)

Consultation	Comment Summary	Response
Caerphilly County Borough Council	21 December 2020 - Email to CCBC with proposed monitoring methodology. 6 January 2021 - CCBC confirmed that the proposed methodology was acceptable.	The proposed monitoring methodology has adopted the methodology agreed with CCBC.
Merthyr Tydfil County Borough Council	6 January 2021 - Email to MTCBC with proposed monitoring methodology. 6 January 2021 - MTCBC confirmed that the proposed methodology was acceptable.	The proposed monitoring methodology has adopted the methodology agreed with MTCBC.
Blaenau Gwent County Borough Council	4 February 2021 - Email to BGCBC to outline the proposed monitoring methodology, and a request for planning documentation in relation to a single turbine development at Unit 29 Tafarnaubach Industrial Estate. 9 February 2021 - BGCBC provided planning documentation.	The proposed monitoring methodology has adopted the methodology set out in email 4 February 2021.

9.4 Approach to the assessment

Study area

Operational noise

- 9.4.1 To assess the effects of operational noise, the spatial extents of the study area from the Proposed Scheme include noise sensitive receptors where operational noise levels are likely to exceed 35 dB L_{A90} , or where there are cumulative operational wind farm noise considerations with other proposed, consented and operational wind developments.

Matters assessed in full

- 9.4.2 Potential effects assessed include:

- Noise during operation of the Proposed Scheme; and
- Cumulative operational noise impacts.

Matters scoped out

9.4.3 Potential effects scoped out of this assessment include:

- Noise and vibration associated with on-site construction and decommissioning activities;
- Vibration associated with construction traffic; and
- Vibration effects during operation.

Planning policy and advice relating to noise

9.4.4 In Wales, Planning Policy Wales (PPW, February 2021) sets out land use policies, and is supplemented by a series of Technical Advice Notes (TANs). With respect to understanding and identifying sources of airborne (air and noise) pollution, PPW states:

“Further guidance on wind turbine noise assessment can be found in ETSU-R-97 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/49869/ETSU_Full_copy__Searchable_.pdf and further good practice guidance published by the Institute of Acoustics: <https://www.ioa.org.uk/publications/wind-turbine-noise>.”

9.4.5 Specific consideration of noise generated by wind energy developments is referenced in Technical Advice Note (TAN, Wales) 11: Noise (1997, updated 2015), which itself references Technical Advice Note (TAN, Wales) 8, Planning for Renewable Energy (2005). Annex C, paragraph 2.16 of TAN 8 guides the assessment process as follows:

“The report “The Assessment and Rating of Noise from Wind Farms” (ETSU-R-97), describes a framework for the measurement of wind farm noise and gives indicative noise levels calculated to offer a reasonable degree of protection to wind farm neighbours, without placing unreasonable restrictions on wind farm development or adding unduly to the costs and administrative burdens on wind farm development or adding unduly to the costs and administrative burdens on wind farm developers or planning authorities. The report presents the findings of a cross-interest Noise Working Group and makes a series of recommendations that can be regarded as relevant guidance on good practice.”

9.4.6 Consequently, the assessment methodology adopted is that found in the ETSU Guidance. The advice presented in the document was produced by the Working Group on Noise from Wind Turbines, a body comprising a number of interested parties including, amongst others, wind farm operators, environmental health officers, acoustic consultants and legal experts. The application of the ETSU Guidance assessment methodology has adopted current good practice, as detailed within the IOA GPG (2013). This approach has been endorsed by Welsh Government (Carl Sargeant AC / AM, Minister of Natural Resources) in TAN 11 (2015):

“Finally, in 2013 I endorsed the Institute of Acoustics Good practice guide to the application of ETSU-R-97 for the assessment and rating of wind turbine noise. Authorities processing wind turbine applications should also note that six supplementary guidance notes have been issued to support this guide (<http://www.ioa.org.uk/publications/good-practice-guide>). The Department of Energy and Climate Change have commenced further work on amplitude modulation and any Welsh Government position on this work would be considered at the appropriate time.”

Determination of significance

Receptor groups

9.4.7 Residential receptors within the study area of the Proposed Scheme, and those considered in the cumulative assessment, have been identified using aerial photography, GIS datasets, site visits, and from a review of the noise related documentation in support of the cumulative developments, as summarised in **Table 9.4**.

9.4.8 The receptors listed are considered to be residential, or to include residential uses.

Table 9.4: Receptors

Receptor	Easting	Northing	Study Area
R1 Blaen-Rhymney Farm	310481	210702	Proposed Scheme
R2 Ty Isaf Farm	310443	210084	Proposed Scheme
R3 Reservoir House	310399	209950	Proposed Scheme
R4 Twyn Yr Arian	310106	209798	Proposed Scheme
R5 Pleasant View	310452	209646	Proposed Scheme
R6 Y Graig Lwyd	310298	209349	Proposed Scheme
R7 Lakeside Farm	310261	209301	Proposed Scheme
R8 Pond Cottage	310033	209239	Proposed Scheme
R9 Gypsy Castle	309367	208906	Proposed Scheme
R10 Blaen-Carno Farm	309013	208708	Proposed Scheme
R11 Blaen-Morlais Farm	307363	209336	Proposed Scheme
R12 Upper Ras Farm	311780	209121	Cumulative
R13 Susannah Cottage	311353	208868	Cumulative
R14 Princetown	311451	209940	Cumulative
R15 Lechryd	310963	209627	Cumulative
R16 Merthyr Road	312518	210381	Cumulative
R17 Penngarnddu	307341	208771	Cumulative

Receptor	Easting	Northing	Study Area
R18 Coedcae Row Terraces	307605	208157	Cumulative
R19 13-24 Station Terrace	307460	208123	Cumulative
R20 Carpenters	307343	208765	Cumulative
R21 Robins	308034	208528	Cumulative
R22 3 High Street	307686	208149	Cumulative
R23 K & M Robins	307987	208480	Cumulative
R24 Station House	307980	208452	Cumulative
R25 Merthyr Road 2	311585	210160	Cumulative
R26 Old Prince Farm	311109	210109	Cumulative

Operational Noise

- 9.4.9 The ETSU Guidance sets noise limits, below which operational wind farm noise is at a level which offers a reasonable degree of protection to receptors without placing an unreasonable restriction on a proposed wind development is advocated in national policy.
- 9.4.10 For proposed wind developments where the noise immission at noise-sensitive receptors are sufficiently low, the ETSU Guidance advocates a simplified assessment approach. The ETSU Guidance (paragraph 25 of the Executive Summary) states:
- “For single turbines or wind farms with very large separation distances between the turbines and the nearest properties a simplified noise condition maybe suitable. We are of the opinion that, if the noise is limited to an $L_{A90,10min}$ of 35dB(A) up to wind speeds of 10m/s at 10m height, then this condition alone would offer sufficient protection of amenity, and background noise surveys would be unnecessary.”*
- 9.4.11 The only exception to the noise limit outlined above is for properties with a financial involvement in the development, where limits can be increased to 45 dB $L_{A90,10min}$. No properties with a financial involvement in the Proposed Scheme have been identified within the assessment’s spatial extents.
- 9.4.12 Preliminary modelling of noise immission from the Proposed Scheme indicated that noise was likely to exceed the 35 dB $L_{A90,10min}$ threshold at noise-sensitive receptors, triggering the requirement for a detailed assessment.
- 9.4.13 For a detailed assessment, the ETSU Guidance recommends that wind farm noise limits should be set relative to existing background noise levels, subject to a fixed minimum limit, and that these limits should reflect the variation in background noise with wind speed. The wind speeds that should be considered range from the cut-in speed (the minimum wind speed before the wind turbine start to generate power, commonly around $4ms^{-1}$) up to $12ms^{-1}$ at 10 m height, the point at which wind turbine is at the maximum rated capacity, and thus no further increases in noise emission is expected. Wind speeds are referenced to 10 m measurement heights (V_{10}).

Operational noise limits

- 9.4.14 The day-time noise limit is derived from background noise data measured during 'quiet day-time' at residential properties, which comprise:
- Weekday evenings from 18:00 - 23:00; plus
 - Saturday afternoons from 13:00 - 23:00; and
 - All day Sunday 07:00 - 23:00.
- 9.4.15 The noise measurements are correlated and plotted with wind speed data measured close to hub height at the Proposed Scheme (and standardised to 10 m) and a 'best fit' polynomial is established.
- 9.4.16 The ETSU Guidance recommends that wind farm noise for day-time periods should be limited to a lower fixed level within the range 35-40dB $L_{A90,10min}$ or 5dB(A) above the prevailing background, whichever is the greater. The choice of which lower fixed level to use within the range is based upon a number of factors as outlined in Paragraph 22 of the ETSU Guidance. These include:
- The number of dwellings in the neighbourhood of the wind farm;
 - The effect of noise limits on the number of kWh generated; and
 - The duration and level of exposure.
- 9.4.17 As a conservative approach the day-time lower fixed limit considered for the Proposed Scheme is 35 dB $L_{A90,10min}$ or 5 dB above the prevailing background, whichever is greater. This takes into account the existing low noise environment at the Site.
- 9.4.18 The night-time noise limit is derived from the background noise data measured during the night-time period of 23:00 to 07:00. As with the day-time data, this is plotted against the concurrent wind speed data and a 'best fit' polynomial established. For night time periods, the recommended limits are 43 dB $L_{A90,10min}$ or 5 dB above the prevailing background, whichever is the greater.
- 9.4.19 The ETSU Guidance's noise criteria assumes that the wind turbine noise contains no audible tones. Where tones are present, a correction is added to the measured or predicted noise level before comparison with the recommended limits. The level of correction will depend on how audible the tone is. It is assumed that the candidate turbine does not emit tones that invoke an ETSU Guidance tonal penalty.
- 9.4.20 The ETSU Guidance states the $L_{A90,10min}$ descriptor should be used for both the background noise and wind farm noise when setting limits, and that the $L_{A90,10min}$ is likely to be about 1.5 to 2.5 dB less than the $L_{Aeq,10min}$. The noise model predicts operational noise levels in terms of $L_{Aeq,10min}$, which is converted to $L_{A90,10min}$ with the subtraction of 2 dB.
- 9.4.21 The assessment of significant operational noise effects is based upon compliance with the ETSU Guidance advocated noise limits. An exceedance of the ETSU Guidance noise limits is considered to be 'significant' in the context of the EIA Regulations. Where operational noise levels are shown to be below the ETSU

Guidance advocated noise limits, the effects are considered to be not 'significant' in the context of the EIA Regulations.

Operational noise - cumulative

- 9.4.22 The noise limits set out in the ETSU Guidance relate to the total noise at noise-sensitive receptors, including contributions from the Proposed Scheme with other proposed, consented and operational wind developments in the assessments spatial extents ('cumulative developments'). No non-wind cumulative developments have been identified within the spatial extents of the 35 dB L_{A90} operational noise contour, and therefore not considered further in this assessment.
- 9.4.23 The cumulative noise limit that applies to all developments is a lower fixed limit of 40 dB $L_{A90,10min}$ or 5 dB(A) above the prevailing background, whichever is greater. The site specific noise limit that applies to the Proposed Scheme is the lesser of the cumulative noise limit minus the noise immissions from the cumulative developments, or 35 dB $L_{A90,10min}$ (or 5 dB above the prevailing background). In cases where the noise immission from the cumulative developments are equal to or greater than the cumulative limit, then the Proposed Scheme noise limit would be 10 dB below the cumulative limit.
- 9.4.24 During the night-time period, the same noise limits have been used, therefore the combined Proposed Scheme with other proposed, consented and operational wind development noise will be assessed against a noise limit of 43 dB $L_{A90,10min}$ or 5dB(A) above prevailing background, whichever is the greater.
- 9.4.25 A cumulative development is not acoustically significant if its noise immission is 10 dB below the Proposed Schemes noise immission, or over 10 dB below the cumulative limit. In addition, the Proposed Scheme is not considered acoustically significant if its noise immissions is 10 dB or less than the cumulative development noise immissions, or 10 dB below the cumulative noise limit.
- 9.4.26 Cumulative developments with noise immission within 10 dB of those from the Proposed Scheme are considered in the cumulative assessment.

Limitations of the assessment

- 9.4.27 This section considers the specific assumptions in relation to each of the assessments.

Design basis and assumptions

- 9.4.28 The operational noise assessment is based on a candidate turbine. The turbine dimensions and noise emissions have been selected in order to represent a typical worst-case scenario. The final selection of turbine will follow a competitive tendering process. However, any final choice of turbine will be required to comply with the noise limits which have been established for the Site within the noise assessment.

