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A GOOD PRACTICE GUIDE TO THE APPLICATION OF ETSU-R-97 FOR THE ASSESSMENT AND RATING OF WIND TURBINE NOISE



#### PREFACE

This document has been produced by a working group on behalf of the Institute of Acoustics consisting of the following members:

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This good practice guide is the output of a process to capture and report good practice in the application of the ETSU-R-97 methodology, which included a 10 week consultation and two peer reviews. The terms of reference for the work and the consultation discussion document can be found at: <u>http://www.ioa.org.uk/about-us/news-article.asp?id=260</u> (Checked 14.05.13).

Prior to publication of this good practice guide, a peer review was undertaken by a separate group consisting of the following members:

Renewable Energy Systems Ltd
Temple Group
ION Acoustics
Infrasonic
Huntingdonshire County Council
TNEI Services
Farm Energy Consulting
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Additional comments were received from members of a Government Oversight Group, with thanks to Hilary Notley, Yvette Hood and Stephen Turner of the Noise and Nuisance Technical Team at DEFRA.

Any comments on this document should be sent to <u>ETSUCONSULT@IOA.ORG.UK</u>. The IOA will keep the document under review, and consider updating when significant changes to current good practice have occurred.

On a personal note, I would also like to take this opportunity to thank all of those individuals not mentioned above who have given their time to assist with the development of this document, through participation at the workshops in London and Dublin, and responding to the consultation.

Richard Perkins Working Group Chairman & Editor.

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A – Glossary of Terms & Reference

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# 1 Context

## 1.1 Background

- 1.1.1 In response to a request from the Department of Energy and Climate Change (DECC), the Institute of Acoustics (IOA) set up a noise working group (IOA-NWG) to take forward (where possible) the recommendations of the Hayes McKenzie Partnership Report<sup>1</sup> on 'Analysis of How Noise Impacts are considered in the Determination of Wind Farm Planning Applications' Ref HM: 2293/R1 dated 6th April 2011. This good practice guide is the output of a process to capture and report good practice in the application of the ETSU-R-97 methodology, which included a 10 week consultation and two peer reviews.
- 1.1.2 This guide will be of relevance to:
  - i. Acoustics consultants;
  - ii. Local Planning Authority (LPA) Environmental Health and Planning departments;
  - iii. Developers;
  - iv. The Planning Inspectorate or equivalent regulating authority;
  - v. The general public.

#### **1.2** Scope of the Document

- 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. The noise limits in ETSU-R-97 have not been examined as these are a matter for Government.
- 1.2.2 Smaller developments such as single turbines warrant a simplified procedure (either based on ETSU-R-97 or other method agreed with the LPA), commensurate with the size and impact of the project. Local Planning Policies should also be checked for any variations to methodologies or limits. Where in place, some turbines types may fall under permitted development orders, and assessment methods contained in those orders should be used.
- 1.2.3 Summary points in the guide appear in the blue boxes, labelled as numbered Summary Boxes (SB). Additional *Supplementary Guidance Notes*, published separately to this guide, expand on some of the aspects considered in the guide to further illustrate the general principles. This guide represents good practice as of the date of publication, and does not exempt further advances from being used. It is anticipated that a regular review of this document will be undertaken, and a new version produced when significant changes have occurred. A Glossary of Terms is included in **Annex A**.

### 1.3 Statutory Context

1.3.1 This Good Practice Guide has been approved by the IOA Council for use by IOA Members and others involved in the assessment and rating of wind turbine noise using ETSU-R-97. It covers technical matters of an acoustic nature which the IOA-NWG believes represent current good practice. The approval of this guide by the IOA Council should not be seen as an endorsement of the noise limits within the ETSU-R-97 document since the setting of these noise limits is a policy matter for Government. An example planning condition is included in **Annex B**, but legal advice should be sought to ensure it is appropriately applied.

#### 1.4 The ETSU-R-97 Noise Assessment Procedure

- 1.4.1 The assessment procedure (represented graphically in Figure 1) consists of the following steps:
  - Predict noise levels from all turbines (existing and proposed) at the nearest receptors;
  - Determine a study area;
  - Identify potentially affected properties;
  - (If required) Undertake a measurement survey consisting of simultaneous measurement of background noise levels at representative properties with wind speed and direction at the proposed turbine site;
  - Analyse the data to remove rain affected and atypical data, and derive the noise limits for the scheme;
  - Update noise predictions & assess compliance with the noise limits for a candidate turbine, and provide design advice if compliance with the limits is considered unlikely.
- 1.4.2 The main purpose of this procedure is to set out the noise data required, and the subsequent analysis needed to allow a decision maker to make an informed decision to assess compliance with ETSU-R-97.









#### 1.5 Engagement

- 1.5.1 ETSU-R-97 states at page 83 that "During the planning stage of a wind farm, discussions are likely to have been held with the local Environmental Health Officer (EHO) with respect to agreeing acceptable levels of noise from the proposed site...the prevailing background noise level at sensitive dwellings will need to be agreed with the local EHO so that noise limits at different turbine operating wind speeds can be set."
- 1.5.2 Engagement of all of the relevant parties at an early stage in the project and continuation of that engagement throughout the project is desirable from site scoping to the drafting of conditions. This will include the local residents potentially affected by the proposed wind farm, and the respective LPA. It is normal for all developments subject to an Environmental Impact Assessment (EIA) to request a Scoping Opinion to be sought from the respective LPA, however current good practice is that this should not be the extent of the consultation on the part of the wind farm developer, or their consultants. Sub-EIA developments would also be expected to undertake engagement.
- 1.5.3 A significant aspect of the consultation should be whether surveys are required, and if they are, agreement on the number and position of background noise level measurement locations should be sought. Such agreement will benefit all parties, as background noise level measurements can be an area of considerable debate, and targeting resources at this early stage in the development process should provide dividends in the future by reducing the likelihood of protracted arguments and potentially the need for additional background noise level measurements.
- 1.5.4 It is encouraged that a LPA representative accepts any invitation from the wind farm developer to witness the installation of background noise level measurement equipment. It is considered good practice for developers to give ample opportunity for a LPA to respond at the respective stages described throughout the process. It is further recognised that the LPA have finite resources which need to be prioritised to where they are most needed, and may not be in a position to respond.
- 1.5.5 Engagement should be viewed as an ongoing process. This will assist in keeping both local residents and the LPA informed regarding the progress of the application and helps develop trust between all involved.

**SB1:** Engagement of all of the relevant parties from an early stage and throughout the project is desirable. This includes from site scoping to the drafting of planning conditions.

#### 2 Background Data Collection

#### 2.1 Introduction

2.1.1 In some cases, the ETSU-R-97 procedure for setting noise limits for wind turbines requires typical background noise levels to be determined at noise-sensitive locations in the vicinity of the proposed site. This guidance develops the recommendations in ETSU-R-97 (page 59 – "*The assessment of typical background noise levels*") in the light of collective experience of carrying out background noise surveys and analysing the data obtained.

#### 2.2 Scoping for Background Noise Surveys

#### Definition of Study Area

2.2.1 The 'study area' for background noise surveys (and noise assessment) should, as a minimum, be the area within which noise levels from the proposed, consented and existing wind turbine(s) may exceed 35 dB L<sub>A90</sub> at up to 10 m/s wind speed. (Note: unless stated, in this document the wind speed reference for noise data is the 10 metre standardised wind speed, derived from the wind speed at turbine hub height as explained in Section 2.6). It should be borne in mind that at the survey scoping stage the definition of the 35 dB L<sub>A90</sub> contour is often preliminary, because (for example) the precise positions and type of wind turbines are not finalised. In specific cases it may be necessary to incorporate the ETSU-R-97 tonal penalty into these predicted noise levels.

**SB2:**The study area should cover at least the area predicted to exceed 35 dB  $L_{A90}$  at up to 10 m/s wind speed from all existing and proposed turbines.

#### Other Wind Turbines

2.2.2 Particular care should be taken with planning surveys where there are other wind turbines in the area. The contribution to background noise levels of existing wind turbines has to be discounted in determining the background noise levels: the relevant background noise levels for the purpose of setting noise limits for a



new installation are the levels with no existing wind turbines operating. Several approaches are described in section 5.2; one or a combination of these may be appropriate.

**SB3:** Any contribution to background noise levels of noise from an existing wind farm must be excluded when assigning background noise and setting noise limits for a new development.

#### Numbers and positions of measurements

- 2.2.3 In many cases there will be significant variation in general background noise levels within the study area, because of topography and the varying influence of existing noise sources such as roads. In rural or semirural areas, noise generated by wind in trees is generally a dominant noise source at higher wind speeds and therefore the proximity of the monitoring location to trees and vegetation, and the type of such vegetation, may be significant. Noise from streams and other watercourses can also be a local factor.
- 2.2.4 Background noise measurements should preferably be made in the vicinity of noise-sensitive receptors, principally houses (existing or for which planning consent is being sought / has been given) and any building used for long-term residential purposes (such as a nursing home). Where there are only a small number of isolated properties (perhaps 4-5) within the study area the selection process is simplified since it is practicable to make measurements close to all receptors. A common situation is where there are groups of houses and the objective is to identify, for each group, a 'representative' location within the curtilage of one property such that the background noise levels measured there can be reliably assigned to all other houses in the group. At the survey planning stage it may not be possible to gain access to gardens, but candidate locations can usually be identified from roadside views, supported by aerial images on website map pages.
- 2.2.5 When choosing a location that will serve as a proxy for others, the basis for selection is that it can reasonably be claimed, from inspection and observation, to be representative of the non-surveyed locations, in line with the criteria of Section 2.5. Measurement locations outside a property's curtilage (such as an adjacent field) may be used when access to a representative property cannot be obtained, provided that such a location can be justified as being representative. No general guidance can therefore be given on the number of measurement locations as this will be site-specific.
- 2.2.6 On some occasions a monitoring location may be found to be unsuitable only after the data from this location has been analysed: for example, it may be found that the data is contaminated by noise from a non-typical source. Repeat measurements or use of alternative data should then be considered.

**SB4:** The background noise monitoring locations within the study area should be selected on the basis of professional judgment, with the objective of collecting sufficient data to enable the background noise levels at each noise-sensitive receptor within the study area to be characterised.

Engagement with the Local Planning Authority and Residents

- 2.2.7 An EHO may be invited to be involved in the selection of monitoring locations: local knowledge of factors such as the variability of local noise sources can assist in the process, and an EHO may also be willing to liaise with residents when requesting access to properties.
- 2.2.8 When potential monitoring locations within a property's curtilage have been identified, access to install equipment has to be requested. Obtaining access for noise monitoring may be the first time residents hear about the development, therefore any requests for access should ideally be made by the land-owner or project representative and may be accompanied by written material describing the development and if necessary the noise monitoring process with a photo of a typical installation. This may include a note that the risks of theft/damage of the equipment are carried by the consultant/developer and not the householder. It is considered to be good practice to provide the noise and meteorological data available to the resident upon request.

**SB5:** The LPA (most usually the Environmental Health Department) should be informed of the plan to carry out background noise surveys and invited to become involved. Landowners or project representatives should make the initial approach to arrange access for monitoring. A description of the monitoring process should ideally be provided to residents in writing.

#### 2.3 Timing of Surveys

2.3.1 Background noise levels at any location may be subject to seasonal variations and (for a given reference wind speed) will be expected to vary with atmospheric factors including wind shear and, at some locations, wind direction. However, there is no compelling evidence that it is necessary to carry out background noise surveys at any particular time of year, or over two or more separate periods. The only common exception is when a measurement position is close to a running watercourse which is a significant noise source.



Although noise from such a source is part of the background noise environment, the effect may be localised. Also, water flow rates and resulting noise levels vary seasonally, and as high flow rates may persist for some days after rainfall, this will be significant in relatively wet periods. Because the objective is to define *typical* background noise levels, the influence of such sources on measured noise should be limited to the levels that would be expected to prevail during drier periods of the year. This might require surveys to be carried out in summer months, although in most cases the influence of non-typical noise can be minimised by selection of monitoring location (see Section 2.5) and/or by selection and exclusion of affected data at the analysis stage (see Section 3.1).

**SB6:** Background noise surveys may be carried out at any time of the year provided that seasonal effects leading to raised noise levels can be excluded by selection of measurement position or by exclusion of non-typical data during analysis.

### 2.4 Noise Measuring Equipment

2.4.1 Noise measurement equipment (excluding the microphone windscreen) and field calibrators should meet Class 1/Type 1 precision standards. Microphones should be housed within enhanced-performance windscreens to reduce the effects of flow-generated noise at the microphone. Standard windshields of a diameter of less than 100 mm cannot be relied upon to provide sufficient reduction of wind noise in most circumstances. Where windscreen/microphone combinations are not certified by the manufacturer as meeting Type 1/Class 1 precision standards, which is generally the case where non-proprietary windscreens are used, the windscreen should have an insertion effect of no greater than +/- 1.0 dB in any octave band from 63 Hz to 4000 Hz inclusive<sup>ii</sup>. This should be confirmed by test data. See **Supplementary Guidance Note 1** for more detail.

