

Appendix 11A – Noise

11A.1 **Ambient Noise:** The ambient noise level is the overall level of noise present at a particular location, including both the background noise and any specific noise sources.

11A.2 **Background Noise:** The background noise level is the underlying level of noise present at a particular location for the majority (usually 90%) of a period of time. As such it excludes any short-duration **noises**, such as individual passing cars (but not continuous traffic), dogs barking or passers by. Sources of background noise typically include such things as wind noise, traffic and continuously operating machinery (e.g. air conditioning or generators).

11A.3 **Specific Noise:** This term is used to refer to a particular noise source that is being discussed or investigated and that while it may form a component of the ambient noise, is distinct from the background noise. In the context of the preceding chapter, the noise from wind turbines could be considered as a specific noise source.

11A.4 **Decibel (dB):** The decibel is the basic unit of noise measurement. It relates to the pressure created by the sound (Sound Pressure Level) and operates on a logarithmic scale, ranging upwards from 0 dB. 0dB is equivalent to the normal threshold of hearing at a frequency of 1000Hz. Each increase of 3 dB on the scale represents a doubling in the Sound Pressure Level, and is typically the minimum noticeable change in sound level under normal listening conditions. For example, while an increase in noise level from 32 dB to 35 dB represents a doubling in sound pressure level, this change would only just be noticeable to the majority of listeners.

11A.5 **dB(A):** Environmental noise levels are usually discussed in terms of dB(A). This is known as the A-weighted **sound** pressure level, and indicates that a correction factor has been applied, which corresponds to the human ear's response to sound across the range of audible frequencies. The ear is most sensitive in the middle range of frequencies (around 1000-3000Hz), and less sensitive at lower and higher frequencies. The A-weighted noise level is derived by analysing the level of a sound at a range of frequencies and applying a specific correction factor for each frequency before calculating the overall level. In practice this is carried out automatically within noise measuring equipment by the use of electronic filters, which adjust the frequency response of the instrument to mimic that of the ear.

11A.6 A scale of common **noise** sources compared to wind turbines is presented below (Source PAN45).

Source/Activity	Indicative Noise Level dB(A)
Threshold of Pain	140
Jet aircraft at 250 m	105
Pneumatic drill at 7 m	95
Truck at 30 mph at 100 m	65
Busy general office	60
Car at 40 mph at 100 m	55
Wind farm at 350 m	35-45
Quiet bedroom	20
Rural night-time background	20-40
Threshold of hearing 0	0

11A.7 **Free Field:** This term refers to a location where the propagation (movement) of sound is not affected by the **presence** of obstacles or surfaces which would cause reflections (echoes).

11A.8 **Frequency:** The **frequency** of a sound is equivalent to its pitch in musical terms. The units of frequency are Hertz (Hz), which represents the number of cycles (vibrations) per second.

11A.9 **L_{A90,t}:** This term is **used** to represent the A-weighted sound pressure level that is exceeded for 90% of a period of time, t. This is used as a measure of the background noise level.

11A.10 **L_{Aeq,t}:** This term is known as the A-weighted equivalent, continuous sound pressure level for a period of time, t. It is similar to an average, and represents the sound pressure level of a sound of continuous intensity that would result in an equal quantity of sound energy as a sound which varies in intensity.

11A.11 **Low frequency noise:** Noise at the lower end of the range of audible frequencies (20Hz – 20kHz). Usually refers to noise below 250Hz. should not be confused with infrasound, which is sound below the lowest audible frequency, 20Hz.

11A.12 **Noise:** Unwanted **sound**. May refer to both natural (e.g. wind, birdsong etc) and artificial sounds (e.g. traffic, noise from wind turbines, etc).

11A.13 **Noise contour plot:** A diagram showing lines of equal sound levels in a similar manner to height contours on an Ordnance Survey map or isobars (lines of equal pressure) on a weather map.

11A.14 **Noise sensitive receptors (NSRs):** Locations that may potentially be adversely affected by the addition of a **new** source of noise. These can include residential properties, outdoor areas and sensitive species.

11A.15 **Sound power (W):** The sound energy radiated per unit time by a sound source, measured in watts (W).

11A.16 **Sound power level (L_w):** Sound power measured on the decibel scale, relative to a reference value (W₀) of 10⁻¹²W.

11A.17 **Sound pressure (P):** The fluctuations in atmospheric pressure measured in Pascals (Pa).

11A.18 **Sound pressure level (Lp)**: Sound pressure measured on the decibel scale, relative to a sound pressure of 2×10^{-5} Pa.