9.5 Existing environment

- 9.5.1 Noise monitoring was undertaken at three locations, selected as having sound environments considered to be representative of those at noise sensitive receptors in the vicinity of the Proposed Scheme. All noise monitoring locations were discussed and agreed with relevant Local Authority representatives.
- 9.5.2 Measurements of background sound levels at the three locations were undertaken during the period 24 March 2021 – 1 June 2021. The equipment used for the background noise monitoring comprised of Rion NL-52 Class 1 integrating logging sound level meters. These were enclosed in an environmental case with sufficient battery power to enable approximately 14-21 days continuous logging at the required 10-minute averaging periods, logging the L_{A90} , L_{Aeq} and a range of other parameters. The sound level meters were calibrated on deployment and retrieval, and during battery change visits.
- 9.5.3 The measurement systems were fitted with appropriate wind and rain protection for the microphone to maintain Class 1 measurement accuracy (the standard required for noise measurements in the UK and within Supplementary Guidance Note 1 of the IOA GPG).
- 9.5.4 All microphones were located away from reflective façades in a location deemed to be representative of background noise at the property, and using dual-skinned windshields. The microphone was located away from any obvious local sources of noise, for example boiler flues.
- 9.5.5 Full details of the noise monitoring kit specifications are given in **Technical Appendix 9.2 (Volume 4)** A summary of the noise monitoring locations is presented in **Table 9.5**.

Table 9.5: Noise monitoring locations

Reference	Receptor	Easting	Northing	Description
M1	Twyn yr Arian	310068.1	209853.6	Location to the north-west of the property. Road traffic noise dominant contributor to the noise environment. The sound level meter (SLM) deployment in the front garden of the property was discounted due to the presence of vegetation. A location at the rear of the property was selected. During deployment, sound from the nearby power lines was inaudible, and the dominant contributor to the sound environment was road traffic noise. The potential for noise from the power lines, such as 'corona discharge', is considered in the data analysis.
M2	Blaen Morlais Farm	307308.0	209330.6	Location to the south-west of the property. Road traffic noise dominant contributor to the noise environment, and psithurism. The deployment of the SLM was in an area away from the properties ventilation building services, located on the other side of the property.
M3	Blaen Rhymney Farm	310467.0	210688.1	Location to the south-west of the property. Road traffic noise dominant contributor to the noise environment, in addition to occasional noise from the property's kennels. An SLM located in close proximity to the property (<20 m), at the front of the property, was discounted due to the influence of noise from the operation of dog kennels. The SLM was deployed in a relatively quiet area of the property.

9.5.6 A summary of the residential receptors within the study area of the Proposed Scheme, and the noise monitoring locations considered to be representative of that location is presented in **Table 9.6**.

Table 9.6: Receptors and representative background noise monitoring locations

Receptor	Representative Monitoring Location	Justification of Representative Monitoring Location
R1 Blaen-Rhymney Farm	M3	M3 was located within the grounds of the property
R2 Ty Isaf Farm	M1	Noise environment at M1 considered to be similar to those at R2
R3 Reservoir House	M1	Noise environment at M1 considered to be similar to those at R2
R4 Twyn Yr Arian	M1	M1 was located within the ground of the property
R5 Pleasant View	M1	Noise environment at M1 considered to be similar to those at R5. Conservative approach given R5 closer to A465
R6 Y Graig Lwyd	M1	Noise environment at M1 considered to be similar to those at R6. Conservative approach given R6 closer to A465
R7 Lakeside Farm	M1	Noise environment at M1 considered to be similar to those at R7. Conservative approach given R7 closer to A465
R8 Pond Cottage	M1	Noise environment at M1 considered to be similar to those at R8. Conservative approach given R8 closer to A465
R9 Gypsy Castle	M1	Noise environment at M1 considered to be similar to those at R9. Conservative approach given R9 closer to A465
R10 Blaen-Carno Farm	M1	Noise environment at M1 considered to be similar to those at R10. Conservative approach given R10 closer to A465
R11 Blaen-Morlais Farm	M2	M3 was located within the ground of the property

9.5.7 Figures showing the noise monitoring locations summarised in **Table 9.5**, and the noise sensitive receptors summarised in **Table 9.6**, in the context of the location of the Proposed Scheme wind turbines, and cumulative development wind turbines is included in **Technical Appendix 9.1**.

Rain measurements

9.5.8 Rain gauges were deployed during the noise monitoring survey to identify periods of rainfall. Rain data was collected using tipping-bucket rain gauges, deployed at M1 –

Twyn yr Arian, and M2 – Blaen Morlais Farm. The rain data from the two sites were combined, and a period was considered as rain affected if either, or both, of the rain gauges had identified rainfall.

Wind measurements

- 9.5.9 Wind speed and directional data were collected from an on-site anemometry mast ('Met mast'). The Met mast had anemometers at: 20 m, 40 m, 62 m, 80 m, and 90.7 m and located at Easting 308962, Northing 210353.
- 9.5.10 The Met mast collected wind speed and directional data in 10-minute periods.

Wind shear

- 9.5.11 The level of wind shear at a particular location defines the relationship between wind speeds at different heights. A low level of wind shear means that the wind speed at the hub height of the turbines is not much greater than that near the ground, whereas a high level of wind shear means that the wind speed at hub height is significantly greater than that near the ground.
- 9.5.12 Wind turbine manufacturers reference their turbine noise emissions to a 10 m height wind speed, derived from hub height wind speeds using a roughness length of 0.05 m. The implication being that should the site experience a high level of wind shear, for a specific 10 m height wind speed, the wind speed at hub height might be greater than assumed within their calculations, and thus actual turbine noise levels would be greater during reference periods.
- 9.5.13 Nevertheless, to allow an assessment compliant with the requirement of best practice guidance (IOA GPG, 2013), the determination of wind speeds at the Proposed Scheme's hub height are required in order to standardise them to a 10 m height, against which the turbine noise emission data is correlated. To do this, the following approach has been taken:
 1. The wind speed data from anemometers at two different heights, the upper being at a height no less than 60 % of the hub height of the proposed turbine and the second anemometer at least 15 metres below it are used to calculate the wind speed at the 105 m hub height using an exponential profile. For the Proposed Scheme, anemometers at 90.7 m (86 % of the Proposed Scheme hub height) and 62 m (28.7 m below 90.7 m anemometer) were used; and
 2. The calculated 105 m hub height wind speeds are used to derive a 10 m height wind speed using the standard roughness length of 0.05 m assumed by wind turbine manufacturers in certifying turbine noise emissions, to maintain the requirement of the ETSU Guidance of deriving noise limits referenced to a 10 m height wind speed.

Background noise levels

- 9.5.14 The above approach allows the measured background noise levels to be compared with calculated wind turbine noise immission.

- 9.5.15 Periods of recorded rainfall, including 10-minutes before and 10-minutes after the rainfall, have been excluded from the measured noise data used to derive the background sound levels.
- 9.5.16 The range of wind speeds and directions recorded over the monitoring periods, standardised to a 10m height using the methodology outlined above are included in **Technical Appendix 9.3 (Figure 9.16 - Figure 9.27, Volume 4)**. The range of wind speeds at each monitoring locations are presented for the entire monitoring period, and also for the assessment periods, summarised in **Table 9.7**.
- 9.5.17 In addition to a presentation of the monitoring data associated with the full range of wind directions measured during the survey, additional analysis has been undertaken to determine whether there are changes in the background noise environment owing to wind direction. These changes can be due to the presence of an existing noise source, such as a wind development, which has differing contributions to the background noise environment depending on wind conditions. This process is called 'directional analysis', and is considered for each of the three monitoring locations.
- 9.5.18 Monitoring locations M2 and M3 are in the vicinity of existing operational wind turbines, and data collected during periods when the monitoring locations were downwind of these wind turbines have been removed from the monitoring data as a conservative approach. The noise environment at M1 is characterised by road traffic noise. As M1 is located between the Proposed Scheme, and the A465, directional analysis of the prevailing background noise levels has been applied to ensure a representative assessment.
- 9.5.19 A summary of the directional analysis at each of the monitoring locations and an associated justification is summarised in **Table 9.7**.

Table 9.7: Noise monitoring locations (directional analysis)

Ref.	Range of Wind Directions to Remove	Range of Wind Directions Included	Justification for Directional Analysis
M1 – Twyn Yr Arian	335 - 245 ⁰	245 - 335 ⁰	The Proposed Scheme is located upwind of M1 and road traffic noise is a significant contributor to the background noise environment during downwind periods.
M2 – Blaen-Morlais Farm	75 - 165 ⁰	165 - 75 ⁰	Range is $\pm 45^0$ of the closest cumulative development
M3 – Blaen-Rhymney	60 - 150 ⁰	150 - 60 ⁰	Range is $\pm 45^0$ of the closest cumulative development

- 9.5.20 The resulting prevailing background noise levels during the quiet day-time (1800-2300hrs Monday-Friday, 1300-2300hrs Saturday, 0700-2300hrs Sunday) and night-time (2300-0400hrs, the period 0400-0700hrs has been removed due to the influence

of dawn chorus) periods for the residential receptors within the study area of the Proposed Scheme are presented in **Table 9.8** at integer wind speeds up to 12ms⁻¹. These are shown with and without the directional analysis (DA).

Table 9.8: Background noise levels derived from noise monitoring data

Receptor	Standardised Wind Speed, ms ⁻¹								
	4	5	6	7	8	9	10	11	12
Day-time (1800-2300hrs Monday-Friday, 1300-2300hrs Saturday, 0700-2300hrs Sunday)									
M1	40.2	40.6	41.1	41.8	42.7	44.0	45.6	47.6	50.1
M1 (DA) [#]	39.0	39.6	40.1	40.6	40.9	41.2	41.3	41.3	41.3
M2	37.6	38.8	40.1	41.6	43.2	44.9	46.5	48.1	49.6
M2 (DA) [#]	38.2	39.2	40.4	41.7	43.0	44.5	46.2	47.9	49.8
M3	33.2	34.7	36.5	38.7	41.1	43.6	46.2	48.7	51.1
M3 (DA)	33.3	34.6	36.3	38.3	40.6	43.0	45.5	48.0	50.5
Night-time (2300-0400hrs)									
M1	31.8	32.6	33.6	34.8	36.5	38.8	41.9	45.9	51.0
M1 (DA) [#]	31.9	32.1	32.5	33.5	35.4	38.7	38.7	38.7	38.7
M2	36.0	36.7	37.4	38.2	39.2	40.7	42.7	45.3	48.8
M2 (DA) [#]	36.9	37.4	37.7	38.2	39.1	40.4	42.5	45.5	45.5
M3	29.3	31.2	33.3	35.6	38.1	40.6	43.2	45.9	48.4
M3 (DA) [#]	29.5	31.4	33.4	35.7	38.0	40.5	43.0	45.6	48.1

[#]Prevailing background noise levels with directional analysis applied, as described in *Table 9.7*

- 9.5.21 The associated charts of the background noise levels at the monitoring locations during the quiet day-time and night-time periods, correlated with wind speed data is included in **Technical Appendix 9.4**.
- 9.5.22 A review of the measured background sound data has shown a ‘best fit’ polynomial curve which has a relatively large range in measured values at each integer wind speed. This would indicate that wind induced noise is not a dominant contributor at these locations, and likely dominated by other noise sources, namely road traffic noise. Whilst the IOA GPG states that the degree of correlation between the measured noise level and wind speed on site is not an indication of the appropriateness of the noise survey data, the measurement data at M3 with directional analysis (‘M3 (DA)’), which is shows a greater correlation between measured noise level and wind speed has been adopted for all receptors presented in **Table 9.6**. The associated derived background noise levels are also lower at a majority of wind speeds, when compared with the other scenarios.

ETSU Guidance – Proposed Scheme: assessment noise limits

- 9.5.23 The prevailing background noise levels summarised in **Table 9.8** have been used to derive day-time and night-time noise limits according to the methodologies advocated in the ETSU Guidance. The noise limits apply to the assessment of the Proposed Scheme in isolation, and are summarised in **Table 9.9**.