#### Calibration

- 2.4.2 Systems should have independent calibration to manufacturer's specification carried out no longer than two years prior to the survey completion date (one year for field calibrators). The system should be check-calibrated on installation, at each battery change, at intervals of no longer than 4 weeks during the survey, and prior to removal from site. Check-calibration should be carried out using a Type 1 acoustic calibrator, subject to independent calibration annually. Remote calibration (e.g. mid-survey) is acceptable provided that the calibration system is equally compliant.
- 2.4.3 All calibrations should be reported, along with any drift. A calibration drift greater than 0.5 dB but less than 1.0 dB need not disqualify the measured data, provided that subsequent calibration to manufacturer's specification confirms that there is no defect in the system, and that the recorded time history does not exhibit any anomalies that might indicate more significant excursions in system sensitivity during the survey. Subject to these qualifications, measurements should be corrected by the amount of the calibration shift but only if such a correction results in lower noise levels. Where the system exhibits a calibration shift greater than 1.0 dB, those measurements should be discarded.

**SB7:** Noise measurement equipment and calibrators used on site should comply with Class 1/Type 1 of the relevant standard(s). Enhanced microphone windscreens should be used. Standard windshields of a diameter of less than 100 mm cannot be relied upon to provide sufficient reduction of wind noise in most circumstances.

### 2.5 Siting Noise Measuring Equipment

- 2.5.1 Where possible, measurements should be made in the vicinity of a dwelling in an area frequently used for rest and recreation. This is a flexible definition, and the way people use their garden areas varies widely. Identifying the most appropriate measurement positions must be a matter of professional judgment and experience but the following guidelines are offered:
- 2.5.2 Equipment should be placed at outdoor positions where noise levels are representative of typical 'low' levels likely to be experienced in the vicinity of a dwelling (or group of dwellings if the measurements are intended to be applied to more than one dwelling). The overriding consideration is that it can reasonably be claimed, from inspection and observation, that there are no other suitable noise-sensitive locations, in the vicinity of any selected location and close to a dwelling, where background noise levels would be expected to be consistently lower than the levels at the selected position. This is a matter of judgment: the objective is to measure 'typical' or 'indicative' not 'absolute lowest' levels of background noise (which could only be determined by extended measurements at a large number of locations over a long period which is neither necessary nor practicable). See **Supplementary Guidance Note 2** for more detail.



- 2.5.3 Ideally the position should be one which would be exposed to noise from the wind turbines whilst being bestscreened from other noise sources such as nearby roads or vegetation.
- 2.5.4 The background surveys provide the basis for setting both daytime and night-time noise limits: the measurement position must therefore reasonably represent external areas (for daytime noise) and also building facades containing windows (for night-time noise).
- 2.5.5 In most locations, background noise levels will be determined by wind in trees and vegetation and noise sources external to the property such as traffic noise. The presence of local noise sources such as boiler flues, garden fountains, domestic drains, watercourses and farm equipment should be identified. Such sources are variable (and may not be significant at other dwellings in the vicinity) and their effects should be excluded where possible by selection of measurement position. Other noise sources influencing the measurements may not be so apparent; for example boiler flues and water features operating at low sound pressure levels and only at certain times of the day or night. Such sources would ideally be identified at the time of selecting the measurement locations or installing equipment. However, they might affect measurements to a degree which may only become evident from detailed inspection of the data.
- 2.5.6 Where it is not possible to exclude the influence of variable local noise sources by selection of monitoring position, it is generally possible to identify such data from inspection of noise level time histories and therefore to exclude it from the data set used to derive noise limits (see Section 3). Periodic downloading of data during service visits can assist with informing the survey length if this arises.
- 2.5.7 In all cases, microphones should be supported at a height of 1.2 1.5 metres above the ground and no closer than 3.5 metres to any significant reflecting surface (such as a building or fence), except the ground. The position should be within 20 metres of the dwelling unless there are particular reasons for measuring at a more distant position (such as the presence of vegetation or denial of access); if so, the reasons should be explained.
- 2.5.8 A resident at a selected property may request that measurements are made at a position which is considered inappropriate; perhaps because the preferred location(s) are inconvenient (it might obstruct lawn mowing, for example). In this situation the consultant should explain clearly the reasons why the measurements could be compromised; if no agreement can be reached, an alternative property or location should be sought. The assistance of the EHO may help to resolve these situations.

#### Other Considerations

- 2.5.9 During site visits, observations should be recorded of the subjective impression of the ambient noise climate: such observations are helpful in building-up a full picture of the various noise sources affecting the site and may assist in data analysis. However, site visits to install, maintain or remove equipment are usually made during the day, which therefore generally does not allow the noise climate during the amenity hours or night-time periods, which are the only periods relevant to the noise assessment, to be directly observed. Where possible, residents in properties where equipment is located should be consulted on particular noise events (such as local building work, harvesting etc.) and particular weather conditions (e.g. fog, snow, heavy frost, wet roads) that can happen during the survey. This can assist data analysis by identifying anomalous data and informing a decision on excluding such data.
- 2.5.10 Photographs of the equipment showing its position relative to the dwelling or other conspicuous features should also be provided, to inform the assessment and to enable the survey to be repeated at the same location if necessary. Permission to use these photos should be sought.

### SB8:

Measurements should be made in amenity areas between 3.5 and 20 metres from a dwelling.

The measurement position should permit measurement of 'background noise levels judged to be typical/ indicative of the area around the associated dwelling and any other dwellings for which the measurement location will serve as a proxy.

The influence of noise from local sources should be taken into account when selecting measurement locations.

The person selecting background noise monitoring positions and visiting these locations should record subjective impressions of sources contributing to local ambient noise levels.

Residents should be consulted to establish the occurrence of unusual noise events during the monitoring period

Photographs showing the positions of measuring equipment should be provided.



#### 2.6 Wind Speed Measurement

- 2.6.1 The noise levels recorded in each 10 minute interval are correlated with the concurrent wind speed at a reference position on the proposed wind turbine site. On sites with multiple turbines, the wind monitoring location should be selected to be reasonably representative of the range of wind speeds considered to be experienced at the wind farm site.
- 2.6.2 The standard procedure should be to reference noise data to standardised 10 metre wind speed. The standardised 10 metre wind speed is obtained from the turbine hub height wind speed by correcting it to 10 metre height using a ground roughness factor of 0.05: see **Annex A**. Hub height wind speed can either be measured directly or derived from wind speeds measured at different heights, using conventional mast-based anemometers or ground-based SODAR/LIDAR systems.
- 2.6.3 Three methods of wind speed measurement may be adopted:
  - a) Direct measurements at hub height using either:
    - i. A met mast carrying one or more anemometer(s) at the proposed turbine hub height.
    - ii. A SODAR or LIDAR system (installed in a suitable location) to determine hub height wind speed directly, or at the two nearest heights to allow hub-height wind speed to be derived using an exponential profile.
  - b) A met mast lower than hub height, but carrying anemometers at two different heights: these are then used to calculate the hub height wind speed, using an exponential profile<sup>1</sup> (see Annex A). A meaningful extrapolation should be undertaken, and this would be achieved with the upper anemometer (2) being at a height not less than 60% of the hub height of the proposed turbine and the lower anemometer (1) at least 15 metres below it. Within those requirements, the two measurement heights closest to the hub height should be used.
  - c) A met mast carrying anemometer(s) at a height of 10 metres (with wind shear corrections to be determined as explained in Section 4.5).
- 2.6.4 Figure 2 illustrates the different wind speed measurement methods, and how they relate to "standardised" wind speed. The figure shows mast-based and ground based methods.



Figure 2 – schematic representation of the methods used for estimating hub height wind speeds during background surveys, which are then standardised (blue arrow) to 10 m height. In case (c), an estimate of the corresponding hub height wind speed is effectively required for calculating the required corrections (as illustrated).

2.6.5 Methods (a) or (b) are preferred. Method (c), using a 10 m mast erected only for the purpose of the background noise survey, should only be adopted for smaller-scale developments for which the installation of a tall met mast or deployment of a SODAR or LIDAR system at the planning stage might not be justified economically.

<sup>&</sup>lt;sup>1</sup> In cases of negative instantaneous shear, assuming zero shear (constant wind speed with height) is considered good practice.



- 2.6.6 If method (c) is used, a correction to take account of the wind shear characteristics on the site should be applied. This is discussed in **Supplementary Guidance Note 4** (wind shear). Such corrections can be made on the basis of long-term anemometry data, although this would not be available if a tall anemometry mast is not justified economically. A simplified correction method is described in Section 4.5. In no circumstances should wind speed measurements at a height less than 10 metres be used.
- 2.6.7 Whichever method is employed, it is crucial that the wind speed reference (hub height, standardised 10 metre, or measured 10 metre) for noise levels and noise limits is clearly and consistently defined, particularly when drafting conditions or assessing compliance.
- 2.6.8 The highest available wind vane should be used to determine mean wind direction for the purposes of relating background noise levels to wind direction, where relevant.
- 2.6.9 In some wind directions, anemometers at intermediate heights on a mast will be downwind of the mast and may not indicate the correct wind speed. Information on the angular positions of anemometers should be sought from the mast installer and taken into account. Where two anemometers at the same height are used, the average of the two data sources should be used.
- 2.6.10 The standard of calibration of the wind measurement system used to provide reference data for background noise monitoring should be in accordance with the requirements of BS EN ISO 61400-11 for determination of sound power levels, which are as follows:
  - The anemometer and its signal processing equipment shall have a maximum deviation from the calibration value of ±0.2 m/s in the wind speed range from 4 m/s to 12 m/s.
  - The wind direction transducer shall be accurate to within ±6°.
- 2.6.11 It is recommended that anemometers should have been calibrated within 24 months of the end of the noise survey on temporary masts. It is recognised that this may be too onerous for long term met mast deployments.
- 2.6.12 Although not yet widely employed, remote measurement of wind speed and direction using ground-based equipment (SODAR, LIDAR) is proving to be a viable alternative to conventional anemometry in most circumstances. Current good practice for installation, operation and data analysis should be followed: guidance in the use of SODAR systems is provided in "Recommended Practices for SODAR in Wind Energy Resource Assessment" (draft), IEA, July 2011, published on <a href="http://www.iedat.com/sodar.html">http://www.iedat.com/sodar.html</a> and an equivalent draft is available from the IEA covering LIDAR measurements. Some of these ground-based systems are powered by generators: their location relative to noise monitoring positions must be carefully selected to avoid contamination of noise data by generator noise. Similarly, SODAR systems emit a regular "chirping" noise, which is generally inaudible at typical separation distances between the SODAR and the measurement locations but this should be verified on site.

**SB9:** Noise measurements should be correlated with values of standardised 10 metre wind speed, calculated from hub height wind speed. Hub height wind speed is either measured directly or calculated from measurements made at two heights with the higher measurement height being no lower than 60% of hub height.

Remote-sensing methods (SODAR or LIDAR) may be used as alternatives to mast-mounted anemometers. The operator of such equipment and the person analysing the data should have appropriate experience of these operations.

An anemometer on a 10 metre mast may be used to provide wind speed data for smaller developments. If 10 metre mast data is used, corrections must be made to allow for wind shear characteristics at the turbine site, and these are generally applied to the predicted turbine noise levels.

### 2.7 Rain Measuring Equipment

- 2.7.1 Noise measurements affected by rainfall should be excluded. The use of one or more recording rain gauges is preferred. Simple tipping bucket gauges with a typical tip resolution of 0.25 mm are adequate. Rain gauges are most conveniently placed close to noise monitoring positions, but should be installed in an exposed location and not placed under trees or close to a building or other vertical structure.
- 2.7.2 Other sources such as Met Office weather radar may provide rainfall information, but must be used with care as it may provide only a limited spatial or temporal coverage of the site. SODAR/LIDAR systems can also provide indication of rainfall, although of uncertain reliability at the current state of the art.

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2.7.3 Snow fall is not detected by rain gauges (until snow melts). If there is any likelihood that snow has fallen during a survey period then measurement made during snowfall (or when there was significant snow cover) should be identified as far as possible (using weather radar data, local observations, examination of noise level time histories etc) and affected data excluded from the data set, as this data is generally considered to be atypical.