11A.19 **Tonal element**: A characteristic of a sound where the sound pressure level in a particular frequency range **is** greater than in those frequency ranges immediately above higher or lower. This would be perceived as a humming or whining sound.

11A.20 **Vibration**: In this context, refers to vibration carried in structures such as the ground or buildings, rather than **airborne** noise.

Appendix 11B – Wind Turbine Noise

11B.1 Wind turbine noise is generated by rotation of the turbine blades. This only occurs above the 'cut-in' wind speed and below the 'cut-out' wind speed. Below the cut-in wind speed there is insufficient energy in the wind to generate electricity and above the cut-out wind speed the turbine is automatically shut down to prevent any malfunctions or damage occurring. The cut-in wind speed at turbine hub height is normally around 4 metres per second (ms^{-1}) and the cut-out wind speed is normally around 25ms^{-1} . The cut-in wind speed of the Siemens SWT-2.3-93 is $\sim 3\text{ms}^{-1}$ and cut-out speed is 25ms^{-1} ($\sim 7\text{mph}$ - 56mph).

11B.2 As the blades rotate in the air, aerodynamic noise is generated, which sounds like a swishing noise. Noise is also produced by the internal machinery, i.e. gearbox and, to a lesser extent, the generator (mechanical noise). The blades are aerodynamically efficient such they extract the maximum 'turning energy' from the wind, which means that any noise produced is minimised. The hub at the top of the tower is usually insulated to minimise noise radiation from the gearbox, generator and other components. The hub is also isolated from the tower and the blade assembly to prevent structure borne noise occurring, which in turn prevents any vibrations being transmitted to the ground.

The Assessment & Rating of Noise from Wind Farms – The Working Group on Noise from Wind Turbines (Report ETSU-R-97)

11B.3 In 1993 a working group was established by the DTI to examine the difficulties experienced in applying various noise guidelines to wind farm noise assessments. The ETSU-R-97 report is the result of the group's work and the report is referred to in PPS22, as the methodology by which noise from wind farms should be assessed. The use of ETSU-R-97 is also referred to in PAN45.

11B.4 In 2007 the Department for Communities and Local Government (DCLG) wrote to all planning authorities in England and the Planning Inspectorate to confirm that the advice in PPS22 and its Companion Guide, that ETSU-R-97 should be used for the assessment and rating of noise from wind farms, is unchanged. In Scotland there are no decisions made by Scottish Ministers in relation to wind farm planning applications which have not applied the ETSU-R-97 assessment procedure or noise limits.

11B.5 ETSU-R-97 recommends that noise limits should be applied to external locations used for relaxation or where a quiet environment is highly desirable. These limits should be set relative to background noise and should reflect the variation in both the wind turbine source noise and background noise with wind speed. Separate noise limits apply for day-time and for night-time as during the night the protection of external amenity becomes less important and the emphasis should be on preventing sleep disturbance.

11B.6 Predicted noise levels from a wind farm are compared with criteria based on noise limits specified in ETSU-R-97. The noise limits proposed by ETSU-R-97 are based on the $L_{A90,10\text{min}}$, assuming free field conditions. Separate noise limits apply for quiet day-time and night time, as outlined below. Quiet daytime is defined as 18:00 – 23:00 every day, as well as 13:00 – 18:00 on Saturday and 07:00 – 18:00 on Sundays. During these periods, the guidance prioritises the protection of outdoor amenity for residents, by applying noise limits that would not significantly affect the enjoyment of areas such as gardens.

11B.7 ETSU-R-97 proposes the adoption of a site standard of $5\text{dB } L_{A90,10\text{min}}$ above the prevailing wind varying background noise level. This is based on wide experience in environmental acoustics that

noise from a new source is unlikely to cause annoyance where the predicted increase is less than 5dB(A) above the existing background. In addition to the limit of 5dB above background, an allowance is included for a fixed limit to be applied at wind speeds or locations where background noise levels are low. Where the quiet daytime background noise level is less than $30\text{-}35\text{dB } L_{A90,10\text{min}}$, the limit is defined as $35\text{-}40\text{dB } L_{A90,10\text{min}}$. The quiet daytime limit also applies to all other daytime periods, with the limits based on the quiet daytime background noise level.

11B.8 Different standards apply at night, where sleep disturbance is the primary concern rather than the requirement to protect outdoor amenity. Night-time is considered to be all periods between 23:00 and 07:00. A minimum limit of $43\text{dB } L_{A90,10\text{min}}$ (derived from World Health Organisation Guidelines on noise levels that can cause sleep disturbance) is recommended for night-time at wind speeds or locations where the background noise level is less than $38\text{dB } L_{A90,10\text{min}}$. This is significantly relevant to the assessment as in rural areas the background can be significantly quieter at night. Where background noise levels exceed $38\text{dB } L_{A90,10\text{min}}$ the limit is set to 5dB above the background noise level.