Table 9.9: Proposed Scheme: Assessment noise limits according to ETSU Guidance (day-time 35 dB L_{A90} lower limit / night-time 43 dB L_{A90} lower limit) [M3 DA at all locations]

Receptor	Standardised Wind Speed, ms ⁻¹								
	4	5	6	7	8	9	10	11	12
Day-time (1800-2300hrs Monday-Friday, 1300-2300hrs Saturday, 0700-2300hrs Sunday)									
R1 Blaen-Rhymney Farm	38.3	39.6	41.3	43.3	45.6	48.0	50.5	53.0	55.5
R2 Ty Isaf Farm	38.3	39.6	41.3	43.3	45.6	48.0	50.5	53.0	55.5
R3 Reservoir House	38.3	39.6	41.3	43.3	45.6	48.0	50.5	53.0	55.5
R4 Twyn Yr Arian	38.3	39.6	41.3	43.3	45.6	48.0	50.5	53.0	55.5
R5 Pleasant View	38.3	39.6	41.3	43.3	45.6	48.0	50.5	53.0	55.5
R6 Y Graig Lwyd	38.3	39.6	41.3	43.3	45.6	48.0	50.5	53.0	55.5
R7 Lakeside Farm	38.3	39.6	41.3	43.3	45.6	48.0	50.5	53.0	55.5
R8 Pond Cottage	38.3	39.6	41.3	43.3	45.6	48.0	50.5	53.0	55.5
R9 Gypsy Castle	38.3	39.6	41.3	43.3	45.6	48.0	50.5	53.0	55.5
R10 Blaen-Carno Farm	38.3	39.6	41.3	43.3	45.6	48.0	50.5	53.0	55.5
R11 Blaen-Morlais Farm	38.3	39.6	41.3	43.3	45.6	48.0	50.5	53.0	55.5
Night-time (2300-0400hrs)									
R1 Blaen-Rhymney Farm	43.0	43.0	43.0	43.0	43.0	45.5	48.0	50.6	53.1
R2 Ty Isaf Farm	43.0	43.0	43.0	43.0	43.0	45.5	48.0	50.6	53.1
R3 Reservoir House	43.0	43.0	43.0	43.0	43.0	45.5	48.0	50.6	53.1
R4 Twyn Yr Arian	43.0	43.0	43.0	43.0	43.0	45.5	48.0	50.6	53.1
R5 Pleasant View	43.0	43.0	43.0	43.0	43.0	45.5	48.0	50.6	53.1
R6 Y Graig Lwyd	43.0	43.0	43.0	43.0	43.0	45.5	48.0	50.6	53.1
R7 Lakeside Farm	43.0	43.0	43.0	43.0	43.0	45.5	48.0	50.6	53.1
R8 Pond Cottage	43.0	43.0	43.0	43.0	43.0	45.5	48.0	50.6	53.1

Receptor	Standardised Wind Speed, ms ⁻¹								
	4	5	6	7	8	9	10	11	12
R9 Gypsy Castle	43.0	43.0	43.0	43.0	43.0	45.5	48.0	50.6	53.1
R10 Blaen-Carno Farm	43.0	43.0	43.0	43.0	43.0	45.5	48.0	50.6	53.1
R11 Blaen-Morlais Farm	43.0	43.0	43.0	43.0	43.0	45.5	48.0	50.6	53.1

9.6 Assessment of effects

Primary Mitigation

Construction noise

- 9.6.1 Construction noise is transient in nature and can generally be controlled by following standard industry practices, applying best practicable means and using modern, well-maintained and serviced items of plant.
- 9.6.2 No specific mitigation is required with regards to construction noise however general guidance for controlling construction noise is given in British Standard 5228-1 (2014). As good practice, the following mitigation measures concerning construction noise should be implemented:
- Restricted hours of working (07:00 to 19:00 Monday to Friday, 07:00 - 12:00 Saturdays) for most heavy vehicle movements to avoid sensitive periods. Any requirement to work outside of these periods would only occur through prior agreement with the local planning authority (for example turbine erection requires low wind speed conditions and may require longer working hours if conditions are poor at the time);
 - All construction activities to be undertaken in accordance with good practice as set out in BS5228-1 (2014);
 - Where possible, employees on the Proposed Scheme construction site will be advised of quieter methods of operating plant and tools, and to report any damage to noise control measures as soon as they are identified;
 - Where possible and practicable to do so, for any particular activity, locally available and suitable plant, machinery and working practices would be adopted. All equipment will be maintained in good working order and will be fitted with appropriate noise controls at all times (e.g. silencers, mufflers and/or acoustic hoods); and
 - Construction plant capable of generating significant noise and vibration levels will be operated in a manner to minimise the duration of the higher magnitude levels.

Operational Noise

- 9.6.3 The candidate wind turbine for the Proposed Scheme is the Nordex N149 (105 m hub height) without serrated trailing edges.

- 9.6.4 The final selection of turbine will follow a competitive tendering process and thus the actual model of turbine may differ from the candidate turbine. However, the final choice of wind turbine will be required to comply with the noise criterion levels which have been established for the Site within the noise assessment. Details of the candidate turbines sound power level emissions, and the octave band centre frequency data is included in **Technical Appendix 9.5 (Volume 4)**.

Operational Noise – Prediction Methodology

- 9.6.5 In line with the assessment methodology advocated within the IOA GPG (2013), the turbine noise prediction model used in this assessment is based on that found in ISO 9613-2 *Acoustics - Attenuation of sound during propagation outdoors*. The noise model takes account of:
- Geometric divergence (attenuation with distance);
 - Air absorption;
 - Topographic screening effects;
 - Screening (including vegetation); and
 - Ground absorption and reflection.
- 9.6.6 The ISO 9613-2 algorithm has been chosen as being the most robust prediction method, which tends to over-estimate noise levels at nearby dwellings, rather than under-estimate. The ISO 9613-2 algorithm tends to predict noise levels that would generally occur under downwind propagation conditions.
- 9.6.7 All noise level predictions have been based upon the following assumed model parameters, which are supported within the best practice guide:
- A receiver height of 4.0 m above local ground level - to represent the height of a typical bedroom window;
 - Mixed ground ($G = 0.5$);
 - Air absorption based on a temperature of 10°C and 70% relative humidity;
 - A reduction of 2 dB associated with topographic screening effects if there is no direct line of sight between the highest point on the turbine (blade tip) and the receiver location;
 - $L_{A90,10min}$ is 2 dB less than $L_{Aeq,10min}$ for both background and wind farm noise; and
 - Predicted turbine noise levels are inclusive of any correction for concave ground correction (discussed below).
- 9.6.8 The IOA GPG (2013) recommends that a noise correction is applied in circumstances where the intervening terrain height between a proposed wind development and sensitive receptors drops away significantly. The correction is to account for the effective decrease in ground absorption at higher propagation paths. Where a 'concave ground (required correction for propagation 'across a valley' as defined in Par 4.3.9 of IOA GPG (2013)) is shown to occur a correction of 3 dB (or 1.5 dB if a

ground absorption factor of 0 is being used) is applied to the overall predicted noise level at receptors.

- 9.6.9 An analysis of the terrain surrounding the Proposed Scheme using Ordnance Survey Terrain50 50m digital terrain data indicated that there are wind turbine to receptor propagation paths that would qualify for the 'concave ground effect' correction.

Operational Noise – Predictions

- 9.6.10 Noise levels from the Proposed Scheme have been predicted in accordance with the methodologies outlined in the sections above.
- 9.6.11 **Table 9.10, Table 9.11, Table 9.12 and Table 9.13** present the following information for each wind speed for each of the assessed noise sensitive receptors for the day-time and night-time periods respectively:
- Values of the quiet day-time amenity and night-time background noise curve at the integer wind speeds, measured and adjusted for wind shear;
 - The day-time amenity and night-time noise limits derived from the background noise curve, in accordance with the ETSU Guidance;
 - The predicted turbine noise levels from the Proposed Scheme, based on worst-case downwind noise propagation at receptors, assuming turbines are operating simultaneously, and inclusive of a 'concave ground effect' correction where applicable; and
 - The margin by which the Proposed Scheme predicted turbine noise levels meets the noise limits at each wind speed using the worst-case downwind noise predictions (negative values indicate the predicted noise levels are lower than the noise limits).
- 9.6.12 **Technical Appendix 9.6, Figure 9.40 - Figure 9.61 (Volume 4)** present the noise levels taken from **Table 9.10, Table 9.11, Table 9.12 and Table 9.13** graphically. The figures are summarised as:

Day-time assessment

- Solid Blue Line – Proposed Scheme predicted turbine noise immission
 - Solid Grey Line – ETSU Guidance noise limit (35 dB L_{A90} lower fixed limit) [based on M3 DA background noise level]
 - Solid Black Line - ETSU Guidance noise limit (40 dB L_{A90} lower fixed limit) [based on M3 DA background noise level]
- 9.6.13 The noise assessment of the Proposed Scheme has adopted the ETSU Guidance advocated lower fixed noise limit as a conservative approach. The figures also show the 40 dB L_{A90} lower fixed noise limit, for reference.

Night-time assessment

- Solid Blue Line – Proposed Scheme predicted turbine noise immission

- Solid Black Line - ETSU Guidance noise limit (43 dB LA₉₀ lower fixed limit) [based on M3 DA background noise level]

9.6.14 The predicted turbine noise immission are equal for both the day and night-time periods, however the assessments are presented separately to take account of the different applicable noise limits.

Table 9.10: Noise Assessment – Day-time

Noise Parameters, LA ₉₀ 10min, dB	10m standardised Wind Speed (m/s)								
	4	5	6	7	8	9	10	11	12
R1									
Proposed Scheme Wind Farm Noise	26.2	30.8	35.2	36.6	36.6	36.6	36.6	36.6	36.6
ETSU-R-97 Derived Noise Limit	38.3	39.6	41.3	43.3	45.6	48.0	50.5	53.0	55.5
Margin Under Noise Limit [#]	-12.1	-8.8	-6.1	-6.7	-9.0	-11.4	-13.9	-16.4	-18.9
R2									
Proposed Scheme Wind Farm Noise	24.3	28.9	33.3	34.7	34.7	34.7	34.7	34.7	34.7
ETSU-R-97 Derived Noise Limit	38.3	39.6	41.3	43.3	45.6	48.0	50.5	53.0	55.5
Margin Under Noise Limit [#]	-14.0	-10.7	-8.0	-8.6	-10.9	-13.3	-15.8	-18.3	-20.8
R3									
Proposed Scheme Wind Farm Noise	24.2	28.8	33.2	34.6	34.6	34.6	34.6	34.6	34.6
ETSU-R-97 Derived Noise Limit	38.3	39.6	41.3	43.3	45.6	48.0	50.5	53.0	55.5
Margin Under Noise Limit [#]	-14.1	-10.8	-8.1	-8.7	-11.0	-13.4	-15.9	-18.4	-20.9
R4									
Proposed Scheme Wind Farm Noise	25.8	30.4	34.8	36.2	36.2	36.2	36.2	36.2	36.2
ETSU-R-97 Derived Noise Limit	38.3	39.6	41.3	43.3	45.6	48.0	50.5	53.0	55.5
Margin Under Noise Limit [#]	-12.5	-9.2	-6.5	-7.1	-9.4	-11.8	-14.3	-16.8	-19.3
R5									
Proposed Scheme Wind Farm Noise	23.1	27.7	32.1	33.5	33.5	33.5	33.5	33.5	33.5
ETSU-R-97 Derived Noise Limit	38.3	39.6	41.3	43.3	45.6	48.0	50.5	53.0	55.5
Margin Under Noise Limit [#]	-15.2	-11.9	-9.2	-9.8	-12.1	-14.5	-17.0	-19.5	-22.0
R6									
Proposed Scheme Wind Farm Noise	23.0	27.6	32.0	33.4	33.4	33.4	33.4	33.4	33.4

Noise Parameters, L_{A90} 10min, dB	10m standardised Wind Speed (m/s)								
	4	5	6	7	8	9	10	11	12
ETSU-R-97 Derived Noise Limit	38.3	39.6	41.3	43.3	45.6	48.0	50.5	53.0	55.5
Margin Under Noise Limit [#]	-15.3	-12.0	-9.3	-9.9	-12.2	-14.6	-17.1	-19.6	-22.1

[#] Negative values indicate turbine noise lies below noise limit

All figures are rounded to the nearest 0.1 dB

Table 9.11: Noise Assessment – Day-time (2)

Noise Parameters, L_{A90} 10min, dB	10m Wind Speed quoted by Manufacturer (m/s)								
	4	5	6	7	8	9	10	11	12
R7									
Proposed Scheme Wind Farm Noise	23.0	27.6	32.0	33.4	33.4	33.4	33.4	33.4	33.4
ETSU-R-97 Derived Noise Limit	38.3	39.6	41.3	43.3	45.6	48.0	50.5	53.0	55.5
Margin Under Noise Limit [#]	-15.3	-12.0	-9.3	-9.9	-12.2	-14.6	-17.1	-19.6	-22.1
R8									
Proposed Scheme Wind Farm Noise	23.9	28.5	32.9	34.3	34.3	34.3	34.3	34.3	34.3
ETSU-R-97 Derived Noise Limit	38.3	39.6	41.3	43.3	45.6	48.0	50.5	53.0	55.5
Margin Under Noise Limit [#]	-14.4	-11.1	-8.4	-9.0	-11.3	-13.7	-16.2	-18.7	-21.2
R9									
Proposed Scheme Wind Farm Noise	25.1	29.7	34.1	35.5	35.5	35.5	35.5	35.5	35.5
ETSU-R-97 Derived Noise Limit	38.3	39.6	41.3	43.3	45.6	48.0	50.5	53.0	55.5
Margin Under Noise Limit [#]	-13.2	-9.9	-7.2	-7.8	-10.1	-12.5	-15.0	-17.5	-20.0
R10									
Proposed Scheme Wind Farm Noise	24.8	29.4	33.8	35.2	35.2	35.2	35.2	35.2	35.2
ETSU-R-97 Derived Noise Limit	38.3	39.6	41.3	43.3	45.6	48.0	50.5	53.0	55.5
Margin Under Noise Limit [#]	-13.5	-10.2	-7.5	-8.1	-10.4	-12.8	-15.3	-17.8	-20.3
R11									
Proposed Scheme Wind Farm Noise	27.1	31.7	36.1	37.5	37.5	37.5	37.5	37.5	37.5
ETSU-R-97 Derived Noise Limit	38.3	39.6	41.3	43.3	45.6	48.0	50.5	53.0	55.5
Margin Under Noise Limit [#]	-11.2	-7.9	-5.2	-5.8	-8.1	-10.5	-13.0	-15.5	-18.0