**SB10:** A recording rain gauge should be deployed (or other methods can be used with care) to identify noise data affected by rainfall

#### 2.8 Synchronisation of Noise, Wind and Rainfall Measurements

- 2.8.1 It is important that noise and wind speed measurements are synchronised, so that the 10-minute averaging periods (average 10 minute wind speeds and L<sub>A90,10min</sub>) correspond meaningfully. In consultation with the supplier of the measured wind data, it is crucial to establish:
  - The time reference used (GMT/BST in the UK, for example). The former is often used by anemometry suppliers to avoid issues with daylight savings during summertime, but separation of data into the ETSU-R-97 time periods must be based on local time.
  - The clock reference used to set the time: for example, GPS receivers provide an accurate source of universal time reference.
  - The time reference convention: this may refer to the start or the end of the 10-minute averaging period.
- 2.8.2 The aim should be that the measurement intervals are synchronised to within 15 seconds at the start of the survey. A synchronisation drift of more than 1 minute over the duration of the survey should be reported and best avoided. In many cases, the review of time histories of wind and measured noise levels (using other parameters such as L<sub>Aeq</sub> if required) can indicate the progression of a synchronisation drift and allow data to be time-shifted to correct a significant synchronisation error.
- 2.8.3 Synchronisation of rainfall data with noise data is less critical because of the inherent limitations of rainfall measurements in identifying noise data that may have been affected by rain at any particular measurement position. However, synchronisation within 1 minute is a reasonable objective.

#### SB11:

Measurement intervals for wind speed, noise level and rainfall should be synchronised to within at most one minute over the survey period. Logging devices may use different time references (GMT or BST) and the logging protocol may apply a time marker at either the start or end of a measurement interval. Such differences must be taken into account. Synchronisation of rainfall measurements is less critical.

### 2.9 Durations of Surveys

2.9.1 The duration of a background noise survey is determined only by the need to acquire sufficient valid data over the range of wind speeds (and directions, if relevant). It is unlikely that this requirement can be met in less than 2 weeks. The possibility of equipment malfunction should also be borne in mind. This section lists relevant factors.

#### Required range of wind speeds

2.9.2 ETSU makes a positive recommendation "*It must be ensured that during the survey period wind speeds over the range zero to at least 12 m/s and a range of wind directions that are typical of the site, are measured*". The 'at least 12 m/s' requirement was intended to address the (then current) use of stall-regulated turbines with a hub height of around 25-30 metres, to provide background noise data (and hence derived noise limits) up to high wind speeds. With increasing hub heights a modern pitch-regulated turbine may achieve its maximum sound power level at a standardised wind speed of 7-8 m/s. In such cases acquisition of background noise data at wind speeds up to 12 m/s is not considered necessary. Also, on some UK sites the occurrence of standardised wind speeds above 7-8 m/s is relatively unusual and acquisition of data at higher wind speeds might require an unnecessarily protracted survey period. Further, neither conventional anemometers nor remote sensing devices (LIDAR or SODAR) can measure wind speeds close to zero. In any event, it is not necessary to measure wind speeds significantly below the cut-in speed of wind turbines (generally 2-4 m/s at hub height).



- 2.9.3 Therefore the recommended minimum wind speed range (10 m standardised) for background noise surveys is:
  - For pitch-regulated turbines: between cut-in wind speed and the wind speed corresponding to its maximum sound power level.
  - For stall-regulated turbines: between cut-in wind speed and 12 m/s.
- 2.9.4 The recommended approach to deriving noise limits for wind speeds outside the range of available background noise data is addressed in Section 3.

#### Required size of data set

- 2.9.5 As a guideline, the survey should be of sufficient duration to acquire no fewer than 200 valid data points for each of the amenity hours and night periods in the wind speed range required and no fewer than 5 valid data points in any 1 m/s wind speed 'bin' within this range. These guidelines are not prescriptive: more data points may be required if the data shows large scatter; fewer may be sufficient if data points are tightly grouped. Further information on this can be found in **Supplementary Guidance Note 3**.
- 2.9.6 The other factor influencing survey duration is the effect of wind direction. At some locations background noise levels are strongly dependent on wind direction. Section 3 discusses specific situations in which these circumstances may be applicable. Where it is considered likely to be appropriate to 'directionally filter' the background noise data for wind direction, a data set comprising no fewer than 100 data points and 3 data points in any wind speed bin, in each of the amenity hours and night-time assessment periods, may be adequate.

#### SB12:

The survey duration is determined entirely by the requirement to collect sufficient valid data over an adequate range of wind speeds. For pitch-regulated turbines, data should cover the range of wind speeds between cut-in and the speed at which maximum sound power level is achieved.

As a guideline, no fewer than 200 valid data points should be recorded in each of the amenity hours and night time periods, with no fewer than 5 valid data points in any 1 m/s wind speed bin. In specific cases (described in Section 3) where background noise levels are dependent on wind direction and data is to be 'filtered' into two or more datasets then a minimum of 100 valid data points and 3 valid data points per 1 m/s bin in each data set may be adequate.

These guidelines are not prescriptive: more data points may be required if the data shows large scatter; fewer may be sufficient if data points are tightly grouped.

#### 3 Data Analysis & Noise Limit Derivation

#### 3.1 Analysis of Background Noise Data

- 3.1.1 The purpose of data analysis is to provide a representative background noise level across a range of wind speeds for the Amenity and Night-time Hours and thereby help define appropriate noise limits for a proposed wind energy development.
- 3.1.2 To obtain a typical representation of the existing noise environment, analysis of the collected data should minimise the influence of atypical noise sources for a representative measurement location (or other locations for which a proxy is being applied) during the period of noise measurement.

#### Temporal Filtering

3.1.3 ETSU-R-97 requires the filtering of noise, wind and rain data for the Amenity Hours and Night-time Hours.

SB13:Amenity Hours are defined as:18:00 - 23:00 hrs Monday - Sunday;13:00 - 18:00 Saturday and 07.00 to 18.00 Sunday(All times are local)

Data Filtering

3.1.4 ETSU-R-97 proposes that measured L<sub>A90,10 minute</sub> noise levels and average 10 minute wind speed data pairs are plotted on a scatter plot. To minimise the influence of atypical noise sources, filtering the data is likely to

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be required. Reviewing the time histories of noise and wind data for the survey period will also assist in atypical noise identification.

- 3.1.5 Despite careful selection of measurement locations, it should be expected that noise sources which are not typical of the environment can occur during the survey. Such sources may be unidentified boiler flue noise, fish pond pumps, bore-hole water pumps, water features, idling engines, etc. The use of the L<sub>A90</sub> index will minimise the influence of transient noise sources which could raise the measured noise levels, e.g.. low flying military jets, bird scarers.
- 3.1.6 When a measurement location is used to represent locations at which measurements are not undertaken, then removal of site-specific noise sources should be undertaken. See **Supplementary Guidance Note 2** for more detail.

**SB14:** The presence of noise sources which are not common to the representative measurement locations and neighbouring noise sensitive properties should be removed from the data, using a review of time histories and scatter plots.

3.1.7 The dawn chorus (marked increase in noise due to birds which can occur at sunrise) has been found to be a significant source of noise for some measurement locations. If present, it is apparent in time histories of the measured levels. It is related to sunrise which will vary for time of year and location. Therefore consideration needs to be given to when this may occur for the noise survey data under analysis, and removed where appropriate.

**SB15:** Where appropriate, clear dawn chorus effects should be removed from night-time data.

Rainfall

- 3.1.8 Data collected during periods of rainfall are required to be removed from the data. ETSU-R-97 states the following with respect to rainfall: "Measurements should not be used for periods of heavy rainfall when noise levels will be high due to the noise of rain itself, and more important, due to the increased water flow in nearby streams and rivers".
- 3.1.9 Tipping bucket rain gauges tip when the bucket has become full. This filling of the bucket can take more than a single ten minute period. Therefore, it is considered that at least the 10 minute period which contains the registered bucket tip and the preceding 10 minute period should be excluded.
- 3.1.10 Rain gauges with greater sensitivity may only require the period when a drip is detected to define when the sample period should be rejected.
- 3.1.11 The influence of rain-induced noise upon a measurement location should also be considered. Noise from streams which dominate the noise environment at a measurement location can vary in level by 20 30 dB L<sub>A90</sub> depending upon whether the stream is in flood or drought conditions.
- 3.1.12 Care should be taken when assessing such situations to provide a noise environment which is representative of the location. Periods of drought are to be considered atypical in a similar manner to periods of flood. During meteorological drought periods, i.e. in the UK normally defined as at least 15 consecutive days or more where there is less than 0.2 mm (0.008 inches) of rainfall, noise levels associated with streams may be minimised. However, this may not be representative of typical conditions for some areas of the Country, e.g.. Wales, Western Scotland and Cumbria.
- 3.1.13 Reasonable efforts should be made to avoid periods of atypical rainfall: in most stream-affected areas, this would be satisfied by including, during, or immediately before the measurement, a period of 5 days or more without significant rainfall. Periods of elevated stream noise levels following heavy rainfall should be excluded to derive more representative levels. Noise from larger rivers and water courses will tend to be less affected by past levels of rainfall, and may be consistent and therefore typical of specific noise environments.
- 3.1.14 Rainfall may also affect noise generated by traffic passing along wet roads. In these circumstances, it may be appropriate to remove data following rain periods for up to an hour or more after the last registered rainfall period for locations where traffic noise is the dominant noise source.

**SB16:** Exclude any data directly affected by rainfall, or when rainfall has resulted in atypical levels.



#### Traffic Noise

- 3.1.15 Locations where traffic noise is dominant may show little or no relationship between wind speed and noise level. In such circumstances, a single fixed level across the wind speed range would be considered appropriate.
- 3.1.16 Rush hour traffic noise that occurs for a measurement location all year round should be considered within the data to be analysed, as recommended in ETSU-R-97. However, such a noise source may significantly influence the derived night-time background noise level. The assessment should consider whether this is representative of the "typical situation". If, for example, the rush hour varies significantly from day to day, such as occurs close to ferry ports in relation to their schedule, then some consideration should always be given as to whether inclusion of such data is appropriate. If the rush hour traffic is not considered to be typical, then it should be excluded.

**SB17:** ETSU-R-97 allows the inclusion of rush hour traffic in the night period where it is a significant feature in the noise environment. If this does not routinely occur, it should be removed.

Derivation of Wind Speed & Background Noise Plots

- 3.1.17 ETSU-R-97 states that noise levels should be plotted against wind speed to determine the prevailing background noise levels at a measurement position. However, there is no indication in ETSU-R-97, when determining the prevailing background noise levels through regression analysis, whether a linear fit or a polynomial best fit line should be adopted.
- 3.1.18 The degree of correlation between measured noise level and wind speed on site is not an indication of the appropriateness of the noise survey data. Locations that are dominated by wind induced noise in rural landscapes should be expected to have a greater degree of correlation than locations where noise is not associated with wind effects, i.e. developed areas or generally noisy areas. However, a lack of relationship between noise and wind speed does not invalidate the noise survey but is indicative of a noise environment which is not wind induced.
- 3.1.19 Unless there is a specific noise source which requires consideration through linear regression analysis (heavy traffic noise may be an example), a polynomial fit will be most appropriate. In many cases third order polynomials should provide sufficient information to allow a reasonable representation of the prevailing background noise levels during the survey period.. Higher or lower order polynomials (up to fourth order) may be appropriate depending upon the nature of the noise environment. The equation of the regression polynomial used should be provided in the assessment (showing coefficients to 4 significant figures). See **Supplementary Guidance Note 2** for some examples.

**SB18:** ETSU-R-97 states that noise levels should be plotted against wind speed to determine the prevailing background noise levels at a measurement position. The order of regression analysis to use (linear to fourth order) will depend upon the nature of the noise environment.

Potential Consequences of Limited Data Range

- 3.1.20 The derived prevailing background noise polynomial curve should not be extended beyond the range covered by adequate data points. Where a noise limit is required at higher wind speeds; it should be restricted to the highest derived point.
- 3.1.21 A similar correction to the curve should be undertaken for the prevailing background noise polynomial curve for low wind speed conditions, i.e. the lowest derived background noise level is adopted for all wind speeds below where this derived minimum occurs. Both of these considerations are illustrated in Figure 3.