Low frequency noise

11B.9 Noise from modern wind turbines is essentially broadband in nature in that it contains similar amounts of noise energy in all frequency bands from low to high frequency. As the distance from a wind farm site increases, the noise level decreases as a result of the geometric spreading-out of the sound energy, but also due to air absorption which increases with increasing frequency. Accordingly, higher frequencies are attenuated more than lower frequencies.

11B.10A recent DTI study (2006) measured low frequency noise at three properties. The level of low frequency noise was below the criterion values recommended by Defra (2005). Therefore, low frequency noise levels from wind farms are not significant.

Infrasound

11B.11 Infra-sound is defined as noise occurring at frequencies below 20Hz , which is considered to be the lowest frequency which is normally audible. In this frequency range, for sound to be perceptible, the amplitude of the sound has to be very high. It is generally considered that when such sounds are perceptible, then they can cause considerable annoyance.

11B.12 Wind farms have often been cited as significant producers of infra-sound. Old technology wind turbines used to produce an audible low frequency thumping sound. These turbines were known as 'downwind' turbines and were common in the USA. Downwind turbines are configured with the blades downwind of the tower, such that the blades pass through the turbulent wake left in the wind stream by the tower resulting in a regular audible thump, with infra-sonic components, each time a blade passes the tower. Virtually all turbines installed in the UK nowadays, including the Siemens, are upwind turbines. In this configuration, the blades are upwind of the tower, such that this 'thumping' effect is eliminated.

11B.13A recent study carried out for the DTI (Salford 2005) concluded that:

Infrasound noise emissions from wind turbines are significantly below the recognised threshold of perception for acoustic energy within this frequency range. Even assuming that the most sensitive members of the population have a hearing threshold which is 12dB lower than the median hearing threshold, measured infrasound levels are well below this criterion.

11B.14 The study goes on to state that based on information from the World Health Organisation:

there is no reliable evidence that infrasounds below the hearing threshold produce physiological or psychological effects' it may be concluded that 'infrasound associated with modern wind turbines is not a source which may be injurious to the health of a wind farm neighbour.

Amplitude Modulation of Aerodynamic Noise

11B.15 It is acknowledged in ETSU-R-97 that all wind turbines exhibit blade swish to a certain extent and that the noise limits specified in those recommendations take this into account without requiring any correction to be applied.

11B.16 Work carried out recently to investigate the extent of low frequency and infrasonic noise received from three UK wind farms (DTI 2006) concluded that:

the common cause of complaints associated with noise at all three wind farms is not associated with low frequency noise, but is the audible modulation of the aerodynamic noise, especially at night.

11B.17 It suggests that:

it may be appropriate to re-visit the issue of aerodynamic modulation and the means by which it should be assessed.

11B.18 In 2007 the University of Salford investigated the amplitude modulation of aerodynamic noise (which essentially means 'varying noise level') on behalf of the DTI. The objectives of the study were:

- to establish the levels and nature of the reported noise complaints received across the UK relating to noise issues from wind farms, both historic and current, and determine whether AM is a significant effect; and
- to review and understand the level of knowledge/understanding that exists throughout the world on AM, and whether AM can be predicted.

11B.19 In July 2007 The Department for Business, Enterprise and Regulatory Reform (BERR formerly DTI and now Department of Energy and Climate Change) stated:

The Salford University study has now been published. The study concluded that although AM cannot be fully predicted, the incidence of AM resulting from wind farms in the UK is low. Out of the 133 wind farms in operation at the time of the study, there were four cases where AM appeared to be a factor. Complaints have subsided for three out of these four sites, in one case as a result of remedial treatment in the form of a wind turbine control system. In the remaining case, which is a recent installation, investigations are ongoing.

11B.20 Based on these findings, Government does not consider there to be a compelling case for further work into AM and will not carry out any further research at this time; however it will continue to keep the issue under review.

11B.21 The statement concluded that:

Government continues to support the approach set out in Planning Policy Statement (PPS) 22 – Renewable Energy. This approach is for local planning authorities to "ensure that renewable energy developments have been located and designed in such a way to minimise increases in ambient noise levels", through the use of the 1997 report by ETSU to assess and rate noise from wind energy developments.

11B.22 Furthermore, there is no compelling evidence to suggest that there are any adverse health effects associated with wind farms.