[#] Negative values indicate turbine noise lies below noise limit

All figures are rounded to the nearest 0.1 dB

Table 9.12: Noise Assessment – Night-time

Noise Parameters, L _{A90} 10min, dB	10m Wind Speed quoted by Manufacturer (m/s)								
	4	5	6	7	8	9	10	11	12
R1									
Proposed Scheme Wind Farm Noise	26.2	30.8	35.2	36.6	36.6	36.6	36.6	36.6	36.6
ETSU-R-97 Derived Noise Limit	43.0	43.0	43.0	43.0	43.0	45.5	48.0	50.6	53.1
Margin Under Noise Limit [#]	-16.8	-12.2	-7.8	-6.4	-6.4	-8.9	-11.4	-14.0	-16.5
R2									
Proposed Scheme Wind Farm Noise	24.3	28.9	33.3	34.7	34.7	34.7	34.7	34.7	34.7
ETSU-R-97 Derived Noise Limit	43.0	43.0	43.0	43.0	43.0	45.5	48.0	50.6	53.1
Margin Under Noise Limit [#]	-18.7	-14.1	-9.7	-8.3	-8.3	-10.8	-13.3	-15.9	-18.4
R3									
Proposed Scheme Wind Farm Noise	24.2	28.8	33.2	34.6	34.6	34.6	34.6	34.6	34.6
ETSU-R-97 Derived Noise Limit	43.0	43.0	43.0	43.0	43.0	45.5	48.0	50.6	53.1
Margin Under Noise Limit [#]	-18.8	-14.2	-9.8	-8.4	-8.4	-10.9	-13.4	-16.0	-18.5
R4									
Proposed Scheme Wind Farm Noise	25.8	30.4	34.8	36.2	36.2	36.2	36.2	36.2	36.2
ETSU-R-97 Derived Noise Limit	43.0	43.0	43.0	43.0	43.0	45.5	48.0	50.6	53.1
Margin Under Noise Limit [#]	-17.2	-12.6	-8.2	-6.8	-6.8	-9.3	-11.8	-14.4	-16.9
R5									
Proposed Scheme Wind Farm Noise	23.1	27.7	32.1	33.5	33.5	33.5	33.5	33.5	33.5
ETSU-R-97 Derived Noise Limit	43.0	43.0	43.0	43.0	43.0	45.5	48.0	50.6	53.1
Margin Under Noise Limit [#]	-19.9	-15.3	-10.9	-9.5	-9.5	-12.0	-14.5	-17.1	-19.6
R6									
Proposed Scheme Wind Farm Noise	23.0	27.6	32.0	33.4	33.4	33.4	33.4	33.4	33.4
ETSU-R-97 Derived Noise Limit	43.0	43.0	43.0	43.0	43.0	45.5	48.0	50.6	53.1
Margin Under Noise Limit [#]	-20.0	-15.4	-11.0	-9.6	-9.6	-12.1	-14.6	-17.2	-19.7

[#] Negative values indicate turbine noise lies below noise limit

All figures are rounded to the nearest 0.1 dB

Table 9.13: Noise Assessment – Night-time (2)

Noise Parameters, L _{A90} 10min, dB	10m Wind Speed quoted by Manufacturer (m/s)								
	4	5	6	7	8	9	10	11	12
R7									
Proposed Scheme Wind Farm Noise	23.0	27.6	32.0	33.4	33.4	33.4	33.4	33.4	33.4
ETSU-R-97 Derived Noise Limit	43.0	43.0	43.0	43.0	43.0	45.5	48.0	50.6	53.1
Margin Under Noise Limit [#]	-20.0	-15.4	-11.0	-9.6	-9.6	-12.1	-14.6	-17.2	-19.7
R8									
Proposed Scheme Wind Farm Noise	23.9	28.5	32.9	34.3	34.3	34.3	34.3	34.3	34.3
ETSU-R-97 Derived Noise Limit	43.0	43.0	43.0	43.0	43.0	45.5	48.0	50.6	53.1
Margin Under Noise Limit [#]	-19.1	-14.5	-10.1	-8.7	-8.7	-11.2	-13.7	-16.3	-18.8
R9									
Proposed Scheme Wind Farm Noise	25.1	29.7	34.1	35.5	35.5	35.5	35.5	35.5	35.5
ETSU-R-97 Derived Noise Limit	43.0	43.0	43.0	43.0	43.0	45.5	48.0	50.6	53.1
Margin Under Noise Limit [#]	-17.9	-13.3	-8.9	-7.5	-7.5	-10.0	-12.5	-15.1	-17.6
R10									
Proposed Scheme Wind Farm Noise	24.8	29.4	33.8	35.2	35.2	35.2	35.2	35.2	35.2
ETSU-R-97 Derived Noise Limit	43.0	43.0	43.0	43.0	43.0	45.5	48.0	50.6	53.1
Margin Under Noise Limit [#]	-18.2	-13.6	-9.2	-7.8	-7.8	-10.3	-12.8	-15.4	-17.9
R11									
Proposed Scheme Wind Farm Noise	27.1	31.7	36.1	37.5	37.5	37.5	37.5	37.5	37.5
ETSU-R-97 Derived Noise Limit	43.0	43.0	43.0	43.0	43.0	45.5	48.0	50.6	53.1
Margin Under Noise Limit [#]	-15.9	-11.3	-6.9	-5.5	-5.5	-8.0	-10.5	-13.1	-15.6

[#] Negative values indicate turbine noise lies below noise limit

All figures are rounded to the nearest 0.1 dB

9.6.15 It is shown in **Table 9.10**, **Table 9.11**, **Table 9.12** and **Table 9.13** that the Proposed Scheme noise immission, are predicted to meet the ETSU Guidance derived noise limits at all locations across all assessed wind speeds.

9.6.16 The day-time noise assessment, as summarised in **Table 9.10** and **Table 9.11**, shows that the Proposed Scheme noise immission are 5.2 dB (R11) or greater below the associated ETSU Guidance derived noise limits. The night-time noise assessment, as summarised in **Table 9.12** and **Table 9.13** shows that the Proposed

Scheme noise immission are 5.5 dB (R11) or greater below the associated ETSU Guidance derived noise limits.

- 9.6.17 At all other assessed locations, greater margins are shown between the Proposed Scheme noise immission and the ETSU Guidance derived noise limits.

Other Operational Noise Issues

Infrasound and Low Frequency Noise

- 9.6.18 Infrasound is generally defined as pressure waves with a frequency below 20Hz. The human hearing threshold is much reduced below 20Hz compared to higher frequencies. The exact definition of low frequency noise varies, but generally spans the infrasonic and audible ranges from around 10Hz to 200Hz.
- 9.6.19 The Department of Trade and Industry-commissioned report *The Measurement of Low Frequency Noise at three UK Wind Farms* (DTI Report, 2006) presents the results of a number of measurements taken at wind farm sites throughout the UK. The study concluded that measured levels were extremely low, such that there would be no audibility or other effects, even accounting for sensitive period. At all of the measurement sites, low frequency noise associated with traffic movement along local roads was greater than that associated with the wind farm.
- 9.6.20 Furthermore, in its discussions of wind farm noise, TAN 8 states in paragraph 2.17: *“There is no evidence that ground transmitted low frequency noise from wind turbines is at a sufficient level to be harmful to human health.”*

Aerodynamic Modulation

- 9.6.21 The aerodynamic noise produced by a turbine can be observed as having a “swish” characteristic, associated with the modulation of the sound related to the rotating blades.
- 9.6.22 The noise limits derived following the procedure recommended by the ETSU Guidance are generally acknowledged to take into account the phenomenon of aerodynamic modulation (AM, also termed amplitude modulation) to a certain extent and thus afford receptors some protection.
- 9.6.23 However, the DTI Report (2006) (later BERR, now DECC) study into low frequency noise referred to above also investigated the phenomenon of AM. It was found that internal noise levels associated with an audible or enhanced AM (often referred to as ‘Excessive Amplitude Modulation’ (EAM)) were above the threshold of audibility at some properties. While measurements within the report indicated these were not high enough to wake occupiers of a room, they could result in difficulties returning to sleep once awoken.
- 9.6.24 The UK Government then commissioned Salford University to undertake a research study to investigate the occurrence of the AM phenomenon in more detail. A survey was conducted of local authorities to investigate the extent of AM, and complaint histories were analysed to determine the number of complainants. The phenomenon was considered to be a factor in four of the sites at which there had been complaints and a possible factor at eight further sites. It was found that meteorological conditions

were such that the effect would prevail for between 7-15% of the time and could persist for several days. The report concluded that given the low incidence of aerodynamic modulation and the low numbers of people involved it is difficult to justify further research; however they do state it may be prudent to attempt to improve our understanding as the phenomenon cannot be predicted at present.

- 9.6.25 In 2013, RenewableUK commissioned extensive research into AM ('Wind Turbine Amplitude Modulation: Research to Improve Understanding as to its Cause and Effect' (2013) which reviewed available research with the aim of identifying the source of enhanced levels of wind turbine AM noise. The RenewableUK research identified the cause of AM which is not normally expected from a wind turbine ('normal AM' (NAM)), termed 'Other AM' (OAM) as being associated with stall in the wind turbine blade.
- 9.6.26 The RenewableUK research developed methods for quantifying AM, which were revisited and revised by an Institute of Acoustics (IOA) Amplitude Modulation Working Group, as reported in the '*A Method for Rating Amplitude Modulation in Wind Turbine Noise*' (2016). The IOA report does not however set out assessment thresholds.
- 9.6.27 The UK Government commissioned a review into the evidence on the response to amplitude modulation from wind turbines¹, and how it may be controlled. The outcome of the research is that a 'character penalty' approach, similar in principle to that adopted in the consideration of tonal noise, should be applied. However, no UK or International Government has adopted or applied this character correction to any developments.
- 9.6.28 Based on the current information, including the guidance and research set out above, the assessment of operational noise is based on the derived noise limits using the methodology specified in the ETSU Guidance is appropriate.

9.7 Grid connection

- 9.7.1 The grid connection is located to the south-west of the Proposed Scheme. The potential effects include:
 - Noise and vibration associated with on-site construction activities; and
 - Noise during operation of the grid connection.
- 9.7.2 The construction programme for the grid connection is not suitably developed to provide detailed phasing and equipment data. Therefore, associated noise impacts will be controlled through general guidance, as described in Section 9.8.
- 9.7.3 With regards to operational noise, the grid connection will be underground, and therefore there will be a negligible impact at receptor locations.

¹ [Review of the evidence on the response to amplitude modulation from wind turbines - GOV.UK \(www.gov.uk\)](https://www.gov.uk/government/reviews/consultation-on-response-to-amplitude-modulation-from-wind-turbines)

9.8 Mitigation

Operational Noise

- 9.8.1 As the noise assessment is an iterative process, the aim of which is to design a scheme which meets the noise limits, no additional mitigation or enhancement measures are required for operational noise as operational noise limits are complied with.

9.9 Summary of effects

- 9.9.1 A noise assessment was carried out for the Proposed Scheme. The assessment considered noise from construction, operation and decommissioning.
- 9.9.2 It is concluded that the separation between turbines and residential areas is of sufficient distance that any construction or decommissioning noise effects will be minimised. No significant effects are anticipated in this regard.
- 9.9.3 Operational noise was assessed in accordance with the ETSU Guidance and assessment methodology advocated within the IoA GPG (2013). The design of the Proposed Scheme is such that based on a commercially available candidate turbine, the operational noise levels from the Proposed Scheme fall within the ETSU Guidance noise limits derived from measurements taken at the surrounding receptors.
- 9.9.4 A range of turbines are appropriate for the Proposed Scheme. Whilst the assessment is based upon a candidate turbine, the final model will eventually be selected by a competitive tendering process. Any wind turbine installed will be required to meet the noise limits set out in this chapter.
- 9.9.5 Consequently, it is concluded that the Proposed Scheme will have **no significant effects** in relation to noise.

9.10 Cumulative effects

- 9.10.1 This section sets out the assessment of cumulative effects from wind turbines either operational, under construction (i.e. not included in the baseline) or in the planning system that have a rated capacity of over 50 kW². Refer also to paragraph 9.4.22 which presents the approach to the assessment of cumulative developments.
- 9.10.2 The cumulative developments within the spatial extents of the operational noise assessment are summarised in **Table 9.14**. The location of the cumulative development wind turbines are included in **Technical Appendix 9.1 (Volume 4)**.

² IOA GPG Paragraph 1.2.1 'This guide presents current good practice in the application of the ETSU-R-97 assessment methodology for all wind turbine developments above 50 kW, reflecting the original principles within ETSU-R-97, and the results of research carried out and experience gained since ETSU-R-97 was published.'

Table 9.14: Cumulative developments

Wind Development	Number of Turbines	Planning Reference
Pen Bryn Oer Wind Farm	3	P13/0483/FULL
Plot 5 Pengarnddu Industrial Estate Wind Turbine	1	P/12/0078
Unit 29 Tafarnaubach Industrial Estate	1	C/2012/0327
St. Merryn Meat Factory	1	P/16/0128

Small wind development

- 9.10.3 There is a consented wind turbine at Valley Heights Filling Station³, as summarised in **Table 9.15**, identified during the planning search. Permission is set out in the decision notice (Ref.P/16/0384, 10 February 2017). The wind turbine is 15 kW, so less than 50 kW, and therefore outside the scope of the IOA GPG and ETSU Guidance.
- 9.10.4 However, for informative purposes, consideration of the noise immissions from the small wind development in addition to those from the Proposed Scheme and cumulative developments is set out in **Technical Appendix 9.5 (Volume 4)**.