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Figure 3: An example of limiting lower and upper prevailing background noise levels

#### The Need for Directional Analysis

- 3.1.22 ETSU-R-97 refers to directional analysis when considering the issue for sheltered receptors located close to a proposed site and the need for special consideration of the wind condition that affords the property maximum shelter. The assumption is that during this wind condition the potential greatest noise impact may occur because background noise levels may be lower for this condition than for the wind direction averaged prevailing background noise level.
- 3.1.23 A similar situation can arise with wind direction and certain distant noise sources which are a significant contributor to the background noise environment. Such noise sources might include: large industrial sources (e.g. oil refinery), motorways, large conurbations and the sea. The propagation of noise is subject to the effects of the wind. The noise environment at a receptor location upwind of a noise source is generally quieter than the receptor noise environment downwind of the noise source. Therefore, the background noise environment can change due to wind direction in the presence of a distant noise source. In these circumstances, a change in wind direction between upwind and downwind of the dominant noise source could result in a 5 15 dB L<sub>A90</sub> difference in levels.
- 3.1.24 Therefore, there may be circumstances where consideration of wind direction when assessing the prevailing background noise level needs to be taken into account. This effect is illustrated in Figure 4. In the first scenario, the receiver is downwind of both the turbine and the nearby road, and no filtering is required. However, in the second scenario, the situation in which the receiver is upwind of the road could require filtering particularly when this corresponds to a prevailing wind direction, as the receiver would be systematically downwind of the turbines in the same wind conditions.

**SB19:** Directional analysis of prevailing background noise levels may be necessary in specific circumstances, where a wind farm is located upwind of a receptor but a significant contributor to the background noise environment is downwind of the receptor in the same wind conditions.



Figure 4: Illustration of upwind and downwind propagation in the presence of a key source



#### 3.2 Determining the ETSU-R-97 Limit

#### ETSU-R-97 Noise Limit

3.2.1 The complete noise limit for each property is obtained from a combination of the respective fixed limit and the derived relative limit (prevailing background curve + 5 dB).

#### Determining the Fixed Part of the Daytime Amenity Noise Limit

- 3.2.2 The day amenity noise limits have been set in ETSU-R-97 on the basis of protecting the amenity of residents whilst outside their dwellings in garden areas. The daytime amenity noise limits are formed in two parts: Part 1 is a simple relationship between the prevailing background noise level (with wind speed) with an allowance of +5 dB; Part 2 is a fixed limit during periods of quiet. ETSU-R-97 describes three criteria to consider when determining the fixed part of the limit in the range of 35 dB to 40 dB L<sub>A90</sub>, all of which should be considered. They are:
  - 1) the number of noise-affected properties;
  - 2) the potential impact on the power output of the wind farm; and
  - 3) the likely duration and level of exposure.
- 3.2.3 The rationale for a choice of this limit, or factors which would assist the determining authority in this respect should be set out in the assessment. It is beneficial to the decision maker to display both sets of limits to illustrate the range available and/or the noise limit for the development if agreed previously with the LPA.
- 3.2.4 Current practice on the three criteria is as follows:
  - The number of neighbouring properties will depend on the nature of the area, (rural, semi-rural, urban) and is sometimes considered in relation to the size of the scheme and study area. The predicted 35 dB L<sub>A90</sub> contour (at maximum noise output up to 12 m/s) can provide a guide to the dwellings to be considered in this respect.
  - 2. This is in practice mainly based on the relative generating capacity of the development, as larger schemes have relatively more planning merit (for noise) according to the description in ETSU-R-97. In cases when the amenity fixed limit has little or no impact on the generating capacity (i.e. noise is not a significant design constraint) then a reduced limit may be applied.
  - 3. This last test is more difficult to formulate. But ETSU-R-97 notes that the likely excess of turbine noise relative to background noise levels should be a relevant consideration. In rural areas, this will often be determined by the sheltering of the property relative to the wind farm site. Account can also be taken of the effects of wind directions (including prevailing ones at the site) and likely directional effects. For cumulative developments, in some cases the effective duration of exposure may increase because of cumulative effects.
- 3.2.5 It can be argued that assessing these factors do not represent an acoustic consideration but ultimately a planning consideration, and therefore are difficult for noise consultants to fully determine. However this is described as part of ETSU-R-97 and therefore represents a relevant consideration when determining applicable noise limits. Furthermore, it is necessary, as part of the EIA process to evaluate the noise impacts, which is arguably not fully possible without a complete determination of the ETSU-R-97 limits. Finally, consideration of cumulative noise impacts may require the determination of partial noise limits which may be difficult to obtain unless the amenity noise limit is precisely determined.
- 3.2.6 Other planning considerations, such as the identification in local planning policy of areas of preferred wind farm development, may also influence or determine the choice of the absolute fixed amenity noise limit.

#### Night-Time Noise Limit

- 3.2.7 ETSU-R-97 indicates that for the protection of sleep of occupants within buildings an external free-field level of 43 dB L<sub>A90</sub> is appropriate when background noise levels are low. When background noise levels are sufficiently high, then the noise limits are set to the prevailing background + 5 dB, in the same manner as that used for the Amenity Hours.
- 3.2.8 It is noted that ETSU-R-97 states (page 63) that: "Where the local authority and the developer are in agreement that the background noise levels do not vary significantly between the amenity periods and the night-time, then a single lower fixed limit of 35 40 dB(A) can be imposed based upon background noise levels taken during the amenity periods and the night analysed together."
- 3.2.9 There is no definition of what is considered significant in this context, but where the amenity and night-time derived background noise levels differ by the order of 3 dB or less, over the key wind speed range between



cut-in to when the turbines reaches their maximum level of noise emissions, it could then be appropriate to apply this clause of ETSU-R-97. An example is included in **Supplementary Guidance Note 2**.

#### Financially Involved Noise Limit

3.2.10 ETSU-R-97 considers it appropriate to allow a higher level of incident noise associated with turbine operation for properties with occupants that have an interest in the development, both as a higher fixed level (45 dB) and/or a higher level above the prevailing background noise level. It is considered that the occupants of a financially involved property should be direct beneficiaries to allow an increase to the fixed limit noise levels.

#### 4 Noise Predictions

#### 4.1 Introduction

- 4.1.1 ETSU-R-97 does not describe a method to predict the immission levels at the nearest residential properties resulting from the operation of the wind farm, but clearly, estimates of the likely noise impact at the nearest receptors are required in any planning situation, and this must be reliable and robust.
- 4.1.2 The general study of outdoor noise propagation has received extensive attention in the past, but there has also been additional research undertaken specifically on the subject of wind turbine noise propagation in recent years and since the publication of ETSU-R-97. An overall review of the subject is presented in Chapter 3 of the book "Wind Turbine Noise".
- 4.1.3 Several recent studies focused on the application of engineering methods to the prediction of noise from wind turbines. Wind turbines are elevated large sources, and calculations are often required at distances of 1 km or more, which may fall outside of the stated scope of well-recognised standards such as ISO 9613-2. The range of meteorological conditions which need to be considered are also more varied and significant than for many other applications. Therefore several relatively recent studies have involved detailed measurements using elevated loudspeaker sources or operational wind turbines: see Bullmore et al. 2009<sup>iv</sup>, Søndergaard / Plovsing 2009<sup>v</sup>, Evans and Cooper 2011<sup>vi</sup>.
- 4.1.4 The outcome of this research has demonstrated that the ISO 9613-2 standard in particular, which is widely used in the UK, can be applied to obtain realistic predictions of noise from on-shore wind turbines during worst case propagation conditions (i.e. sound speed gradients due to downwind conditions or temperature inversions), but only provided that the appropriate choice of input parameters and correction factors are made. In particular, the use of "soft-ground" factor should be avoided, and the full theoretical effects of terrain screening will usually not be achieved.
- 4.1.5 It should be recognised that the choices which are made in the calculation parameters adopted for the prediction calculation can have a significant bearing on the outcome results, and can lead to unrealistic estimates. In addition, as not all wind turbine sound power level data is defined in the same manner, care needs to be exercised before any calculations can be performed. The choices which are made in the calculation parameters adopted for the prediction calculation should be clearly outlined and detailed in any noise assessment so that they can be reviewed by any assessor.
- 4.1.6 Whilst some developments may already have a preferred turbine selection, most sites will not at this stage of the project, and it is therefore standard practice to consider a "candidate turbine" at the planning stage, which is representative of the range of turbines which may be installed at the site, to provide an appropriate estimate. The suitability of the final turbine model (post-consent) can be secured through the imposition of adequate planning conditions.

### 4.2 Turbine Source Noise Data

- 4.2.1 The testing of turbine source levels, in terms of overall dB(A) sound power, is defined in the international IEC 61400-11 standard.
- 4.2.2 Different types of emission data can be found in practice, subject to availability and confidentiality restrictions:
  - **Tested sound power data in accordance with IEC 61400-11.** Test reports should normally state the measurement uncertainty<sup>2</sup>  $\sigma$ , these being typically around 1 dB(A) although sometimes up to 2 dB(A). Test data may not however present results over the entire operating range of the turbine,

<sup>&</sup>lt;sup>2</sup> Determined in accordance with Annex D of the IEC 61400-11 standard. This annex notes that  $\sigma$  = 0.9 dB would be typical.



which may require some assumptions to be made. Some of the test data may also be derived from tests on superseded prototype units which have features such as tonality which would not be present in other units. In some cases, only test summaries are provided with no indication of test uncertainties.

- **Declared sound power values** are derived in accordance with the TS IEC 61400-14 technical specification. This procedure is based on considering the average of several individual IEC 61400-11 test results, with the addition of an expanded uncertainty factor. In practice, this is rarely directly available from manufacturers, but can be derived from several test reports (if available) using the method specified in TS IEC 61400-14.
- **Manufacturer warranted values** represent values which the manufacturer will guarantee not to be exceeded (sometimes subject to conditions). They are therefore often higher than "raw" tested values, and incorporate uncertainty margins comparable to typical measurement uncertainty; however this is not always the case and warranty conditions can sometimes indicate that uncertainties need to be added in the test procedure itself. This may vary from one document to the next for the same turbine. Warranted data should therefore be used with caution, but data is often more generally provided over a wider range of wind speeds than individual test reports. The presence or absence of a margin of uncertainty in the data can be established by comparing the warranty with available test reports (see below).
- **Manufacturer specification values** may also incorporate a margin of uncertainty in some cases, or in others be closer to average tested values, and the same note of caution applies.
- 4.2.3 A third edition of IEC 61400-11 has been approved to replace the current version of the standard. This will introduce several changes including in particular the use of hub height wind speed as a main reference, with the application of the standardisation at 10 m height obtained as a second step (possibly optional). It also includes an additional section which is applicable to smaller wind turbines, with an adapted test methodology.
- 4.2.4 RenewableUK (formerly BWEA) previously issued guidance in 2008 which described a sound power test procedure adapted to the characteristics of small turbines<sup>3</sup>, and which includes an allowance for measurement uncertainty. This is likely to be superseded by the specific procedure set out in the third edition of IEC 61400-11. It must equally be recognised that for many small turbine models, no such data may be available. Noise emission data measured in accordance with older or less rigorous methods should be interpreted with care.
- 4.2.5 The source sound power levels determined according to IEC 61400-11 are provided in terms of L<sub>Aeq</sub>. To obtain the L<sub>A90</sub> parameter required by ETSU-R-97, it is necessary to apply a correction to the prediction results. Based on the experience of the IOA-NWG and recent research<sup>vii</sup>, the assumption described in ETSU-R-97 in this regard continues to remain valid. A correction of -2 dB is commonly applied.
- 4.2.6 IEC 61400-11 test reports provide spectral data which should be used as input to the predictions unless unavailable. As such spectra are usually only given for a limited number of wind speeds, the spectrum provided for a single, reference wind speed, can be scaled in relation to the overall A-weighted sound power at other wind speeds. If a range is available, the data should be chosen for the wind speed corresponding to the highest level of noise emissions; typically 8 m/s is used. Where available, specific tested spectra for each wind speed can be used.

### Tonality

4.2.7 It is highly unlikely that any specific information on tonality at representative receptor separation distances in accordance with the ETSU-R-97 methodology will be available at the planning application stage. When such information is available, it should be appropriately applied. It is standard to control the potential presence of tones in practice through the use of suitable planning conditions.

### 4.3 Noise Propagation Model and Input Parameters

4.3.1 Noise propagation prediction is the process of calculating the noise (immission) levels at the nearest receptors, which takes into account the sound power of the turbines, the distances between the turbines and the receptors, and the various propagation factors that influence the spread of sound, such as ground effects and air absorption.

<sup>&</sup>lt;sup>3</sup> Small turbines are defined as having a rotor swept area of 200 m<sup>2</sup> or less. In a horizontal-axis wind turbine this equates to a rotor diameter of approximately 16 m.