W/45/00656/00/00 The Measurement of Low Frequency Noise at Three UK Windfarms. Department of Trade and Industry 2006

11B.23 DEFRA NANR45 Project Report Proposed Criteria for the Assessment of Low Frequency Noise Disturbance Moorhouse A., Waddington D, & Adams M. University of Salford 2005

11B.24 University of Salford, 'Research into Amplitude Modulation of Wind Turbine Noise'. April 2007, NANR233

Appendix 11C – Noise Modelling and Assessment Details

11C.1 There is no wind farm specific British or International Standard which prescribes the method to calculate wind turbine noise emissions.

11C.2 However, it is accepted by UK acoustic consultants that wind farm noise is calculated according to ISO 9613-1 and ISO 9613-2 “Acoustics – Attenuation of sound during propagation outdoors”. Although there are other sound propagation methodologies, the ISO is regarded as a very useful tool when calculating sound emission levels.

11C.3 Due to the complexity of the equations contained within parts 1 and 2 of the ISO, it is standard practice to undertake these calculations using commercially available computer modelling software programmes. These programmes are fully quality assured and assuming that the correct input data is used then the results are highly unlikely to be subject to any user generated errors.

11C.4 Parts 1 and 2 of ISO 9613 are incorporated within SoundPLAN sound modelling software. SoundPLAN was used to generate the Scheme’s turbine sound levels at the identified sites and to produce noise contour maps.

Wind Turbine Modelling

11C.5 As with any noise modelling exercise there are a number of potential constraints which will influence the accuracy/uncertainty of any calculated sound levels and these are discussed below.

11C.6 The ISO provides calculation procedures for the following physical effects:

- geometric divergence (A_{div}) - reduction in sound level due to distance - (not frequency dependent);
- atmospheric absorption (A_{atm}) - absorption of sound by the air (frequency dependent);
- ground effect (A_{gr}) - absorption of sound by the ground (frequency dependent);
- reflection from surfaces (not frequency dependent, rarely employed for wind farms);
- screening by obstacles (A_{bar}) - shielding by a feature or the ground, this causes a reduction in the noise level (frequency dependent); and
- miscellaneous effects (A_{misc}) - such as propagation through trees.

11C.7 These effects are combined with the sound power level of the turbine (L_w) in the following equation to derive the sound pressure level (L_p) for each turbine.

$$L_p = L_w - (A_{div} + A_{atm} + A_{gr} + A_{bar} + A_{misc})$$

11C.8 For the purposes of modelling, a wind turbine is considered to have a single emission point, the hub of the turbine. Within SoundPLAN the turbines are modelled as an industrial point source at the hub height of the proposed turbines and single spot receivers are used to calculate the combined turbine noise levels at the closest NSRs. There are no corrections for the directivity of the sound emitted from the turbine.

11C.9 The SoundPLAN model does not take into account the shielding effects of barriers or buildings or miscellaneous effects such as the influence of sound propagation through foliage.

11C.10 Manufacturer’s warranted noise emission data (expressed as sound power levels) has been used in the prediction process and are summarised below. For the purposes of this assessment, the Siemens SWT 2.3-93 model does not require a tonal penalty under the requirements of ETSU-R-97.

Siemens SWT 2.3-93 – Manufacturer’s Warranted Sound Power Level Data

Windspeed / ms^{-1}	6	7	8	9	10
L_{WA} / dB	104.1	105.4	105.4	105.4	105.4

Taken from a reference report dated 2009 for a 80m hub height turbine

11C.11 The sound power levels are based on the assessment approached stated in International Standard IEC-61400-11 Wind turbine generator systems – Part 11: Acoustic noise measurement techniques. The Standard enables the overall A-weighted sound power and one-third octave band spectrum to be obtained at normalised integer wind speeds. It also enables the directivity and the tonality of the noise emission to be determined.

Assessment Assumptions

11C.12 The assessment was based on the methodology specified in ISO 9613. Conservative assumptions have been made in the modelling process and it is more likely that the model will over-predict than under-predict noise levels. The assumptions made were:

- Air Pressure = 1013.25 mbar;
- Relative Humidity = 70%;
- Temperature = 10°C;
- Semi-Hard-ground attenuation occurred between the turbines and the NSRs ($G=0.5$);
- manufacturer’s warranted sound power level data for normal power operating mode;
- one-third octave band frequency spectra has been used in the calculations;
- day time calculation height of 4.0m to represent outdoor amenity areas;
- night time calculation height of 4.0m to represent first floor bedroom windows; and
- calculation locations were considered to be representative of the most exposed façade of the property, i.e. the closest façade to the Wind Farm.