Table 9.15: Small wind turbine developments

Wind Development	Number of Turbines	Planning Reference
Valley Heights Filling Station	1	P/16/0384

Existing Environment

- 9.10.5 The receptors considered in the cumulative assessment, as summarised in **Table 9.4**, have been identified from aerial photography, site visits, and a review of the noise related documentation in support of those developments. The receptors are residential receptors, or receptors with residential uses.

Table 9.16: Cumulative receptors and assessment noise limits

Receptor	Source Background Noise Levels
R12 Upper Ras Farm	Decision Notice ⁴
R13 Susannah Cottage	Decision Notice ⁵
R14 Princetown	Decision Notice ⁵

³ Erection of a single micro wind turbine with a hub height of 15 metres and blade tip height 20.2 metres (Planning Ref. P/16/0384)

⁴ Amec Environment & Infrastructure UK Limited, 'Pen Bryn Oer Wind Farm' (June 2013)

Receptor	Source Background Noise Levels
R15 Lechryd	Decision Notice ⁵
R16 Merthyr Road	Decision Notice ⁵
R17 Penngarnddu	M3 DA
R18 Coedcae Row Terraces	M3 DA
R19 13-24 Station Terrace	M3 DA
R20 Carpenters	M3 DA
R21 Robins	Noise Report (2016a) ⁵
R22 3 High Street	Noise Report (2016b) ⁶
R23 K & M Robins	Noise Report (2016b) ⁷
R24 Station House	Noise Report (2016b) ⁷
R25 Merthyr Road 2	M3 DA
R26 Old Prince Farm	M3 DA

ETSU Guidance – Cumulative developments: assessment noise limits

- 9.10.6 The prevailing background noise levels summarised in **Table 9.8**, and/or those stated in noise related documentation in support of the cumulative developments have been used to derive day-time and night-time noise limits according to the methodologies advocated in the ETSU Guidance.
- 9.10.7 The noise limits apply to the assessment of the Cumulative Developments and are summarised in **Table 9.17**.

Table 9.17: Cumulative Developments: assessment noise limits

Receptor	Standardised Wind Speed, ms ⁻¹								
	4	5	6	7	8	9	10	11	12
Day-time									
R12 Upper Ras Farm	42.2	42.4	42.8	43.5	44.8	46.8	49.5	49.5	49.5
R13 Susannah Cottage	45.4	45.8	46.1	46.7	47.6	48.9	50.6	50.6	50.6
R14 Princetown	56.1	55.5	54.8	54.3	54.4	55.1	56.5	56.5	56.5
R15 Lechryd	56.1	55.5	54.8	54.3	54.4	55.1	56.5	56.5	56.5
R16 Merthyr Road	50.5	50.9	51.2	51.6	52.1	52.9	54.0	54.0	54.0

⁵ Dragonfly Consultant, 'St Merryn Meats, Merthyr Tydfil, Wind Turbine Noise Assessment (DC1990-R1v2, March 2016)

⁶ 24Acoustics, 'Proposed Wind Turbine at Millenium Service Station Merthyr Tydfil: Noise Impact Assessment) (R6212-1 Rev 0, November 2016)

Receptor	Standardised Wind Speed, ms ⁻¹								
	4	5	6	7	8	9	10	11	12
R17 Penngarnddu	40.0	40.0	41.3	43.3	45.6	48.0	50.5	53.0	55.5
R18 Coedcae Row Terraces	40.0	40.0	41.3	43.3	45.6	48.0	50.5	53.0	55.5
R19 13-24 Station Terrace	40.0	40.0	41.3	43.3	45.6	48.0	50.5	53.0	55.5
R20 Carpenters	40.0	40.0	41.3	43.3	45.6	48.0	50.5	53.0	55.5
R21 Robins	44.0	44.0	46.0	47.7	49.6	51.7	54.0	54.0	54.0
R22 3 High Street	51.4	52.2	52.9	53.6	54.4	55.1	55.8	56.5	56.5
R23 K & M Robins	44.0	44.0	46.0	47.7	49.6	51.7	54.0	54.0	54.0
R24 Station House	44.0	44.0	46.0	47.7	49.6	51.7	54.0	54.0	54.0
R25 Merthyr Road 2	40.0	40.0	41.3	43.3	45.6	48.0	50.5	53.0	55.5
R26 Old Prince Farm	40.0	40.0	41.3	43.3	45.6	48.0	50.5	53.0	55.5
Night-time									
R12 Upper Ras Farm	43.0	43.0	43.0	43.0	43.0	46.2	49.8	49.8	49.8
R13 Susannah Cottage	43.0	43.0	43.0	43.6	45.1	47.0	49.1	49.1	49.1
R14 Princetown	43.0	43.0	43.0	43.0	44.8	46.9	49.2	49.2	49.2
R15 Lechryd	43.0	43.0	43.0	43.0	44.8	46.9	49.2	49.2	49.2
R16 Merthyr Road	44.4	45.2	45.8	46.3	46.8	47.4	48.7	48.7	48.7
R17 Penngarnddu	43.0	43.0	43.0	43.0	43.0	45.5	48.0	50.6	53.1
R18 Coedcae Row Terraces	43.0	43.0	43.0	43.0	43.0	45.5	48.0	50.6	53.1
R19 13-24 Station Terrace	43.0	43.0	43.0	43.0	43.0	45.5	48.0	50.6	53.1
R20 Carpenters	43.0	43.0	43.0	43.0	43.0	45.5	48.0	50.6	53.1
R21 Robins	44.0	44.0	46.0	47.7	49.6	51.7	54.0	54.0	54.0
R22 3 High Street	43.0	43.0	43.0	43.6	44.7	46.0	47.6	49.4	49.4
R23 K & M Robins	44.0	44.0	46.0	47.7	49.6	51.7	54.0	54.0	54.0
R24 Station House	44.0	44.0	46.0	47.7	49.6	51.7	54.0	54.0	54.0
R25 Merthyr Road 2	43.0	43.0	43.0	43.0	43.0	45.5	48.0	50.6	53.1
R26 Old Prince Farm	43.0	43.0	43.0	43.0	43.0	45.5	48.0	50.6	53.1

Cumulative Developments: Operational Noise – Prediction Methodology

- 9.10.8 The cumulative noise assessment has adopted the same prediction methodology as the assessment of noise from the Proposed Scheme.
- 9.10.9 For considering cumulative noise impacts, the IOA GPG (2013) does present a methodology for accounting for wind turbine propagation directivity i.e. at certain distances in upwind conditions between receivers and the wind farm, noise levels from a wind turbine are likely to be lower than in downwind conditions. However, in

order to present a conservative noise assessment, corrections for directivity have not been applied when calculating the wind turbine noise levels using the ISO 9613-2 algorithm.

- 9.10.10 Details of the cumulative development wind turbine sound power level emissions, and the octave band centre frequency data is included in **Appendix 9.5**.

Cumulative Developments: Operational Noise – Predictions

- 9.10.11 Noise levels from the Cumulative Developments have been predicted in accordance with the methodologies outlined in the sections above.

- 9.10.12 **Table 9.18 - Table 9.27** present the following information for each wind speed for each of the assessed noise sensitive receptors for the day-time and night-time periods respectively:

- The quiet day-time amenity and night-time noise limits for the cumulative assessment;
- The predicted turbine noise levels from the cumulative developments (all developments, including the Proposed Scheme), based on worst-case downwind noise propagation at receptors, assuming turbines are operating simultaneously, and inclusive of a 'concave ground effect' correction where applicable; and
- The margin by which the cumulative developments predicted turbine noise levels (inclusive of any 'concave ground effect' correction) meets the noise limits at each wind speed using the worst-case downwind noise predictions (negative values indicate the predicted noise levels are lower than the noise limits).

- 9.10.13 **Appendix 9.6, Figure 9.62 - Figure 9.73** present the noise levels taken from **Table 9.18 - Table 9.27** graphically. The figures are summarised as:

Day-time assessment

- Solid Blue Line – Proposed Scheme predicted turbine noise immission
- Solid Black Line - ETSU Guidance noise limit (40 dB L_{A90} lower fixed limit)

- 9.10.14 The noise assessment of the Proposed Scheme has adopted the ETSU Guidance advocated lower fixed noise limit as a conservative approach. The figures also show the 40 dB L_{A90} lower fixed noise limit, for reference.

Night-time assessment

- Solid Blue Line – Proposed Scheme predicted turbine noise immission
- Solid Black Line - ETSU Guidance noise limit (43 dB L_{A90} lower fixed limit)

- 9.10.15 The predicted turbine noise immission are equal for both the day and night-time periods, however the assessments are presented separately to take account of the different applicable noise limits

Table 9.18: Cumulative Development: Noise Assessment – Day-time (1)

Noise Parameters, $L_{A90\ 10min}$, dB	10m Wind Speed quoted by Manufacturer (m/s)								
	4	5	6	7	8	9	10	11	12
R1									
Cumulative Wind Farm Noise	27.7	32.3	36.4	37.8	38.0	38.0	38.0	38.0	38.0
Background Noise Curve	33.3	34.6	36.3	38.3	40.6	43.0	45.5	48.0	50.5
ETSU-R-97 Derived Noise Limit	40.0	40.0	41.3	43.3	45.6	48.0	50.5	53.0	55.5
Margin Under Noise Limit [#]	-12.3	-7.7	-4.9	-5.5	-7.6	-10.0	-12.5	-15.0	-17.5
R2									
Cumulative Wind Farm Noise	25.6	30.2	34.3	35.7	35.9	35.9	35.9	35.9	35.9
Background Noise Curve	33.3	34.6	36.3	38.3	40.6	43.0	45.5	48.0	50.5
ETSU-R-97 Derived Noise Limit	40.0	40.0	41.3	43.3	45.6	48.0	50.5	53.0	55.5
Margin Under Noise Limit [#]	-14.4	-9.8	-7.0	-7.6	-9.7	-12.1	-14.6	-17.1	-19.6
R3									
Cumulative Wind Farm Noise	26.1	30.7	34.7	36.1	36.3	36.3	36.3	36.3	36.3
Background Noise Curve	33.3	34.6	36.3	38.3	40.6	43.0	45.5	48.0	50.5
ETSU-R-97 Derived Noise Limit	40.0	40.0	41.3	43.3	45.6	48.0	50.5	53.0	55.5
Margin Under Noise Limit [#]	-13.9	-9.3	-6.6	-7.2	-9.3	-11.7	-14.2	-16.7	-19.2
R4									
Cumulative Wind Farm Noise	27.5	32.0	36.0	37.4	37.6	37.6	37.6	37.6	37.6
Background Noise Curve	33.3	34.6	36.3	38.3	40.6	43.0	45.5	48.0	50.5
ETSU-R-97 Derived Noise Limit	40.0	40.0	41.3	43.3	45.6	48.0	50.5	53.0	55.5
Margin Under Noise Limit [#]	-12.5	-8.0	-5.3	-5.9	-8.0	-10.4	-12.9	-15.4	-17.9
R5									
Cumulative Wind Farm Noise	26.4	31.1	34.8	36.1	36.4	36.4	36.4	36.4	36.4
Background Noise Curve	33.3	34.6	36.3	38.3	40.6	43.0	45.5	48.0	50.5
ETSU-R-97 Derived Noise Limit	40.0	40.0	41.3	43.3	45.6	48.0	50.5	53.0	55.5
Margin Under Noise Limit [#]	-13.6	-8.9	-6.5	-7.2	-9.2	-11.6	-14.1	-16.6	-19.1
R6									
Cumulative Wind Farm Noise	26.2	30.7	34.4	35.7	35.9	35.9	35.9	35.9	35.9
Background Noise Curve	33.3	34.6	36.3	38.3	40.6	43.0	45.5	48.0	50.5
ETSU-R-97 Derived Noise Limit	40.0	40.0	41.3	43.3	45.6	48.0	50.5	53.0	55.5
Margin Under Noise Limit [#]	-13.8	-9.3	-6.9	-7.6	-9.7	-12.1	-14.6	-17.1	-19.6

[#] Negative values indicate turbine noise lies below noise limit

All figures are rounded to the nearest 0.1 dB

Table 9.19: Cumulative Development: Noise Assessment – Day-time (2)