- 4.3.2 The following applies to predictions for the assessment of on-shore wind turbine noise. They are relevant to the application of the (widely-used) ISO 9613-2 standard. The guidance provided below does not cover long-distance propagation over sea such as will be relevant to off-shore wind farms (which are considered in **Supplementary Guidance Note 6**).
- 4.3.3 Equation (9) of the ISO 9613-2 standard should be used to calculate ground effects for different octave bands, based on the turbine emission spectra. In the absence of representative spectral data, instead of applying equation (10) of the standard, a conservative calculation should be made using Agr = -3 dB (effectively hard ground), and the air absorption rate corresponding to the 250 Hz octave band.
- 4.3.4 A soft ground factor (G=1.0) should not be used. Although a ground factor<sup>4</sup> of G=0.0 is commonly used, as it will tend to provide robust predictions in most situations, this can over predict noise levels. For consistency it is recommended to use a ground factor of G=0.5.
- 4.3.5 If the majority of the propagation between source and receiver occurs over paved ground (such as may occur in urban environments) or over large bodies of water such as wide rivers or lakes, the use of G=0.0 is advised.
- 4.3.6 When using G=0.5, sound power levels (see 4.2 above) should incorporate an allowance for measurement uncertainty. The following sets out data types which can be used, with guidance for accounting for uncertainties in turbine emission data. Examples are shown in **Supplementary Guidance Note 3**.
  - **Declared sound power** (in accordance with TS IEC 61400-14, on the basis of two or more tests): this can be used directly.
  - Warranted or specified manufacturer data can be used provided that a margin to account for uncertainty has been included. This is more likely the case for warranted data than for specifications. If not, a correction factor to allow for uncertainty needs to be added to the values provided, and this should clearly be explained in the assessment. The presence of such an uncertainty margin can be established through comparison with at least one measurement report.
    - When comparing warranted/specified data with results of a representative test report, obtained in accordance with the IEC 61400-11 standard, with a reported test uncertainty σ, a margin of 1.645 σ (between 1 and 2 dB(A)) between the tested and stated values over the majority of wind speeds represents a clear indication that suitable uncertainties have been incorporated.
    - If the document prescribes a value of uncertainty or a correction factor applicable to the data then this can be added to the values stated, unless the above test is already satisfied;
    - If no data on uncertainty or test reports are available for the turbine then a factor of +2 dB should be added.
  - Tested sound power: in the absence of the above, the results of a test made in accordance with the IEC 61400-11 standard, including a reported test uncertainty σ, can be referenced. The reported sound power with the addition of a margin equal to 1.645 σ can be used<sup>5</sup>. In the absence of test uncertainty being stated in the report, then 2 dB should be added<sup>6</sup>.
- 4.3.7 Although such source information is subject to change, as noted above, predictions are indicative and usually based on a candidate model. The source of the data used should be clearly set out with a statement on how robust it is considered to be. Any reduced mode operation for the turbines (if used) should be clearly explained.
- 4.3.8 The adoption of a receiver height of 4.0 m is recommended (regardless of time of day), as it has the effect of reducing the potential over-sensitivity of the calculation to the receiver region ground factor compared to lower receiver heights. Atmospheric conditions of 10°C and 70% humidity are recommended to represent a reasonably low level of air absorption. Calculations should be made at points representative of the relevant outdoor amenity area (as defined in ETSU-R-97) at locations nearest to the proposed wind farm development;

<sup>&</sup>lt;sup>4</sup> Used as input to the formulae of Table 3 of ISO 9613-2.

<sup>&</sup>lt;sup>5</sup> The factor of 1.645 applied to the uncertainty  $\sigma$  reflects a wider confidence interval, which is used in TS IEC 61400-14 albeit in a different context.

<sup>&</sup>lt;sup>6</sup> For a typical value of  $\sigma$  = 0.9 dB then 1.645  $\sigma$  = 1.5 dB, therefore 2 dB will represent a reasonable assumption in the absence of specific data.



4.3.9 A further correction of +3 dB (or +1.5 dB if using G=0.0) should be added to the calculated overall A-weighted noise level for propagation "across a valley", i.e. a concave ground profile, or where the ground falls away significantly, between the turbine and the receiver location. The following criterion<sup>viii</sup> of application is recommended:

$$h_m \ge 1.5 x (abs (h_s - h_r) / 2)$$

where  $h_m$  is the mean height above the ground of the direct line of sight from the receiver to the source (as defined in ISO 9613-2, Figure 3), and  $h_s$  and  $h_r$  are the heights above local ground level of the source and receiver respectively. This may be calculated using standard topographic data with a resolution of 50 m or less. Care needs to be exercised when evaluating this condition, as small changes in distance and height may trigger (or not) the criterion when the actual situation has not changed significantly. Examination of ground profiles between sources and receivers can assist in determining its application.

4.3.10 This increase can be explained by the reduced ground effect and the potential for additional reflection paths that may exist (as illustrated in Figure 5), and is supported by recent studies<sup>vi</sup>.



# Figure 5: Schematic diagram of multiple reflection paths for sound propagation across concave ground

4.3.11 Topographic screening effects of the terrain (ISO 9613-2, Equation 12) should be limited to a reduction of no more than 2 dB, and then only if there is no direct line of sight between the highest point on the turbine rotor and the receiver location. If significant screening from a landform barrier is present in close proximity to the receiver, higher barrier attenuation values of up to -10 dB(A) may be appropriate, but any such cases are uncommon and should be fully justified in the assessment.

#### SB20:

Whilst it is acknowledged that some of the source documents for sound power levels may be confidential, numerical values of the source data should be clearly set out in any assessment and it is good practice to reference the data sources used.

 $L_{\mbox{\scriptsize A90}}$  levels should be determined from calculated  $L_{\mbox{\scriptsize Aeq}}$  levels by subtraction of 2 dB.

Predictions should be based on octave band frequency data whenever available.

Current good practice is that tonal issues for wind farms are generally best dealt with through a suitable planning condition.

When applying the ISO 9613-2 standard:

- Equation 9 of the standard should be used to calculate ground effects; if no representative spectral data can be obtained, Agr = -3 dB should be used and the air absorption rate corresponding to the 250 Hz octave band;
- A ground factor of G=1 should not be used;

With the exception of propagation over large bodies of water or in urban areas, it is recommended to use a ground factor of G=0.5, in combination with emission levels which include a margin of uncertainty;

The input data used should be clearly set out with reference to its source, and a statement on how robust it is considered to be;

Any assumed reduced mode operation for the turbines should be clearly set out;

A receiver height of 4.0 m, and atmospheric conditions of 10°C and 70% humidity should be used. Topographic screening effects of the terrain (ISO 9613-2, Equation 12) should be limited to a reduction of no more than 2 dB, and then only if there is no direct line of sight between the highest point on the turbine rotor and the receiver location.

A further correction of +3 dB should be added to the calculated overall A-weighted noise level for propagation across a concave ground profile.

#### 4.4 **Propagation Directivity**

4.4.1 Predictions made using the ISO 9613-2 standard relate to "worst-case" conditions (typically downwind propagation from source to receiver and/or downward refraction under temperature inversions). When considering cumulative noise impacts, the effects of propagation in different wind directions can be considered. Any such direction attenuation factors, if used, should be clearly stated in any assessment.

#### A GOOD PRACTICE GUIDE TO THE APPLICATION OF ETSU-R-97 FOR THE ASSESSMENT AND RATING OF WIND TURBINE NOISE



- 4.4.2 Based on evidence from the Joule project<sup>viii</sup> in conjunction with advice in BS 8233 and ISO 9613-2, current practice suggests that for a range of headings from directly downwind (0°) up to 10 degrees from crosswind (80°), there may be little to no reduction in noise levels; once in crosswind directions (90°) then the reduction may be around 2 dB(A); and when at sufficient distance upwind the reduction would be at least 10 dB(A). For intermediate directions between crosswind to upwind, a simple linear or polynomial interpolation can be used. Such reductions (due to "shadow zone" refraction effects) will in practice only progressively come into play at distances of between 5 and 10 turbine tip heights.
- 4.4.3 Reference can also be made to the work undertaken for NASA described by Shepherd and Hubbard<sup>ix</sup> and in the Wyle Report<sup>x</sup>. Examples of the resulting propagation directivities are shown in Figure 6a for flat landscapes, and in Figure 6b for complex landscapes.



Figure 6: Example of assumed relationship of the change of noise levels with wind direction, 180° is where the receptor is downwind of the turbine and 0° where the receptor is upwind of the turbine. a) Flat Landscapes b) Complex Landscapes. Black = <5.25 Tip Height; Green = 7.5 Tip Height; Blue = 11 Tip Height; Red = 18 Tip Height



#### 4.5 Wind Shear Corrections

- 4.5.1 Basing the predictions on sound power data tested in accordance with the IEC 61400-11 standard (or equivalent) should mean that the wind reference used corresponds to hub height wind speeds, standardised to 10 m height using a fixed correction (see **Annex A**). These predictions can then be compared to background levels and/or associated noise limits derived using an equivalent wind speed reference, which will have wind shear taken into account directly.
- 4.5.2 When this is not the case, for example when considering background data measured against direct wind speed measurements at 10 m height, it is necessary to apply corrections to account for this. Any such corrections should be clearly outlined and detailed in any noise assessment so that they can be reviewed by any assessor. The assessment should be made using the most detailed information available.
- 4.5.3 Examples of methods which can be used to correct predictions to account for wind shear effects, when only using a 10 m mast, are included in **Supplementary Guidance Note 4** (wind shear). This note presents methods to calculate corrections on the basis of long-term data measured at different heights, but as such data may not be available for a specific site, typical shear values are also presented. Alternatively, similarly derived corrections representing typical (average) shear values can be applied to the wind speed reference used for the derived typical background noise levels.
- 4.5.4 The following simplified method is proposed for ease of use: applying a fixed correction by subtracting the following factors from the wind speed reference used in the turbine predictions: 1 m/s for turbine hub heights of up to 30 m, 2 m/s for hub heights of up to 60 m and 3 m/s for hub heights of more than 60 m. Such a generic approach would be suitable in the context of a study made using a 10 m mast to limit costs, in the absence of site-specific data.
- 4.5.5 If it can be demonstrated that the predicted levels are below the applicable lower fixed limits regardless of wind speed, it can be seen that wind shear would not have an effect on the assessment and this may form the basis of a suitable planning condition.

#### 5 Cumulative Issues

#### 5.1 Cumulative Noise Assessment Principles

- 5.1.1 ETSU-R-97 states at page 58, "...absolute noise limits and margins above background should relate to the cumulative effect of all wind turbines in the area which contribute to the noise received at the properties in question..."
- 5.1.2 The HMP Report<sup>i</sup> states that "If an existing wind farm has permission to generate noise levels up to ETSU-R-97 limits, planning permission noise limits set at any future neighbouring wind farm would have to be at least 10 dB lower than the limits set for the existing wind farm to ensure there is no potential for cumulative noise impacts to breach ETSU-R-97 limits (except in such cases where a higher fixed limit could be justified)". Such an approach could prevent any further wind farm development in the locality, and a more detailed analysis can be undertaken on a case by case basis.
- 5.1.3 As with the assessment of noise for all wind farm developments, sequential steps need to be taken, but such steps require more detailed attention due to the added complexity of cumulative noise impacts. The advice of the EHO could be invaluable to this part of the assessment.

#### Cumulative impact assessment necessary

- 5.1.4 During scoping of a new wind farm development consideration should be given to cumulative noise impacts from any other wind farms in the locality. If the proposed wind farm produces noise levels within 10 dB of any existing wind farm/s at the same receptor location, then a cumulative noise impact assessment is necessary.
- 5.1.5 Equally, in such cases where noise from the proposed wind farm is predicted to be 10 dB greater than that from the existing wind farm (but compliant with ETSU-R-97 in its own right), then a cumulative noise impact assessment would not be necessary.



## 5.2 Acquisition of Background Noise and Concurrent Wind Speed Measurements

- 5.2.1 In the case of wind farms that may have cumulative effects, further aspects need to be considered in establishing appropriate background noise levels.
- 5.2.2 Where a new wind farm is proposed and a receptor is also within the area acoustically affected by an already operational wind farm, then noise from the existing wind farm must not be allowed to influence the background noise measurements for the proposed development.
- 5.2.3 In the presence of an existing wind farm, suitable background noise levels can be derived by one of the following methods:
  - switching off the existing wind farm during the background noise level survey (with associated significant cost implications);
  - accounting for the contribution of the existing wind farm in the measurement data e.g. directional filtering (only including background data when it is not influenced by the existing turbines e.g. upwind of the receptor, but mindful of other extraneous noise sources e.g. motorways) or subtracting a prediction of noise from the existing wind farm from the measured noise levels;
  - utilising an agreed proxy location removed from the area acoustically affected by the existing wind farm/s; or
  - utilising background noise level data as presented within the Environmental Statement/s for the original wind farm/s (the suitability of the background noise level data should be established).
- 5.2.4 If the developer wishes to utilise previously presented background noise level data, care should also be taken with respect to any differences in wind speed conditions between the original and proposed site. The underlying principle of ETSU-R-97 requires that the background noise levels at any given location must be correlated with the wind speeds measured on the wind farm site of interest. Where a systematic difference exists between the wind conditions on the two sites, then a correction will need to be applied, meaning that the derived background noise curves for the two sites will be different.