11C.13 Possible uncertainties in the modelling approach may arise from the use of the ground effect methods in section 7.3 of ISO9613-2. The ISO suggests two methods:

- method 1 - spectral dependent term and is applicable to ground which is generally flat, either horizontally or with a constant slope; and
- method 2 - applicable to ground surfaces of any shape but is only used when the overall sound pressure level is of interest, i.e. not spectral dependent.

11C.14 Method 1 was used to derive the wind turbine noise levels presented within the ES assessment since the ground is generally sloping with no significant changes in elevation across the sites and spectral data was available for the turbine sound levels.

11C.15 The ISO 9613 method predicts noise levels likely to occur under conditions favourable to noise propagation, i.e. downwind or under a moderate ground-based temperature inversion that may occur at night. Under down wind conditions the noise model assumes that the wind is ‘blowing’ from each individual turbine equally in all directions. This situation would not occur in practice and therefore the reported wind farm noise levels assume a worst case prevailing wind direction. This is demonstrated on the noise contour map.

11C.16 Additional meteorological conditions, as described in ISO 9613, were not considered further as charts in ISO 9613 show there is negligible change to the noise level and during extreme meteorological conditions background noise levels would raise inline with the turbine noise.

11C.17 ISO 9613-2, Acoustics - Attenuation of Sound During Propagation Outdoors. International Organization for Standardization, 1996

Manufacturer’s Datasheet Extract for Siemens SWT-2.3-93



Acoustic Emission, SWT-2.3-93
 Document ID: E R WP-EN431-10-0000-0165-00
 PE / 2009.03.31
 Conveyed confidentially as trade secret

**SWT-2.3-93
 Acoustic Emission**

Sound Power Levels

The warranted sound power levels are presented with reference to the code IEC 61400-11:2002 with amendment 1 dated 2006-05 based on a hub height of 80 m and a roughness length of 0.05 m as described in the IEC code. The sound power levels (L_{WA}) presented are valid for the corresponding wind speeds referenced to a height of 10 m above ground level.

Wind speed [m/s]	6	7	8	9	10
Standard setting	104.1	105.4	105.4	105.4	105.4
Setting -1 dB	103.0	104.0	104.4	104.4	104.4
Setting -2 dB	102.0	103.0	103.3	103.3	103.3
Setting -3 dB	101.0	101.6	102.0	102.0	102.0
Setting -4 dB	99.8	100.5	101.0	101.0	101.0
Setting -5 dB	99.0	99.6	100.0	100.0	100.0

Table 1: Noise emission, L_{WA} [dB(A) re 1 pW]

Typical Octave Band

Typical, not warranted octave band spectra are tabulated below for 6 and 8 m/s referenced to 10m height.

Octave band, center frequency [Hz]	63	125	250	500	1000	2000	4000	8000
Standard setting	82.1	92.9	99.7	99.1	95.4	92.4	88.9	82.7
Setting -1 dB	83.3	93.6	99.2	97.1	93.2	91.4	86.8	79.6
Setting -2 dB	82.8	93.2	98.4	95.4	91.6	90.6	86.5	80.1
Setting -3 dB	82.2	92.7	97.6	93.7	90.0	89.8	86.1	80.5
Setting -4 dB	82.6	92.2	96.2	91.9	88.8	88.8	85.7	80.1
Setting -5 dB	83.4	92.0	95.1	90.5	88.0	88.2	85.7	80.2

Table 2: Typical octave band for 6 m/s

Octave band, center frequency [Hz]	63	125	250	500	1000	2000	4000	8000
Standard setting	84.6	93.6	100.3	100.7	97.8	94.3	89.0	85.3
Setting -1 dB	85.5	93.9	99.1	99.2	96.9	93.5	89.0	85.4
Setting -2 dB	83.4	92.1	98.1	98.3	95.8	92.3	87.4	83.8
Setting -3 dB	84.0	92.1	96.6	96.5	94.6	91.2	87.1	83.6
Setting -4 dB	83.9	91.7	95.5	95.2	93.6	90.3	86.6	83.1
Setting -5 dB	83.8	91.3	94.3	93.9	92.6	89.3	86.0	82.6

Table 3: Typical octave band for 8 m/s

Noise Restricted Operation

The lower sound power levels presented for "Setting -1 dB", "Setting -2 dB", "Setting -3 dB", "Setting -4 dB" and "Setting -5 dB" are achieved by controlling the SWT-2.3-93 wind turbine in a noise restricted mode of operation. This noise restricted mode of operation will, depending on the mode, have an impact on the power output of the turbine. Please contact Siemens for further information on this option.