Noise Parameters, $L_{A90\ 10min}$, dB	10m Wind Speed quoted by Manufacturer (m/s)								
	4	5	6	7	8	9	10	11	12
R7									
Cumulative Wind Farm Noise	26.1	30.6	34.3	35.6	35.8	35.8	35.8	35.8	35.8
Background Noise Curve	33.3	34.6	36.3	38.3	40.6	43.0	45.5	48.0	50.5
ETSU-R-97 Derived Noise Limit	40.0	40.0	41.3	43.3	45.6	48.0	50.5	53.0	55.5
Margin Under Noise Limit [#]	-13.9	-9.4	-7.0	-7.7	-9.8	-12.2	-14.7	-17.2	-19.7
R8									
Cumulative Wind Farm Noise	26.3	30.7	34.5	35.8	36.0	36.0	36.0	36.0	36.0
Background Noise Curve	33.3	34.6	36.3	38.3	40.6	43.0	45.5	48.0	50.5
ETSU-R-97 Derived Noise Limit	40.0	40.0	41.3	43.3	45.6	48.0	50.5	53.0	55.5
Margin Under Noise Limit [#]	-13.7	-9.3	-6.8	-7.5	-9.6	-12.0	-14.5	-17.0	-19.5
R9									
Cumulative Wind Farm Noise	27.5	31.4	35.1	36.5	36.6	36.6	36.6	36.6	36.6
Background Noise Curve	33.3	34.6	36.3	38.3	40.6	43.0	45.5	48.0	50.5
ETSU-R-97 Derived Noise Limit	40.0	40.0	41.3	43.3	45.6	48.0	50.5	53.0	55.5
Margin Under Noise Limit [#]	-12.5	-8.6	-6.2	-6.8	-9.0	-11.4	-13.9	-16.4	-18.9
R10									
Cumulative Wind Farm Noise	28.7	31.9	35.1	36.4	36.6	36.7	36.7	36.7	36.7
Background Noise Curve	33.3	34.6	36.3	38.3	40.6	43.0	45.5	48.0	50.5
ETSU-R-97 Derived Noise Limit	40.0	40.0	41.3	43.3	45.6	48.0	50.5	53.0	55.5
Margin Under Noise Limit [#]	-11.3	-8.1	-6.2	-6.9	-9.0	-11.3	-13.8	-16.3	-18.8
R11									
Cumulative Wind Farm Noise	30.4	33.7	36.9	38.3	38.4	38.5	38.5	38.5	38.5
Background Noise Curve	33.3	34.6	36.3	38.3	40.6	43.0	45.5	48.0	50.5
ETSU-R-97 Derived Noise Limit	40.0	40.0	41.3	43.3	45.6	48.0	50.5	53.0	55.5
Margin Under Noise Limit [#]	-9.6	-6.3	-4.4	-5.0	-7.2	-9.5	-12.0	-14.5	-17.0
R12									
Cumulative Wind Farm Noise	32.9	37.9	41.0	42.2	42.6	42.6	42.6	42.6	42.6
Background Noise Curve	37.2	37.4	37.8	38.5	39.8	41.8	44.5	44.5	44.5
Consented Noise Limit	42.2	42.4	42.8	43.5	44.8	46.8	49.5	49.5	49.5
Margin Under Noise Limit [#]	-9.3	-4.5	-1.8	-1.3	-2.2	-4.2	-6.9	-6.9	-6.9

[#] Negative values indicate turbine noise lies below noise limit

All figures are rounded to the nearest 0.1 dB

Table 9.20: Cumulative Development: Noise Assessment – Day-time (3)

Noise Parameters, $L_{A90\ 10min}$, dB	10m Wind Speed quoted by Manufacturer (m/s)								
	4	5	6	7	8	9	10	11	12
R13									
Cumulative Wind Farm Noise	27.5	32.3	35.6	36.8	37.1	37.1	37.1	37.1	37.1
Background Noise Curve	40.4	40.8	41.1	41.7	42.6	43.9	45.6	45.6	45.6
Consented Noise Limit	45.4	45.8	46.1	46.7	47.6	48.9	50.6	50.6	50.6
Margin Under Noise Limit [#]	-17.9	-13.5	-10.5	-9.9	-10.5	-11.8	-13.5	-13.5	-13.5
R14									
Cumulative Wind Farm Noise	29.5	34.4	37.8	39.2	40.0	40.0	40.0	40.0	40.0
Background Noise Curve	51.1	50.5	49.8	49.3	49.4	50.1	51.5	51.5	51.5
Consented Noise Limit	56.1	55.5	54.8	54.3	54.4	55.1	56.5	56.5	56.5
Margin Under Noise Limit [#]	-26.6	-21.1	-17.0	-15.1	-14.4	-15.1	-16.5	-16.5	-16.5
R15									
Cumulative Wind Farm Noise	26.7	31.3	34.8	36.1	36.6	36.6	36.6	36.6	36.6
Background Noise Curve	51.1	50.5	49.8	49.3	49.4	50.1	51.5	51.5	51.5
Consented Noise Limit	56.1	55.5	54.8	54.3	54.4	55.1	56.5	56.5	56.5
Margin Under Noise Limit [#]	-29.4	-24.2	-20.0	-18.2	-17.8	-18.5	-19.9	-19.9	-19.9
R16									
Cumulative Wind Farm Noise	27.4	32.3	35.6	36.8	37.3	37.3	37.3	37.3	37.3
Background Noise Curve	45.5	45.9	46.2	46.6	47.1	47.9	49.0	49.0	49.0
Consented Noise Limit	50.5	50.9	51.2	51.6	52.1	52.9	54.0	54.0	54.0
Margin Under Noise Limit [#]	-23.1	-18.6	-15.6	-14.8	-14.8	-15.6	-16.7	-16.7	-16.7
R17									
Cumulative Wind Farm Noise	31.3	33.4	35.5	36.9	37.2	37.3	37.3	37.3	37.3
Background Noise Curve	33.3	34.6	36.3	38.3	40.6	43.0	45.5	48.0	50.5
ETSU-R-97 Derived Noise Limit	40.0	40.0	41.3	43.3	45.6	48.0	50.5	53.0	55.5
Margin Under Noise Limit [#]	-8.7	-6.6	-5.8	-6.4	-8.4	-10.7	-13.2	-15.7	-18.2
R18									
Cumulative Wind Farm Noise	31.0	32.3	34.3	35.7	36.1	36.2	36.2	36.2	36.2
Background Noise Curve	33.3	34.6	36.3	38.3	40.6	43.0	45.5	48.0	50.5
ETSU-R-97 Derived Noise Limit	40.0	40.0	41.3	43.3	45.6	48.0	50.5	53.0	55.5
Margin Under Noise Limit [#]	-9.0	-7.7	-7.0	-7.6	-9.5	-11.8	-14.3	-16.8	-19.3

[#] Negative values indicate turbine noise lies below noise limit

All figures are rounded to the nearest 0.1 dB

Table 9.21: Cumulative Development: Noise Assessment – Day-time (4)

Noise Parameters, $L_{A90\ 10min}$, dB	10m Wind Speed quoted by Manufacturer (m/s)								
	4	5	6	7	8	9	10	11	12
R19									
Cumulative Wind Farm Noise	29.4	31.1	33.2	34.5	34.9	35.0	35.0	35.0	35.0
Background Noise Curve	33.3	34.6	36.3	38.3	40.6	43.0	45.5	48.0	50.5
ETSU-R-97 Derived Noise Limit	40.0	40.0	41.3	43.3	45.6	48.0	50.5	53.0	55.5
Margin Under Noise Limit [#]	-10.6	-8.9	-8.1	-8.8	-10.7	-13.0	-15.5	-18.0	-20.5
R20									
Cumulative Wind Farm Noise	31.3	33.4	35.5	36.8	37.2	37.3	37.3	37.3	37.3
Background Noise Curve	33.3	34.6	36.3	38.3	40.6	43.0	45.5	48.0	50.5
ETSU-R-97 Derived Noise Limit	40.0	40.0	41.3	43.3	45.6	48.0	50.5	53.0	55.5
Margin Under Noise Limit [#]	-8.7	-6.6	-5.8	-6.5	-8.4	-10.7	-13.2	-15.7	-18.2
R21									
Cumulative Wind Farm Noise	45.6	45.8	47.5	48.9	49.5	49.5	49.5	49.5	49.5
Background Noise Curve	39.0	39.0	41.0	42.7	44.6	46.7	49.0	49.0	49.0
ETSU-R-97 Derived Noise Limit	44.0	44.0	46.0	47.7	49.6	51.7	54.0	54.0	54.0
Margin Under Noise Limit [#]	1.6	1.8	1.5	1.2	-0.1	-2.2	-4.5	-4.5	-4.5
R22									
Cumulative Wind Farm Noise	31.6	32.9	34.8	36.2	36.6	36.7	36.7	36.7	36.7
Background Noise Curve	46.4	47.2	47.9	48.6	49.4	50.1	50.8	51.5	51.5
ETSU-R-97 Derived Noise Limit	51.4	52.2	52.9	53.6	54.4	55.1	55.8	56.5	56.5
Margin Under Noise Limit [#]	-19.8	-19.3	-18.1	-17.4	-17.8	-18.4	-19.1	-19.8	-19.8
R23									
Cumulative Wind Farm Noise	43.9	44.1	45.8	47.2	47.8	47.8	47.8	47.8	47.8
Background Noise Curve	39.0	39.0	41.0	42.7	44.6	46.7	49.0	49.0	49.0
ETSU-R-97 Derived Noise Limit	44.0	44.0	46.0	47.7	49.6	51.7	54.0	54.0	54.0
Margin Under Noise Limit [#]	-0.1	0.1	-0.2	-0.5	-1.8	-3.9	-6.2	-6.2	-6.2
R24									
Cumulative Wind Farm Noise	42.2	42.6	44.2	45.6	46.2	46.2	46.2	46.2	46.2
Background Noise Curve	39.0	39.0	41.0	42.7	44.6	46.7	49.0	49.0	49.0
ETSU-R-97 Derived Noise Limit	44.0	44.0	46.0	47.7	49.6	51.7	54.0	54.0	54.0
Margin Under Noise Limit [#]	-1.8	-1.4	-1.8	-2.1	-3.4	-5.5	-7.8	-7.8	-7.8

[#] Negative values indicate turbine noise lies below noise limit

All figures are rounded to the nearest 0.1 dB

Table 9.22: Cumulative Development: Noise Assessment – Day-time (5)

Noise Parameters, $L_{A90\ 10min}$, dB	10m Wind Speed quoted by Manufacturer (m/s)								
	4	5	6	7	8	9	10	11	12
R25									
Cumulative Wind Farm Noise	31.1	36.1	39.7	41.4	42.7	42.7	42.7	42.7	42.7
Background Noise Curve	33.3	34.6	36.3	38.3	40.6	43.0	45.5	48.0	50.5
ETSU-R-97 Derived Noise Limit	40.0	40.0	41.3	43.3	45.6	48.0	50.5	53.0	55.5
Margin Under Noise Limit [#]	-8.9	-3.9	-1.6	-1.9	-2.9	-5.3	-7.8	-10.3	-12.8
R26									
Cumulative Wind Farm Noise	29.2	34.0	37.5	38.9	39.6	39.6	39.6	39.6	39.6
Background Noise Curve	33.3	34.6	36.3	38.3	40.6	43.0	45.5	48.0	50.5
ETSU-R-97 Derived Noise Limit	40.0	40.0	41.3	43.3	45.6	48.0	50.5	53.0	55.5
Margin Under Noise Limit [#]	-10.8	-6.0	-3.8	-4.4	-6.0	-8.4	-10.9	-13.4	-15.9

[#] Negative values indicate turbine noise lies below noise limit

All figures are rounded to the nearest 0.1 dB

Table 9.23: Cumulative Development: Noise Assessment – Night-time (1)

Noise Parameters, $L_{A90\ 10min}$, dB	10m Wind Speed quoted by Manufacturer (m/s)								
	4	5	6	7	8	9	10	11	12
R1									
Cumulative Wind Farm Noise	27.7	32.3	36.4	37.8	38.0	38.0	38.0	38.0	38.0
Background Noise Curve	29.5	31.4	33.4	35.7	38.0	40.5	43.0	45.6	48.1
ETSU-R-97 Derived Noise Limit	43.0	43.0	43.0	43.0	43.0	45.5	48.0	50.6	53.1
Margin Under Noise Limit [#]	-15.3	-10.7	-6.6	-5.2	-5.0	-7.5	-10.0	-12.6	-15.1
R2									
Cumulative Wind Farm Noise	25.6	30.2	34.3	35.7	35.9	35.9	35.9	35.9	35.9
Background Noise Curve	29.5	31.4	33.4	35.7	38.0	40.5	43.0	45.6	48.1
ETSU-R-97 Derived Noise Limit	43.0	43.0	43.0	43.0	43.0	45.5	48.0	50.6	53.1
Margin Under Noise Limit [#]	-17.4	-12.8	-8.7	-7.3	-7.1	-9.6	-12.1	-14.7	-17.2
R3									
Cumulative Wind Farm Noise	26.1	30.7	34.7	36.1	36.3	36.3	36.3	36.3	36.3
Background Noise Curve	29.5	31.4	33.4	35.7	38.0	40.5	43.0	45.6	48.1
ETSU-R-97 Derived Noise Limit	43.0	43.0	43.0	43.0	43.0	45.5	48.0	50.6	53.1
Margin Under Noise Limit [#]	-16.9	-12.3	-8.3	-6.9	-6.7	-9.2	-11.7	-14.3	-16.8
R4									
Cumulative Wind Farm Noise	27.5	32.0	36.0	37.4	37.6	37.6	37.6	37.6	37.6