#### 5.3 Derivation of the Appropriate Amenity Lower Fixed Limits

- 5.3.1 A decision on the amenity lower fixed limit for the proposed wind farm cumulatively with any other wind farms in the locality should be agreed. Cumulatively, the power generation will have increased due to proposed additional wind turbines, as well as potential noise impact. It is suggested that the various wind farms be considered as a single entity in the setting of the amenity lower fixed limit for the cumulative noise impact. The amenity lower fixed limit for the existing individual wind farms would remain as granted.
- 5.3.2 The consideration of the various wind farms as a single entity may result in the cumulative amenity lower fixed limit relating to the proposed wind farm in combination with the existing wind farms, differing from the existing individual wind farm's amenity lower fixed limit. However, the proposed wind farm's individual amenity lower fixed limit (which most likely will form the basis of the noise conditions) should still be determined on an individual basis.

#### 5.4 Derivation of the Relative Noise Limits

5.4.1 In setting appropriate noise limits, the most frequent scenarios are discussed.

#### **Concurrent applications**

5.4.2 Concurrent applications with no pre-existing wind farms permit the apportionment of the ETSU-R-97 limits on an energy basis to each wind farm from the outset. LPAs may wish to bring together concurrent wind farm applicants, such that apportionment can be discussed and agreed in conjunction with the applicants. Noise limits for all the wind farms operating cumulatively are derived at all noise sensitive receptors, just as they would be if one wind farm were being considered. Having derived noise limits for the cumulative effects of all the contributing wind farms, the wind farm developers can then work together to 'apportion' the noise limits for each wind farm operating in isolation such that the cumulative effects of all wind farms operating together cannot cause the cumulative noise limits derived in accordance with ETSU-R-97 to be exceeded. Thus the noise limits which meet with the requirements of ETSU-R-97 could only be exceeded if one or more of the wind farms were to operate above its own apportioned noise limits. This is illustrated in Figure 7.





Figure 7: Apportionment of ETSU-R-97 limits between two wind farms

5.4.3 Examples of the apportionment of concurrent applications in practice are included within Appeal ref: GDBC/001/00245C Middlemoor, North Charlton, Alnwick, Northumberland and Appeal ref: APP/J0540/A/08/2083801 Land at Nutsgrove Farm, Scolding Drive, Thorney.

#### Existing wind farm/s consented with less than total ETSU-R-97 limits

- 5.4.4 If an existing wind farm is consented to noise limits of less than the total ETSU-R-97 limits, a future wind farm applicant can then use these limits as a base within their predictions. Whether the existing wind farm is currently operating or not is immaterial to the assessment, as it will not be able to exceed its own conditions. It is becoming more common to apply noise limits which are less than total ETSU-R-97 limits because of cumulative considerations.
- 5.4.5 This should be undertaken in consultation with the LPA and relevant applicant(s). An example of this in practice is the apportionment of the ETSU-R-97 noise limit between concurrent applications. It may be the case that conditioning the scheme to the exact predicted noise levels (at all wind speeds) for the candidate turbine presented within the submitted noise impact assessment may constrain the applicant in future turbine procurement options. Therefore, a constant margin above the predicted noise levels (or below the total ETSU-R-97 limits) could be chosen which provides the applicant with procurement options but in combination with the neighbouring wind farm/s can still achieve the ETSU-R-97 limits.

Existing wind farm/s, consented to the total ETSU-R-97 limits, currently operating

- 5.4.6 In the first instance, the consented noise limits should be used within the cumulative noise impact calculations unless otherwise agreed with the local authority. Provided the sum of the noise limits derived for the proposed site when added to those already consented for the operational sites does not exceed the limits that would otherwise be within the requirements of ETSU-R-97 for the cumulative impact, then the noise limits derived for the proposed site can be applied directly. However, if the sum of the noise limits for all the sites exceeds those within the requirements of ETSU-R-97, then further consideration and a more detailed review of the existing noise impact will be necessary. It may be the case that the existing wind farm is not utilising the total ETSU-R-97 limits, and hence headroom might be present. Undertaking measurements of the actual noise levels emanating from the existing wind farm would provide direct evidence of any potential headroom; however this would require both consent and information from the existing wind farm operator, as well as direct access to specific residential locations, which is rarely available.
- 5.4.7 If consent is not forthcoming from the existing wind farm operator to measure the noise impact from the existing wind farm, then the second wind farm developer is left with no option but to predict the noise impact from the existing wind farm. However, as the existing wind farm operator has the right to produce noise to their consented total ETSU-R-97 limits, even if it can be demonstrated that headroom currently exists, it may not be the case that that headroom will be present indefinitely.



5.4.8 For the development to proceed, the presented 'headroom' needs to be maintained (permitted other mitigating factors such as critical controlling properties or significant separation distance, described below, are not relevant); this could be achieved via the 'cumulative conditioning' or 'negotiation' methods described in Section 5.7. There is however limited experience of either approach being applied in practice.

### "Controlling" property

- 5.4.9 It may be the case that for the existing wind farm to operate to the total ETSU-R-97 noise limits at a key cumulative receptor it would have to breach the noise limit at another receptor (i.e. a receptor closer to the existing wind farm than the key cumulative receptor). Consideration could then be given to the available 'headroom' at the key cumulative receptor such a scenario permits.
- 5.4.10 This is illustrated in Figure 8. In this example, wind farm A is conditioned to the same noise limit at properties R2 and R3; however, it could not produce noise levels equal to the limit at property R2 without breaching this limit at property R3 which is closer. Therefore lower immission levels can be assumed at R2 than at R3, and there may be sufficient headroom for wind farm B to use.

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Figure 8: Controlling Property example

#### Significant presented headroom

5.4.11 In cases where there is significant headroom (e.g. 5 to 10 dB) between the predicted noise levels from the existing wind farm and the total ETSU-R-97 limits, where there would be no realistic prospect of the existing wind farm producing noise levels up to the total ETSU-R-97 limits, agreement could be sought with the LPA as to a suitable predicted noise level (including an appropriate margin to cover factors such as potential increases in noise) from the existing wind farm to be used to inform the available headroom for the cumulative assessment without the need for negotiation or cumulative conditioning. This may be the case particularly at low wind speeds.

Permitted wind farm, consented to total ETSU-R-97 limits, but not yet constructed

5.4.12 This situation replicates the above, in that the second wind farm developer will have to predict the noise impact from the existing wind farm. To ensure that predictions are as accurate as possible the existing wind farm developer would have had to have chosen their wind turbine to be installed. If the existing wind farm developer had yet to choose their wind turbine, it is recommended that a worst case scenario be undertaken utilising the highest sound power level data (or a combined "envelope") for wind turbines that would fit within the dimensional confines and noise limits of the permission granted.

### 5.5 Comparison of Cumulative Noise Impacts with Derived Noise Limits

- 5.5.1 If suitable predictions are used as a basis for the assessment, it should be borne in mind that in many situations receptors will not be downwind of different wind farms simultaneously and consideration of wind directional effects can be included within cumulative noise impact predictions to present more realistic impacts.
- 5.5.2 Consideration should also be given to wind speed referencing within existing noise conditions when endeavouring to consider cumulative noise impact. A number of existing wind farm noise limits are governed by actual 10 m height wind speeds whilst other existing wind farms are governed by hub height wind speeds standardised to 10 m height. The amalgamation of these two separate limits is difficult and the onus is on the proposed wind farm developer to demonstrate that such reconciliation can be reasonably performed.

### 5.6 Wording and Validity of Planning Conditions

5.6.1 The wording of conditions will be reflective of the cumulative scenario presented. For 'concurrent applications' and 'existing wind farm consented to less than the total ETSU-R-97 limits', the conditions will be worded as per an individual wind farm, except that the noise limit will be the apportioned limit relevant to the individual scheme.



#### 5.7 Additional Means of Resolving Cumulative Noise Issues

5.7.1 Due to the legacy of conditioning wind farm developments to the total ETSU-R-97 limits, difficulties have arisen with regards to additional wind farm developments in the locality of existing wind farms. Some of the following suggestions have been considered or applied as a means of progressing developments.

#### Strategic planning

- 5.7.2 In considering individual applications, if the local planning authority was aware of other wind farm developments within the locality, a strategic approach to conditioning could be undertaken. Apportioned limits could be calculated for each wind farm that will ensure that cumulatively, ETSU-R-97 limits are not exceeded at any particular dwelling. LPAs could adopt local policies within their Development Plans to support the use of lower than the total ETSU-R-97 limits for strategic reasons. This would ensure that headroom would be maintained under the total ETSU-R-97 limits and hence any developers wishing to construct an additional wind farm in the locality would not necessarily need to negotiate with the original wind farm developer. This would require a review of current practice and could not be back dated to those wind farms that have already gained consent to the total ETSU-R-97 noise limits.
- 5.7.3 An example of such strategic planning can be found for Strategic Search Area A in Wales: Denbighshire County Council and Conwy County Borough Council examined the issues associated with the cumulative impact of wind farms within their relevant Strategic Search Area (Clocaenog Forest) contained within TAN 8<sup>7</sup>. A framework was developed to assess individual applications in the context of their cumulative effect.

#### Negotiation

5.7.4 Where an existing wind farm has the total ETSU-R-97 limits applied, but in reality the actual noise output from the existing wind farm is below the total ETSU-R-97 limits, the second wind farm developer may approach the existing wind farm operator to negotiate (e.g. through financial remuneration, become a partner in the existing wind farm etc.) a review of the original noise limits. Further to agreement, the existing wind farm operator would apply to get their original planning conditions amended, such that the noise limits would be reduced. Subsequently, the second wind farm developer would then be able to take advantage of the headroom under the total ETSU-R-97 limits, in progressing their particular wind farm development. However, there is limited experience of this happening in practice to date. In the case of an extension of an existing wind farm, the process is simplified in that the developer would simply have to apply to get the condition amended as opposed to having to negotiate with a competing operator.

#### Cumulative Conditioning

- 5.7.5 There may be scenarios where the existing wind farm operator cannot negotiate with subsequent wind farm developers, even though in reality the actual noise output from the existing wind farm is below the total ETSU-R-97 limits. In this situation, it has been suggested that a planning condition could be constructed that places cumulative impacts responsibilities on any subsequent wind farm developers, i.e. if noise levels from the existing wind farm increase (but are maintained within the existing wind farm's noise conditions) then noise levels from the second wind farm will have to reduce in compensation to ensure that cumulative noise limits are not breached. Such an approach places considerable risk on the second wind farm developer and to date the IOA-NWG is not aware of it being accepted in practice.
- 5.7.6 The cumulative conditioning approach was proposed in respect to the Rowantree Wind Farm, which required the Rowantree developer to not only meet individual noise limits but also cumulative noise limits in combination with the existing wind farm. The decision is due at the time of publication. However, it is recognised that the Planning Inspector with respect to the Brechfa Forest West Wind Farm determined that the construction of such a condition was 'not straightforward, with potential difficulties of enforceability' and 'is questionable whether such a requirement would meet the tests which are applicable to planning conditions'.

#### SB21:

Whenever a cumulative situation is encountered, the noise limits for an individual wind farm should be determined in such a way that no cumulative excess of the total ETSU-R-97 noise limit would occur.

<sup>&</sup>lt;sup>7</sup> Planning Policy Wales, Technical Advice Note 8: Planning for Renewable Energy, 2005



## 6 Reporting Results of the Noise Assessment

## 6.1 Reporting

6.1.1 Table 1 suggests key points which good practice suggests should be included in such assessments.

Consultations	Consultation with Local Planning Authority
	EHO input into selection of Background Noise Measurement Equipment
Background	Number of Monitoring Locations
Measurements	Map Showing Monitoring Locations; Description of Monitoring Locations
	Description of Noise Environment; Photos of Monitoring Locations
	Monitoring Period; Description of Noise Measurement Equipment Wind Shield;
	Certification / Calibration of all Equipment Used & any Calibration Drift ;
	Wind (speed and direction) & Rainfall Measurement Data Sources
	Clear Representation of Excluded Data In Time Histories or Scatter Plots;
	Chart Showing Distribution of Wind Speeds & Direction;
	Cumulative Issues in Background Measurements
Noise	Prediction Methodology: Candidate Turbine Model
Predictions	Turbine Source Noise Data (including noise-reduced modes if used)
	Turbine Source Octave Band Noise Levels
	Description of Noise Propagation/Attenuation Factors
	Atmospheric Attenuation - Assumed Temperature and Relative Humidity
	Ground Effects – Assumed Ground Factor
	Assumed Receiver Height; Barrier/Screening Attenuation
	Wind Direction Filtering (if considered); Noise Contours
Assessment	Wind Shear Assessment Method: Derivation of Prevailing Background Noise
	Type. Order and Coefficients of Regression Line
	Scatter Data Shown on Plots: Derivation of Noise Limits & Numerical Values
	Amenity Noise Limit; Justification for Amenity Noise Limit if Chosen
	Night-Time Noise Limit; Financially Involved Noise Limit
	Capping of Noise Limits at Highest Wind Speed Measured
	Comparison of Predicted Noise Level with Derived Noise Limits
	Correction from $L_{Aeg}$ to $L_{A90}$ ; Potential Tonal Content
	Properties Covered by Assessment
	Incorporated Mitigation (Turbines Running in Low Noise Mode) (if relevant)
	Cumulative Issues

 Table 1: Suggested key points for inclusion in a wind turbine noise assessment report

6.1.2 This list does not preclude other methods of presenting the data, as long as the data is available. For example, larger developments subject to EIA are submitted with a short summary chapter in the EIA, accompanied by a lengthy technical report in the Appendix.