Noise Parameters, $L_{A90\ 10min}$, dB	10m Wind Speed quoted by Manufacturer (m/s)								
	4	5	6	7	8	9	10	11	12
Background Noise Curve	29.5	31.4	33.4	35.7	38.0	40.5	43.0	45.6	48.1
ETSU-R-97 Derived Noise Limit	43.0	43.0	43.0	43.0	43.0	45.5	48.0	50.6	53.1
Margin Under Noise Limit [#]	-15.5	-11.0	-7.0	-5.6	-5.4	-7.9	-10.4	-13.0	-15.5
R5									
Cumulative Wind Farm Noise	26.4	31.1	34.8	36.1	36.4	36.4	36.4	36.4	36.4
Background Noise Curve	29.5	31.4	33.4	35.7	38.0	40.5	43.0	45.6	48.1
ETSU-R-97 Derived Noise Limit	43.0	43.0	43.0	43.0	43.0	45.5	48.0	50.6	53.1
Margin Under Noise Limit [#]	-16.6	-11.9	-8.2	-6.9	-6.6	-9.1	-11.6	-14.2	-16.7
R6									
Cumulative Wind Farm Noise	26.2	30.7	34.4	35.7	35.9	35.9	35.9	35.9	35.9
Background Noise Curve	29.5	31.4	33.4	35.7	38.0	40.5	43.0	45.6	48.1
ETSU-R-97 Derived Noise Limit	43.0	43.0	43.0	43.0	43.0	45.5	48.0	50.6	53.1
Margin Under Noise Limit [#]	-16.8	-12.3	-8.6	-7.3	-7.1	-9.6	-12.1	-14.7	-17.2

[#] Negative values indicate turbine noise lies below noise limit

All figures are rounded to the nearest 0.1 dB

Table 9.24: Cumulative Development: Noise Assessment – Night-time (2)

Noise Parameters, $L_{A90\ 10min}$, dB	10m Wind Speed quoted by Manufacturer (m/s)								
	4	5	6	7	8	9	10	11	12
R7									
Cumulative Wind Farm Noise	26.1	30.6	34.3	35.6	35.8	35.8	35.8	35.8	35.8
Background Noise Curve	29.5	31.4	33.4	35.7	38.0	40.5	43.0	45.6	48.1
ETSU-R-97 Derived Noise Limit	43.0	43.0	43.0	43.0	43.0	45.5	48.0	50.6	53.1
Margin Under Noise Limit [#]	-16.9	-12.4	-8.7	-7.4	-7.2	-9.7	-12.2	-14.8	-17.3
R8									
Cumulative Wind Farm Noise	26.3	30.7	34.5	35.8	36.0	36.0	36.0	36.0	36.0
Background Noise Curve	29.5	31.4	33.4	35.7	38.0	40.5	43.0	45.6	48.1
ETSU-R-97 Derived Noise Limit	43.0	43.0	43.0	43.0	43.0	45.5	48.0	50.6	53.1
Margin Under Noise Limit [#]	-16.7	-12.3	-8.5	-7.2	-7.0	-9.5	-12.0	-14.6	-17.1
R9									
Cumulative Wind Farm Noise	27.5	31.4	35.1	36.5	36.6	36.6	36.6	36.6	36.6
Background Noise Curve	29.5	31.4	33.4	35.7	38.0	40.5	43.0	45.6	48.1
ETSU-R-97 Derived Noise Limit	43.0	43.0	43.0	43.0	43.0	45.5	48.0	50.6	53.1
Margin Under Noise Limit [#]	-15.5	-11.6	-7.9	-6.5	-6.4	-8.9	-11.4	-14.0	-16.5

Noise Parameters, $L_{A90\ 10min}$, dB	10m Wind Speed quoted by Manufacturer (m/s)								
	4	5	6	7	8	9	10	11	12
R10									
Cumulative Wind Farm Noise	28.7	31.9	35.1	36.4	36.6	36.7	36.7	36.7	36.7
Background Noise Curve	29.5	31.4	33.4	35.7	38.0	40.5	43.0	45.6	48.1
ETSU-R-97 Derived Noise Limit	43.0	43.0	43.0	43.0	43.0	45.5	48.0	50.6	53.1
Margin Under Noise Limit [#]	-14.3	-11.1	-7.9	-6.6	-6.4	-8.8	-11.3	-13.9	-16.4
R11									
Cumulative Wind Farm Noise	30.4	33.7	36.9	38.3	38.4	38.5	38.5	38.5	38.5
Background Noise Curve	29.5	31.4	33.4	35.7	38.0	40.5	43.0	45.6	48.1
ETSU-R-97 Derived Noise Limit	43.0	43.0	43.0	43.0	43.0	45.5	48.0	50.6	53.1
Margin Under Noise Limit [#]	-12.6	-9.3	-6.1	-4.7	-4.6	-7.0	-9.5	-12.1	-14.6
R12									
Cumulative Wind Farm Noise	32.9	37.9	41.0	42.2	42.6	42.6	42.6	42.6	42.6
Background Noise Curve	31.2	31.6	32.8	34.8	37.7	41.2	44.8	44.8	44.8
Consented Noise Limit	43.0	43.0	43.0	43.0	43.0	46.2	49.8	49.8	49.8
Margin Under Noise Limit [#]	-10.1	-5.1	-2.0	-0.8	-0.4	-3.6	-7.2	-7.2	-7.2

[#] Negative values indicate turbine noise lies below noise limit
All figures are rounded to the nearest 0.1 dB

Table 9.25: Cumulative Development: Noise Assessment – Night-time (3)

Noise Parameters, $L_{A90\ 10min}$, dB	10m Wind Speed quoted by Manufacturer (m/s)								
	4	5	6	7	8	9	10	11	12
R13									
Cumulative Wind Farm Noise	27.5	32.3	35.6	36.8	37.1	37.1	37.1	37.1	37.1
Background Noise Curve	35.6	36.4	37.4	38.6	40.1	42.0	44.1	44.1	44.1
Consented Noise Limit	43.0	43.0	43.0	43.6	45.1	47.0	49.1	49.1	49.1
Margin Under Noise Limit [#]	-15.5	-10.7	-7.4	-6.8	-8.0	-9.9	-12.0	-12.0	-12.0
R14									
Cumulative Wind Farm Noise	29.5	34.4	37.8	39.2	40.0	40.0	40.0	40.0	40.0
Background Noise Curve	33.5	34.7	36.1	37.9	39.8	41.9	44.2	44.2	44.2
Consented Noise Limit	43.0	43.0	43.0	43.0	44.8	46.9	49.2	49.2	49.2
Margin Under Noise Limit [#]	-13.5	-8.6	-5.2	-3.8	-4.8	-6.9	-9.2	-9.2	-9.2
R15									
Cumulative Wind Farm Noise	26.7	31.3	34.8	36.1	36.6	36.6	36.6	36.6	36.6
Background Noise Curve	33.5	34.7	36.1	37.9	39.8	41.9	44.2	44.2	44.2
Consented Noise Limit	43.0	43.0	43.0	43.0	44.8	46.9	49.2	49.2	49.2
Margin Under Noise Limit [#]	-16.3	-11.7	-8.2	-6.9	-8.2	-10.3	-12.6	-12.6	-12.6
R16									
Cumulative Wind Farm Noise	27.4	32.3	35.6	36.8	37.3	37.3	37.3	37.3	37.3
Background Noise Curve	39.4	40.2	40.8	41.3	41.8	42.4	43.7	43.7	43.7
Consented Noise Limit	44.4	45.2	45.8	46.3	46.8	47.4	48.7	48.7	48.7
Margin Under Noise Limit [#]	-17.0	-12.9	-10.2	-9.5	-9.5	-10.1	-11.4	-11.4	-11.4
R17									
Cumulative Wind Farm Noise	31.3	33.4	35.5	36.9	37.2	37.3	37.3	37.3	37.3
Background Noise Curve	29.5	31.4	33.4	35.7	38.0	40.5	43.0	45.6	48.1
ETSU-R-97 Derived Noise Limit	43.0	43.0	43.0	43.0	43.0	45.5	48.0	50.6	53.1
Margin Under Noise Limit [#]	-11.7	-9.6	-7.5	-6.1	-5.8	-8.2	-10.7	-13.3	-15.8
R18									
Cumulative Wind Farm Noise	31.0	32.3	34.3	35.7	36.1	36.2	36.2	36.2	36.2
Background Noise Curve	29.5	31.4	33.4	35.7	38.0	40.5	43.0	45.6	48.1
ETSU-R-97 Derived Noise Limit	43.0	43.0	43.0	43.0	43.0	45.5	48.0	50.6	53.1
Margin Under Noise Limit [#]	-12.0	-10.7	-8.7	-7.3	-6.9	-9.3	-11.8	-14.4	-16.9

[#] Negative values indicate turbine noise lies below noise limit

All figures are rounded to the nearest 0.1 dB

Table 9.26: Cumulative Development: Noise Assessment – Night-time (4)

Noise Parameters, $L_{A90\ 10min}$, dB	10m Wind Speed quoted by Manufacturer (m/s)								
	4	5	6	7	8	9	10	11	12
R19									
Cumulative Wind Farm Noise	29.4	31.1	33.2	34.5	34.9	35.0	35.0	35.0	35.0
Background Noise Curve	29.5	31.4	33.4	35.7	38.0	40.5	43.0	45.6	48.1
ETSU-R-97 Derived Noise Limit	43.0	43.0	43.0	43.0	43.0	45.5	48.0	50.6	53.1
Margin Under Noise Limit [#]	-13.6	-11.9	-9.8	-8.5	-8.1	-10.5	-13.0	-15.6	-18.1
R20									
Cumulative Wind Farm Noise	31.3	33.4	35.5	36.8	37.2	37.3	37.3	37.3	37.3
Background Noise Curve	29.5	31.4	33.4	35.7	38.0	40.5	43.0	45.6	48.1
ETSU-R-97 Derived Noise Limit	43.0	43.0	43.0	43.0	43.0	45.5	48.0	50.6	53.1
Margin Under Noise Limit [#]	-11.7	-9.6	-7.5	-6.2	-5.8	-8.2	-10.7	-13.3	-15.8
R21									
Cumulative Wind Farm Noise	45.6	45.8	47.5	48.9	49.5	49.5	49.5	49.5	49.5
Background Noise Curve	39.0	39.0	41.0	42.7	44.6	46.7	49.0	49.0	49.0
ETSU-R-97 Derived Noise Limit	44.0	44.0	46.0	47.7	49.6	51.7	54.0	54.0	54.0
Margin Under Noise Limit [#]	1.6	1.8	1.5	1.2	-0.1	-2.2	-4.5	-4.5	-4.5
R22									
Cumulative Wind Farm Noise	31.6	32.9	34.8	36.2	36.6	36.7	36.7	36.7	36.7
Background Noise Curve	37.2	37.4	37.9	38.6	39.7	41.0	42.6	44.4	44.4
ETSU-R-97 Derived Noise Limit	43.0	43.0	43.0	43.6	44.7	46.0	47.6	49.4	49.4
Margin Under Noise Limit [#]	-11.4	-10.1	-8.2	-7.4	-8.1	-9.3	-10.9	-12.7	-12.7
R23									
Cumulative Wind Farm Noise	43.9	44.1	45.8	47.2	47.8	47.8	47.8	47.8	47.8
Background Noise Curve	39.0	39.0	41.0	42.7	44.6	46.7	49.0	49.0	49.0
ETSU-R-97 Derived Noise Limit	44.0	44.0	46.0	47.7	49.6	51.7	54.0	54.0	54.0
Margin Under Noise Limit [#]	-0.1	0.1	-0.2	-0.5	-1.8	-3.9	-6.2	-6.2	-6.2
R24									
Cumulative Wind Farm Noise	42.2	42.6	44.2	45.6	46.2	46.2	46.2	46.2	46.2
Background Noise Curve	39.0	39.0	41.0	42.7	44.6	46.7	49.0	49.0	49.0
ETSU-R-97 Derived Noise Limit	44.0	44.0	46.0	47.7	49.6	51.7	54.0	54.0	54.0
Margin Under Noise Limit [#]	-1.8	-1.4	-1.8	-2.1	-3.4	-5.5	-7.8	-7.8	-7.8

[#] Negative values indicate turbine noise lies below noise limit

All figures are rounded to the nearest 0.1 dB

Table 9.27: Cumulative Development: Noise Assessment – Night-time (5)

Noise Parameters, $L_{A90\ 10min}$, dB	10m Wind Speed quoted by Manufacturer (m/s)								
	4	5	6	7	8	9	10	11	12
R25									
Cumulative Wind Farm Noise	31.1	36.1	39.7	41.4	42.7	42.7	42.7	42.7	42.7
Background Noise Curve	29.5	31.4	33.4	35.7	38.0	40.5	43.0	45.6	48.1
ETSU-R-97 Derived Noise Limit	43.0	43.0	43.0	43.0	43.0	45.5	48.0	50.6	53.1
Margin Under Noise Limit [#]	-11.9	-6.9	-3.3	-1.6	-0.3	-2.8	-5.3	-7.9	-10.4
R26									
Cumulative Wind Farm Noise	29.2	34.0	37.5	38.9	39.6	39.6	39.6	39.6	39.6
Background Noise Curve	29.5	31.4	33.4	35.7	38.0	40.5	43.0	45.6	48.1
ETSU-R-97 Derived Noise Limit	43.0	43.0	43.0	43.0	43.0	45.5	48.0	50.6	53.1
Margin Under Noise Limit [#]	-13.8	-9.0	-5.5	-4.1	-3.4	-5.9	-8.4	-11.0	-13.5

[#] Negative values indicate turbine noise lies below noise limit

All figures are rounded to the nearest 0.1 dB

Cumulative Developments: Summary of effects

9.10.16 The cumulative development noise assessment is summarised in **Table 9.18 – Table 9.27**.

9.10.17 As shown, at all assessed receptors apart from R21 and R23, the cumulative development noise immissions are predicted to meet the associated noise limits across all assessed wind speeds.

9.10.18 At R21 and R23, where there are exceedances of the associated noise limits, further analysis is summarised in Table 9.28, which shows noise immission from cumulative developments, namely St Merryn Wind Turbine are greater (>10 dB) than those from the Proposed Scheme.

9.10.19 As advocated in the IOA GPG (2013) (Par 5.1.2), where consented (or if the development is proposed, calculated) noise immission from cumulative wind farms can be demonstrated to be at least 10 dB lower than those associated with the Proposed Scheme, cumulative noise impacts are considered to be ‘negligible’ and not ‘significant’ in EIA terms. This is also the case where noise immission from the Proposed Scheme can be demonstrated to be 10 dB lower than those associated with existing or consented cumulative wind farms, which is the case at R21 and R23

9.10.20 Consequently, it is concluded that the Proposed Scheme in combination with cumulative developments will have no significant effects in relation to noise.

Table 9.28: Cumulative Development: Noise Assessment Analysis – R21 and R23

Noise Parameters, LA90 10min, dB	10m Wind Speed quoted by Manufacturer (m/s)								
	4	5	6	7	8	9	10	11	12
R21									
Proposed Scheme Wind Farm Noise	24.0	28.6	33.0	34.4	34.4	34.4	34.4	34.4	34.4
Cumulative Wind Farm Noise (all turbines)	45.6	45.8	47.5	48.9	49.5	49.5	49.5	49.5	49.5
Pen Bryn Oer Wind Farm	12.5	17.5	20.6	21.7	22.1	22.1	22.1	22.1	22.1
Pengarnddu Wind Turbine	31.7	34.2	32.7	33.7	34.7	35.2	35.2	35.2	35.2
Tafarnaubach IE Wind Turbine	3.4	8.4	12.4	14.4	16.4	16.4	16.4	16.4	16.4
St Merryn Wind Turbine	45.4	45.4	47.2	48.6	49.2	49.2	49.2	49.2	49.2
Maximum Cumulative Development Noise	45.4	45.4	47.2	48.6	49.2	49.2	49.2	49.2	49.2
Proposed Scheme Wind Farm Noise - Maximum Cumulative Development Noise [#]	-21.4	-16.8	-14.2	-14.2	-14.8	-14.8	-14.8	-14.8	-14.8
R23									
Proposed Scheme Wind Farm Noise	23.6	28.2	32.6	34.0	34.0	34.0	34.0	34.0	34.0
Cumulative Wind Farm Noise (all turbines)	43.9	44.1	45.8	47.2	47.8	47.8	47.8	47.8	47.8
Pen Bryn Oer Wind Farm	12.3	17.3	20.4	21.5	21.9	21.9	21.9	21.9	21.9
Pengarnddu Wind Turbine	30.6	33.1	31.6	32.6	33.6	34.1	34.1	34.1	34.1
Tafarnaubach IE Wind Turbine	3.3	8.3	12.3	14.3	16.3	16.3	16.3	16.3	16.3
St Merryn Wind Turbine	43.6	43.6	45.4	46.8	47.4	47.4	47.4	47.4	47.4
Maximum Cumulative Development Noise	43.6	43.6	45.4	46.8	47.4	47.4	47.4	47.4	47.4
Proposed Scheme Wind Farm Noise - Maximum Cumulative Development Noise [#]	-20.0	-15.4	-12.8	-12.8	-13.4	-13.4	-13.4	-13.4	-13.4

[#] Negative values indicates margin of Proposed Scheme turbine noise below cumulative development noise
All figures are rounded to the nearest 0.1 dB

9.11 References

- A Good Practice Guide to the Application of ETSU-R-97 for the Assessment and Rating of Wind Turbine Noise, Institute of Acoustics, May 2013.
- BS 5228-1:2009-A:2014 'Code of practice for noise and vibration control on construction and open sites – Part 1: Noise'.
- BS 5228-2:2009-A:2014 'Code of practice for noise and vibration control on construction and open sites – Part 2: Vibration'.
- ETSU-R-97, the Assessment and Rating of Noise from Wind Farms, Final ETSU-R-97 Report for the Department of Trade & Industry. The Working Group on Noise from Wind Turbines, 1997.
- Guidelines for Community Noise. World Health Organisation, 1980
- ISO 9613-2:1996 'Acoustics – Attenuation of sound during propagation outdoors – Part 2: General method of calculation', International Standards Organisation, 1996

Glossary of Acoustic Terminology

Table 9.29: Glossary of acoustic terminology

Terminology	Description
A-weighting	Electronic weighting that adjusts low and high frequencies to measure how the human ear experiences sound; this correction factor is carried out within noise measuring equipment. It is noted as dB(A)
Acoustic Calibrator	Device that applies a sound pressure of very accurate level and frequency to the microphone of an acoustic measuring device to maintain its measurement accuracy. It is essential that a calibrator meets the performance requirements of the IEC 60942:2017
Acoustic Character	Properties of a sound that are distinctive against the background sound environment e.g. whistles, hums, tones
Acoustic Screening	Natural or artificial barrier to sound propagation, which reduces the sound pressure level of a source at the receiver
Ambient Sound	Totally encompassing sound at a specific location at a certain time, usually including far-field and near-field sound sources. If present, it comprises residual and specific sound
Annoyance	The feeling being irritated by noise
Attenuation	The reduction in sound pressure level from a source at a receiver due to atmospheric absorption, distance, ground, and other effects
Audio Frequency	Any frequency in the audible human range, i.e. 20 Hz to 20 KHz
Background Noise Level	A-weighted sound pressure level that is exceeded for 90% of a time interval, T, by the residual sound. It is noted as $L_{A90,T}$
Broadband Noise	Noise that has a wide range of frequency components
dB	Abbreviation of the term “decibel”
dB (A)	Abbreviation of A-weighted sound level in decibel
Concave Ground Effect	Required correction for propagation ‘across a valley’ as defined in Par 4.3.9 of IOA GPG (2013)
Decibel	Logarithmic function that expresses the magnitude of sound as a ratio between two values
Directivity	Directional feature of a sound source which has a propagation strength greater in specific direction(s)
Equivalent Continuous Sound Pressure Level	A-weighted level of a steady sound that has the same energy as a fluctuating sound over the same period of time (in dB)

Terminology	Description
Frequency	Also known as “pitch”, it is the number of acoustic pressure cycles that occur per unit of time (seconds). Unit Hertz (Hz),
Ground Effect	Also called G Factor, it refers to the attenuation of the sound propagating, from source to receiver, due to the porosity of a ground
Hertz (Hz)	Unit of sound frequency, it is equal to the number of acoustic sound pressure fluctuation cycles occurring per second
Impulsive Sound	Energy of a sound that it is concentrated in a short period of time
Instantaneous Sound Pressure	Difference between the instantaneous sound pressure and the average atmospheric at certain time and location in decibels
$L_{Aeq,T}$	Abbreviation of a-weighted equivalent continuous sound level over a given period of time, T
L_{Amax}	A-weighted maximum recorded noise level during a measurement period (in dB)
$L_{A10,T}$	A-weighted sound level exceeded for 10% of the measurement period, T. It is widely used as a descriptor of road traffic noise (in dB)
$L_{A90,T}$	A-weighted sound level exceeded for 90% of the measurement period, T. Often referred to as the background sound level (in dB)
Sound Level	Description of sound converted in decibels
Loudness	Attribute of a sound that is amplitude dependant and allows humans to subjectively rate sound from barely audible to painfully loud
Noise	In physics is the same as sound (see below), but subjectively it represents “unwanted” or “unpleasant” sound
Noise Emission	The release of sound from a source into the environment
Noise Immission	The emitted noise at a given location, i.e. at the receptor
Octave Band Frequency Analysis	Frequency analysis that uses an octave band filter in which the upper frequency limit is twice its lower limit
Receptor/Receiver	Any location or person that may be affected by noise or vibration
Residual Noise Level	A-weighted equivalent continuous ambient sound level remaining when the specific sound level has decreased to a degree in which it does not contribute to the ambient sound level (in dBs)
Sound	In physics it is an oscillation of air molecules that propagates from a source through a medium creating positive and negative acoustic pressure that fluctuates in the atmospheric pressure; subjectively it is the reception and perception of these oscillations

Terminology	Description
Sound Level Meter (SLM)	Sound pressure level measuring equipment
Sound Pressure Amplitude	Measure of the root mean square variation in atmospheric mean pressure caused by a sound wave in Pascals (Pa)
Sound Pressure Level (SPL)	Measure of sound pressure amplitude in decibels relative to a sound pressure of 2×10^{-5} Pa.
Sound Power Level (SWL)	Measure of the acoustic energy of a source, in decibels, relative to a reference value (W_0) of 10^{-12} W.
Specific Sound Level	A-weighted equivalent continuous sound pressure level produced by the specific sound source at the reference location over a reference time interval, T (in dB)
Spectrum	Representation of sound as amplitude and function of frequency
Threshold of Hearing	The lowest sound amplitude that can be heard by the average human ear and is 0.00002 Pascals (Pa)
Tone	Energy of a sound that it is concentrated into a very narrow frequency range
Vibration	Cyclic motions experienced by buildings or the ground; vibrations are typically vertical
Wind Shear	Increases in wind velocity with height above the ground

Sound, noise and vibration

- 9.11.1 In physics sound is an oscillation of air molecules that propagates from a source through a medium creating positive and negative acoustic pressure, that fluctuates in the atmospheric pressure. Subjectively, it is the *reception* by the human ear and *perception* by the human brain of these oscillations. Unlike the eyes, the ear catches sound waves from any direction, even while asleep, from 20 Hz to 20000 Hz frequency range. Humans and animals use sound for communication, localisation and many other useful functions.
- 9.11.2 On the contrary, noise is perceived by humans as an “unwanted”, “unpleasant” sound, and can have negative effects on human health and the environment. In physics, noise has the same acoustic properties of sound.
- 9.11.3 While noise propagates through fluid media, vibration is a low-frequency motion that propagates through solid structures, and can be caused by intense sound emissions. Vibrations are generally perceived by humans as being unpleasant.

Sound levels and decibels

- 9.11.4 The decibel scale is a logarithmic function that is used to quantify sound instead of using the average audible frequency range, and it goes from 0 dB to 120 dB. When sound is described in decibels, it is defined as level, e.g., amplitude sound pressure expressed in decibels is denoted as Sound Pressure Level, *SPL* or *Lp*.

- 9.11.5 As decibels are expressed in a logarithmic scale the levels cannot be added or subtracted using the linear arithmetic rules. For example, when adding two equal SPL the total will be 3 dB higher than one source radiating in isolation.

Frequency, and A-weighting

- 9.11.6 The human audible spectrum goes from 20 Hz to 20 KHz for the average healthy ear but, the ear is not equally sensitive at all frequencies of this range. In fact, the human ear is most sensitive at frequencies between 500 Hz and 4 KHz, and this is important when evaluating sound pressure level using subjective ratings like loudness.
- 9.11.7 To represent sound as is heard by the human, an electronic weighting was developed so that, when measuring sound, low and high frequencies are adjusted. This correction factor, called A-weighting, has become a requirement in standards and guidelines internationally, to best replicate the human experience of sound. The A-weighting filter is carried out within acoustic measuring equipment, the measured A-weighted sound is denoted with capital “A” final or in brackets, i.e., LA or dB(A).

Environmental noise metrics

- 9.11.8 $L_{Aeq,T}$ or equivalent continuous sound level is the A-weighted level of a steady sound that has the same energy as a fluctuating sound over the same period of time T , at a given location. It is A-weighted, expressed in decibels and it is a “general” useful noise descriptor for subjective rating of environmental noise, adopted in both UK and European standards and guidance. The disadvantage of L_{Aeq} is the lack of information regarding the variation in time of the sound measured, that can be the result of a continuous sound pressure or of a wide variation in level. This is more apparent when the ambient noise is very low, and the measurements are affected by sudden noisy events like birds singing or a helicopter passing, and therefore other indexes may be necessary to accurately assess environmental noise.
- 9.11.9 L_{Amax} is another useful index used to assess noise effects on human health and the environment. It represents the A-weighted maximum recorded noise level during a measurement period, expressed in decibels, but it does not tell how many times this maximum or similar levels have occurred.
- 9.11.10 L_{A10} and L_{A90} are percentile exceeded sound levels that give some information about the variation in time of sound pressure. L_{A10} is the A-weighted sound level exceeded for 10% of the measurement period, T , and it is widely used as a descriptor of road traffic noise, while L_{A90} is the A-weighted sound level exceeded for 90% of the measurement period, T , often referred to as the background sound level. L_{A10} provides data of the level noise peaks, whereas L_{A90} provides information of the lulls in between the noise peaks.