## 7 Other Matters

#### 7.1 Planning Condition

- 7.1.1 All developers, consultants and decision making bodies will at some stage have to discuss appropriate planning conditions to be placed on the development if permission is granted. Typical conditions and agreements that existed up to 1996 were reviewed and reported in ETSU-R-97, but these have been developed, iterated and moved on with current practice.
- 7.1.2 This Guide cannot provide definitive guidance on this issue, not least because ultimately it will be for the legal process to verify if a planning condition is fit for purpose on a case by case basis. However, a sample planning condition is enclosed in **Annex B**.

#### 7.2 Amplitude Modulation

7.2.1 The evidence in relation to "Excess" or "Other" Amplitude Modulation (AM) is still developing. At the time of writing, current practice is not to assign a planning condition to deal with AM.

#### 7.3 Post Completion Measurements

7.3.1 Information on post completion measurements is contained in **Supplementary Guidance Note 5**.

#### 7.4 Supplementary Guidance Notes

7.4.1 More detailed information on topics covered within this guide can be found in the following separately published Supplementary Guidance Notes:

Number	Title	Information
1	Data Collection	Equipment specifications; measurement surveys: Practical considerations and set-up guidance and examples.
2	Data Processing & Derivation of ETSU-R-97 background curves	Data filtering, processing and regression analysis for different types of noise environments.
3	Sound Power Level Data	Manufacturer's data and warranties analysis.
4	Wind Shear	Wind speed references and long-term data analysis.
5	Post Completion measurements	Examples, considerations and strategies.
6	Offshore Wind	Noise propagation over large bodies of water.

 Table 2: Supplementary Guidance Notes



# ANNEX A

# **Glossary of Terms & Reference**



# Glossary of Terms

A-weighting	a filter that represents the frequency response of the human ear
Amenity Hours	ETSU-R-97 defines the amenity hours as 18.00 to 23.00 Monday to Friday, 13.00 to 23.00 on Saturdays and 07.00 to 23.00 on Sundays
Amplitude Modulation	a sound is modulated in amplitude when its level exhibits periodic fluctuations.
Attenuation	the reduction in level of a sound between the source and a receiver due to any combination of effects including: distance, atmospheric absorption, acoustic screening, the presence of a building façade, etc.
A.G.L.	abbreviation for above ground level
Background noise	the noise level rarely fallen below in any given location over any given time period, often classed according to day time, evening or night time periods
Bin	subset or group into which data can be sorted; in the case of wind speeds, bins are often centred on integer wind speeds with a width of 1 m/s. For example the 4 m/s bin would include all data with wind speeds of 3.5 to 4.5 m/s.
Dawn Chorus	noise due to birds which can occur at sunrise
dB	abbreviation for 'decibel'
dB(A)	abbreviation for the decibel level of a sound that has been A-weighted
Decibel	the unit normally employed to measure the magnitude of sound
Directivity	the property of a sound source that causes more sound to be radiated in one direction than another
Equivalent continuous sound pressure level	the steady sound level which has the same energy as a time varying sound signal when averaged over the same time interval, T, denoted by $L_{\mbox{Aeq},T}$
Environmental Health Officer	employee of the local planning authority responsible for noise and vibration matters in relation to statutory nuisance and advice on planning matters
Environmental Impact Assessment	an environmental impact assessment is an assessment of the possible positive or negative impact that a proposed project may have on the environment, submitted to support a planning application at the planning approval stage of a project
External noise level	the noise level, in decibels, measured outside a building
Filter	a device for separating components of an acoustic signal on the basis of their frequencies; <i>or</i> , the selection of data for exclusion or analysis.
Frequency	the number of acoustic pressure fluctuations per second occurring about the atmospheric mean pressure (related to the 'pitch' of a sound)
Frequency analysis	the analysis of a sound into its frequency components
Ground effects (G)	the modification of sound at a receiver location due to the interaction of the sound wave with the ground along its propagation path from source to receiver. Described using the term 'G', and ranges between 0 (hard) and 1 (soft).
Hard Ground	the ISO 9613-2 standard considers that for propagation over surfaces such as paving, water, ice, concrete, or tamped ground around industrial sites, the ground should be considered hard, as represented by the factor $G = 0.0$ .
Hertz	the unit normally employed to measure the frequency of a sound, equal to cycles per second of acoustic pressure fluctuations about the atmospheric mean pressure
L <sub>Aeq</sub>	the abbreviation of the A-weighted equivalent continuous sound pressure level
L <sub>A10</sub>	a noise level exceeded for 10% of the time during a measurement period, often used for the measurement of road traffic noise
L <sub>A90</sub>	a noise level exceeded for 90% of the time during a measurement period, often used for



	the measurement of background noise
Level	the general term used to describe a sound once it has been converted into decibels
Local Planning Authority	a local planning authority is the local authority or council that is empowered by law to exercise statutory town planning functions for a particular area
Masking	the effect whereby an otherwise audible sound is made inaudible by the presence of other sounds
Night Time Hours	ETSU-R-97 defines the night time hours as 23.00 to 07.00 every day.
Noise	sound that evokes a feeling of displeasure in the environment in which it is heard, and is therefore unwelcomed by the receiver
Noise emission	the noise emitted by a source of sound
Noise immission	the noise to which a receiver is exposed
Octave band frequency analysis	a frequency analysis using a filter that is an octave wide (the upper limit of the filter's frequency band is exactly twice that of its lower frequency limit)
Percentile exceeded sound level	the noise level exceeded for n% of the time over a given time period, T, denoted by $L_{\text{An},\text{T}}$
Receiver	a person or property exposed to the noise being considered
Residual noise	the ambient noise that remains in the absence of the specific noise whose effects are being assessed
Soft (or Porous) Ground	the ISO 9613-2 standard considers that for propagation over surfaces such as ground covered by grass or trees (or other vegetation), and farming land, the ground should be considered soft or porous as represented by the factor $G = 1.0$ .
Sound	physically: a regular and ordered oscillation of air molecules due to a source of vibration which creates fluctuating positive and negative acoustic pressure above and below atmospheric pressure. Subjectively: the sensation of hearing caused by the ear being excited by the acoustic oscillations described above
Sound level meter	an instrument for measuring sound pressure level
Sound pressure amplitude	the root mean square of the amplitude of the acoustic pressure fluctuations in a sound wave around the atmospheric mean pressure, usually measured in Pascals
Sound pressure level	a measure of the sound pressure at a point, in decibels
Sound power level	the total sound power radiated by a source, in decibels
Spectrum	a description of the amplitude of a sound as a function of frequency
Standardised wind speed	a wind speed measured at a height different than 10 m (generally measured at the turbine hub height) which is expressed to a reference height of 10 m using a roughness length of 0.05 for standardisation purpose (in accordance with the IEC 61400-11 standard)
Third-octave band frequency analysis	a frequency analysis using frequency bands one third of an octave wide
Threshold of hearing	the lowest amplitude sound capable of evoking the sensation of hearing in the average healthy human ear (0.00002 Pa, equivalent to 0 dB)
Tone	the concentration of acoustic energy into a very narrow frequency range
Wind shear	the increase of wind speed with height above the ground



Shear exponent	this uses the following equation:
profile:	$U = U_{ref} \cdot \left[\frac{H}{H_{ref}}\right]^m$
	Where:
	U calculated wind speed.
	U <sub>ref</sub> measured wind speed
	H height at which the wind speed will be calculated
	H <sub>ref</sub> height at which the wind speed is measured
	m <u>shear exponent</u> = $\log(U/U_{ref})/\log(H/H_{ref})$
Roughness length (or logarithmic) shear profile:	$U_{1} = U_{2} \cdot \frac{\ln\left(\frac{H_{1}}{z}\right)}{\ln\left(\frac{H_{2}}{z}\right)}$
	Where:
	$H_1$ The height of the wind speed to be calculated (10 m)
	H <sub>2</sub> The height of the measured wind speed
	U <sub>1</sub> The wind speed to be calculated
	U <sub>2</sub> The measured wind speed
	z The <u>roughness length</u>
	A roughness length of 0.05 m is used to standardise hub height wind speeds to 10m height in the IEC 61400-11:2003 standard, regardless of what the actual roughness length seen on a site may have been. This 'normalisation' procedure was adopted for comparability between test results for different turbines.

# REFERENCE

<sup>iv</sup> A. Bullmore, J. Adcock, M. Jiggins, M. Cand, Wind Farm Noise Predictions and Comparison with Measurements. Proc. Wind Turbine Noise 2009 Conference, Aalborg Denmark, June 2009.

<sup>v</sup> B. Søndergaard, B. Plovsing, Prediction of noise from wind farms with Nord2000, Part 1 and 2, Proc. Wind Turbine Noise 2009 Conference, Aalborg Denmark, June 2009.

<sup>vi</sup> T. Evans and J. Cooper, Comparison of predicted and measured wind farm noise levels and implications for assessments of new wind farms, Proceedings of ACOUSTICS 2011, 2-4 November 2011, Gold Coast, Australia (The Australian Acoustical Society).

<sup>vii</sup> T. Evans and J. Cooper, Comparison of compliance results obtained from the various wind farm standards used in Australia, Proceedings of ACOUSTICS 2011, 2-4 November 2011, Gold Coast, Australia (The Australian Acoustical Society).

<sup>ix</sup> Shepherd, K. P.; Hubbard, H. H. Wind Turbine Acoustics, NASA Technical Paper (TP) 3057, Dec 1990.

<sup>&</sup>lt;sup>i</sup> Hayes McKenzie Partnership Ltd. Report on "Analysis of How Noise Impacts are considered in the Determination of Wind Farm Planning Applications" Ref HM: 2293/R1 dated 6th April 2011

<sup>&</sup>lt;sup>ii</sup> "Noise Measurements in Windy Conditions", R.A. Davis & M.C. Lower, ISVR Consultancy Services. ETSU Report W/13/00386/REP (1996).

<sup>&</sup>lt;sup>iii</sup> Wind Turbine Noise, Dick Bowdler and Geoff Leventhall (Eds). Multi-Science Publishing Co Ltd (2011).

<sup>&</sup>lt;sup>viii</sup> JOR3-CT95-0091 'Development of a Wind farm Noise Propagation Prediction Model', Bass J H, Bullmore A J, Sloth E, Final Report for EU Contract JOR3 CT95 0051, 1998

<sup>&</sup>lt;sup>x</sup> Measurement and Evaluation of Environmental Noise From Wind Energy Conversion Systems in Alameda and Riverside Counties, Wyle Research Report WR 99-19,1988



# ANNEX B

# **Example Planning Condition**

N.B. the following is an example condition, with attached guidance notes, the form of which has been the basis for the control of noise for several larger-scale UK wind farm developments, for example at recent planning appeals. More concise conditions may be acceptable, particularly for smaller-scale developments, and it is recommended that legal advice is sought.

The condition below assumes noise limits were referenced to standardised 10 metres height wind speed (derived from hub height). If considering noise limits referenced to measured 10 metres height, the condition should be modified appropriately: see in particular the Tables and Guidance Note 1 (d).



## Example Planning Condition

The rating level of noise immissions from the combined effects of the wind turbines (including the application of any tonal penalty) when determined in accordance with the attached Guidance Notes (to this condition), shall not exceed the values for the relevant integer wind speed set out in, or derived from, the tables attached to these conditions at any dwelling which is lawfully existing or has planning permission at the date of this permission and:

- a) The wind farm operator shall continuously log power production, wind speed and wind direction, all in accordance with Guidance Note 1(d). These data shall be retained for a period of not less than 24 months. The wind farm operator shall provide this information in the format set out in Guidance Note 1(e) to the Local Planning Authority on its request, within 14 days of receipt in writing of such a request.
- b) No electricity shall be exported until the wind farm operator has submitted to the Local Planning Authority for written approval a list of proposed independent consultants who may undertake compliance measurements in accordance with this condition. Amendments to the list of approved consultants shall be made only with the prior written approval of the Local Planning Authority.
- c) Within 21 days from receipt of a written request from the Local Planning Authority following a complaint to it from an occupant of a dwelling alleging noise disturbance at that dwelling, the wind farm operator shall, at its expense, employ a consultant approved by the Local Planning Authority to assess the level of noise immissions from the wind farm at the complainant's property in accordance with the procedures described in the attached Guidance Notes. The written request from the Local Planning Authority shall set out at least the date, time and location that the complaint relates to and any identified atmospheric conditions, including wind direction, and include a statement as to whether, in the opinion of the Local Planning Authority, the noise giving rise to the complaint contains or is likely to contain a tonal component.
- d) The assessment of the rating level of noise immissions shall be undertaken in accordance with an assessment protocol that shall previously have been submitted to and approved in writing by the Local Planning Authority. The protocol shall include the proposed measurement location identified in accordance with the Guidance Notes where measurements for compliance checking purposes shall be undertaken, whether noise giving rise to the complaint contains or is likely to contain a tonal component, and also the range of meteorological and operational conditions (which shall include the range of wind speeds, wind directions, power generation and times of day) to determine the assessment of rating level of noise immissions. The proposed range of conditions shall be those which prevailed during times when the complainant alleges there was disturbance due to noise, having regard to the written request of the Local Planning Authority under paragraph (c), and such others as the independent consultant considers likely to result in a breach of the noise limits.
- e) Where a dwelling to which a complaint is related is not listed in the tables attached to these conditions, the wind farm operator shall submit to the Local Planning Authority for written approval proposed noise limits selected from those listed in the Tables to be adopted at the complainant's dwelling for compliance checking purposes. The proposed noise limits are to be those limits selected from the Tables specified for a listed location which the independent consultant considers as being likely to experience the most similar background noise environment to that experienced at the complainant's dwelling. The rating level of noise immissions resulting from the combined effects of the wind turbines when determined in accordance with the attached Guidance Notes shall not exceed the noise limits approved in writing by the Local Planning Authority for the complainant's dwelling.
- f) The wind farm operator shall provide to the Local Planning Authority the independent consultant's assessment of the rating level of noise immissions undertaken in accordance with the Guidance Notes within 2 months of the date of the written request of the Local Planning Authority for compliance measurements to be made under paragraph (c), unless the time limit is extended in writing by the Local Planning Authority. The assessment shall include all data collected for the purposes of undertaking the compliance measurements, such data to be provided in the format set out in Guidance Note 1(e) of the Guidance Notes. The instrumentation used to undertake the measurements shall be calibrated in accordance with Guidance Note 1(a) and certificates of calibration shall be submitted to the Local Planning Authority with the independent consultant's assessment of the rating level of noise immissions.
- g) Where a further assessment of the rating level of noise immissions from the wind farm is required pursuant to Guidance Note 4(c), the wind farm operator shall submit a copy of the further assessment



within 21 days of submission of the independent consultant's assessment pursuant to paragraph (d) above unless the time limit has been extended in writing by the Local Planning Authority.

# Table 1 – Between 07:00 and 23:00 – Noise limits expressed in dB $L_{A90,10 \text{ minute}}$ as a function of the standardised wind speed (m/s) at 10 metre height as determined within the site averaged over 10 minute periods.

Location	Standardised wind speed at 10 meter height (m/s) within the site averaged over 10-minute periods											
	1	2	3	4	5	6	7	8	9	10	11	12

# Table 2 – Between 23:00 and 07:00 – Noise limits expressed in dB $L_{A90}$ ,10-minute as a function of the standardised wind speed (m/s) at 10 metre height as determined within the site averaged over 10 minute periods.

Location	Standardised wind speed at 10 meter height (m/s) within the site averaged over 10-minute periods											
	1	2	3	4	5	6	7	8	9	10	11	12

# Table 3: Coordinate locations of the properties listed in Tables 1 and 2.

Property	Easting	Northing

Note to Table 3: The geographical coordinate references are provided for the purpose of identifying the general location of dwellings to which a given set of noise limits applies.



#### **Guidance Notes for Noise Conditions**

These notes are to be read with and form part of the noise condition. They further explain the condition and specify the methods to be employed in the assessment of complaints about noise immissions from the wind farm. The rating level at each integer wind speed is the arithmetic sum of the wind farm noise level as determined from the best-fit curve described in Guidance Note 2 of these Guidance Notes and any tonal penalty applied in accordance with Guidance Note 3. Reference to ETSU-R-97 refers to the publication entitled "The Assessment and Rating of Noise from Wind Farms" (1997) published by the Energy Technology Support Unit (ETSU) for the Department of Trade and Industry (DTI).

#### Guidance Note 1

(a) Values of the  $L_{A90,10 \text{ minute}}$  noise statistic should be measured at the complainant's property, using a sound level meter of EN 60651/BS EN 60804 Type 1, or BS EN 61672 Class 1 quality (or the equivalent UK adopted standard in force at the time of the measurements) set to measure using the fast time weighted response as specified in BS EN 60651/BS EN 60804 or BS EN 61672-1 (or the equivalent UK adopted standard in force at the time of the measurements). This should be calibrated in accordance with the procedure specified in BS 4142: 1997 (or the equivalent UK adopted standard in force at the time of the measurements). Measurements shall be undertaken in such a manner to enable a tonal penalty to be applied in accordance with Guidance Note 3.

(b) The microphone should be mounted at 1.2 – 1.5 metres above ground level, fitted with a two-layer windshield or suitable equivalent approved in writing by the Local Planning Authority, and placed outside the complainant's dwelling. Measurements should be made in "free field" conditions. To achieve this, the microphone should be placed at least 3.5 metres away from the building facade or any reflecting surface except the ground at the approved measurement location. In the event that the consent of the complainant for access to his or her property to undertake compliance measurements is withheld, the wind farm operator shall submit for the written approval of the Local Planning Authority details of the proposed alternative representative measurement location prior to the commencement of measurements and the measurements shall be undertaken at the approved alternative representative measurement location.

(c) The  $L_{A90,10 \text{ minute}}$  measurements should be synchronised with measurements of the 10-minute arithmetic mean wind and operational data logged in accordance with Guidance Note 1(d), including the power generation data from the turbine control systems of the wind farm.

(d) To enable compliance with the conditions to be evaluated, the wind farm operator shall continuously log arithmetic mean wind speed in metres per second and wind direction in degrees from north at hub height for each turbine and arithmetic mean power generated by each turbine, all in successive 10-minute periods. Unless an alternative procedure is previously agreed in writing with the Planning Authority, this hub height wind speed, averaged across all operating wind turbines, shall be used as the basis for the analysis. All 10 minute arithmetic average mean wind speed data measured at hub height shall be 'standardised' to a reference height of 10 metres as described in ETSU-R-97 at page 120 using a reference roughness length of 0.05 metres. It is this standardised 10 metre height wind speed data, which is correlated with the noise measurements determined as valid in accordance with Guidance Note 2, such correlation to be undertaken in the manner described in Guidance Note 2. All 10-minute periods shall commence on the hour and in 10-minute increments thereafter.

(e) Data provided to the Local Planning Authority in accordance with the noise condition shall be provided in comma separated values in electronic format.

(f) A data logging rain gauge shall be installed in the course of the assessment of the levels of noise immissions. The gauge shall record over successive 10-minute periods synchronised with the periods of data recorded in accordance with Note 1(d).

#### Guidance Note 2

(a) The noise measurements shall be made so as to provide not less than 20 valid data points as defined in Guidance Note 2 (b)

(b) Valid data points are those measured in the conditions specified in the agreed written protocol under paragraph (d) of the noise condition, but excluding any periods of rainfall measured in the vicinity of the sound



level meter. Rainfall shall be assessed by use of a rain gauge that shall log the occurrence of rainfall in each 10 minute period concurrent with the measurement periods set out in Guidance Note 1. In specifying such conditions the Local Planning Authority shall have regard to those conditions which prevailed during times when the complainant alleges there was disturbance due to noise or which are considered likely to result in a breach of the limits.

(c) For those data points considered valid in accordance with Guidance Note 2(b), values of the  $L_{A90,10 \text{ minute}}$  noise measurements and corresponding values of the 10- minute wind speed, as derived from the standardised ten metre height wind speed averaged across all operating wind turbines using the procedure specified in Guidance Note 1(d), shall be plotted on an XY chart with noise level on the Y-axis and the standardised mean wind speed on the X-axis. A least squares, "best fit" curve of an order deemed appropriate by the independent consultant (but which may not be higher than a fourth order) should be fitted to the data points and define the wind farm noise level at each integer speed.

### Guidance Note 3

(a) Where, in accordance with the approved assessment protocol under paragraph (d) of the noise condition, noise immissions at the location or locations where compliance measurements are being undertaken contain or are likely to contain a tonal component, a tonal penalty is to be calculated and applied using the following rating procedure.

(b) For each 10 minute interval for which  $L_{A90,10 \text{ minute}}$  data have been determined as valid in accordance with Guidance Note 2 a tonal assessment shall be performed on noise immissions during 2 minutes of each 10 minute period. The 2 minute periods should be spaced at 10 minute intervals provided that uninterrupted uncorrupted data are available ("the standard procedure"). Where uncorrupted data are not available, the first available uninterrupted clean 2 minute period out of the affected overall 10 minute period shall be selected. Any such deviations from the standard procedure, as described in Section 2.1 on pages 104-109 of ETSU-R-97, shall be reported.

(c) For each of the 2 minute samples the tone level above or below audibility shall be calculated by comparison with the audibility criterion given in Section 2.1 on pages 104109 of ETSU-R-97.

(d) The tone level above audibility shall be plotted against wind speed for each of the 2 minute samples. Samples for which the tones were below the audibility criterion or no tone was identified, a value of zero audibility shall be used.

(e) A least squares "best fit" linear regression line shall then be performed to establish the average tone level above audibility for each integer wind speed derived from the value of the "best fit" line at each integer wind speed. If there is no apparent trend with wind speed then a simple arithmetic mean shall be used. This process shall be repeated for each integer wind speed for which there is an assessment of overall levels in Guidance Note 2.



(f) The tonal penalty is derived from the margin above audibility of the tone according to the figure below.

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#### Guidance Note 4

(a) If a tonal penalty is to be applied in accordance with Guidance Note 3 the rating level of the turbine noise at each wind speed is the arithmetic sum of the measured noise level as determined from the best fit curve described in Guidance Note 2 and the penalty for tonal noise as derived in accordance with Guidance Note 3 at each integer wind speed within the range specified by the Local Planning Authority in its written protocol under paragraph (d) of the noise condition.

(b) If no tonal penalty is to be applied then the rating level of the turbine noise at each wind speed is equal to the measured noise level as determined from the best fit curve described in Guidance Note 2.

(c) In the event that the rating level is above the limit(s) set out in the Tables attached to the noise conditions or the noise limits for a complainant's dwelling approved in accordance with paragraph (e) of the noise condition, the independent consultant shall undertake a further assessment of the rating level to correct for background noise so that the rating level relates to wind turbine noise immission only.

(d) The wind farm operator shall ensure that all the wind turbines in the development are turned off for such period as the independent consultant requires to undertake the further assessment. The further assessment shall be undertaken in accordance with the following steps:

(e). Repeating the steps in Guidance Note 2, with the wind farm switched off, and determining the background noise (L3) at each integer wind speed within the range requested by the Local Planning Authority in its written request under paragraph (c) and the approved protocol under paragraph (d) of the noise condition.

(f) The wind farm noise (L1) at this speed shall then be calculated as follows where L2 is the measured level with turbines running but without the addition of any tonal penalty:

$$L_1 = 10 \log \left[ 10^{\frac{L_2}{10}} - 10^{\frac{L_3}{10}} \right]$$

(g) The rating level shall be re-calculated by adding arithmetically the tonal penalty (if any is applied in accordance with Note 3) to the derived wind farm noise L1 at that integer wind speed.

(h) If the rating level after adjustment for background noise contribution and adjustment for tonal penalty (if required in accordance with note 3 above) at any integer wind speed lies at or below the values set out in the Tables attached to the conditions or at or below the noise limits approved by the Local Planning Authority for a complainant's dwelling in accordance with paragraph (e) of the noise condition then no further action is necessary. If the rating level at any integer wind speed exceeds the values set out in the Tables attached to the conditions or the noise limits approved by the Local Planning Authority for a complainant's dwelling in accordance with paragraph (e) of the noise condition then the development fails to comply with the conditions.

