UK Government

Assessment and Rating of Wind Turbine Noise

Department for Energy Security and Net Zero (2026)

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Executive Summary

This Assessment and Rating of Wind Turbine Noise report provides technical guidance for assessing and controlling operational noise from wind turbines in the planning context. It replaces the 1996 ETSU-R-97 document. It provides guidelines for the control of wind turbine noise, such that wind farm neighbours receive a reasonable degree of protection without placing unreasonable restrictions on wind farm development.

Noise assessment criteria for wind turbine noise are provided based on a combination of fixed levels and those based on a margin above existing sound levels (in the absence of noise from any wind turbines). The total noise assessment criteria are determined on a project-specific basis with consideration of a range of factors and apply to the cumulative noise levels from all nearby wind farm sites. Individual limits are then defined for the application site such that cumulative noise levels meet the total noise assessment criteria. Individual site-specific noise limits can then be enforced through planning conditions, with example wording and technical clauses provided in the document.

Guidance is also provided on monitoring of noise from operational wind farms, to assess the noise levels produced against planning condition requirements, including the assessment of specific audible characteristics of the noise.

There are certain technical areas which are not covered in detail and where the assessment should be carried out in line with good practice, such as that published by the Institute of Acoustics. The assessment methods set out in this guidance have built on research and the recommendations of previous reviews, as well as policy considerations.

Contents

1 Introduction

1.1 The aim of this document is to provide technical guidance to practitioners, developers, planners and other stakeholders on the environmental assessment and control of operational noise from wind turbines. This document is a targeted update and replacement for the original document, ETSU-R-97 [1] *'The Assessment and Rating of Noise from Wind Farms'*. This targeted technical update follows the scoping review commissioned by Government and published by WSP [2] in 2023, which considered evolutions in turbine technology and developments in wind turbine noise assessment methodologies since 1996, as well as established best practice and the latest available evidence in the field.

1.2 The technical guidance has been informed by advice from specialists on wind turbine noise (the 'technical advisory team') from Noise Consultants Limited (part of Logika Group), Hoare Lea LLP and Hayes McKenzie Partnership Limited. The Project Team has also drawn on the experience of external peer reviewers. For a full list of contributors, please refer to the Acknowledgments section at the beginning of this document.

Scope

1.3 The aim of this technical guidance is to provide a framework for assessing and rating operational noise from individual wind turbines and wind farms. It provides guidelines for the control of wind turbine noise, such that wind farm neighbours receive a reasonable degree of protection without placing unreasonable restrictions on wind farm development. Compliance with this technical guidance may therefore result in levels of noise that could be audible at noise sensitive receptor locations but are considered reasonable in the context of the need for renewable energy generation.

1.4 The noise assessment criteria are consistent with the UK's statutory commitment to achieve net zero greenhouse gas emissions by 2050, supporting the deployment of renewable energy infrastructure while ensuring that potential adverse impacts on people are appropriately limited. The assessment and rating methods are presented in a manner suitable for use in the planning system and for controlling operational noise during the lifetime of a wind energy development. This includes a methodology for assessing operational wind turbine noise. An example planning condition is included, which should form the basis of consents or planning permissions for wind turbines or wind farms.

1.5 The noise assessment criteria defined in this technical guidance have been derived with reference to:

- Standards and guidance relating to noise emissions and control of wind turbine noise in the previous ETSU-R-97 [1] guidance, as well as the subsequent

Institute of Acoustics (IOA) Good Practice Guidance [3] and proposed planning conditions for Amplitude Modulation.

- A scoping review on behalf of Government which was published in February 2023 (WSP report [2]), which included:
  - An extensive literature review;
  - Results of field measurements;
  - Engagement with stakeholders, including local authorities, government departments and professional associations.
- The societal need for renewable energy sources to reduce carbon dioxide emissions in line with Government energy policy.
- The ability of manufacturers and developers to meet these noise limits whilst delivering viable schemes.
- Advances in wind turbine technology since the publication of the previous ETSU-R-97 guidance.
- Available research on human response to wind turbine noise and associated impacts, including on health.
- Approaches and methodologies adopted internationally for the control of noise from wind turbines.
- The professional experience of qualified acousticians involved in the formal assessment and regulation of noise emissions from wind turbines and other noise sources.
- Discussions with a panel of representative stakeholders who were invited by the Department for Energy Security and Net Zero to three workshops.
- Comments received during the consultation period for this guidance.

1.6 This technical guidance applies to noise from operational wind turbines and not to operational noise from related infrastructure. Other elements that may be incorporated into a wind energy development which can produce operational noise, such as battery storage systems, substation(s) and solar installations, are assessed through application of alternate assessment methods, which are not applicable to wind turbine noise, and therefore fall outside of the scope of these guidelines.

1.7 The assessment of construction or decommissioning noise and vibration impacts also falls outside of the scope of these guidelines, as other applicable guidance and legislation exists that covers these aspects.

1.8 This guidance does not prescribe the methodology for prediction of wind turbine noise, and does not provide a comprehensive discussion on best practices that should be followed when implementing this guidance. More detailed aspects of the assessment, such as equipment requirements, are more appropriately addressed in good practice guidance, such as that maintained and published by the Institute of Acoustics.

1.9 This guidance also does not include a comprehensive discussion of the evidence underpinning the various aspects of wind turbine noise assessment discussed in this document. Discussion of the current evidence in relation to wind turbine noise has been intentionally omitted from this document in the interests of brevity, however evidence reviews can be found in other publicly available documents (e.g. [2]).

1.10 This technical guidance applies to all types of wind turbines except those allowed under permitted development rights. This guidance should therefore be applied to all wind turbine applications that do not fall under permitted development rights, under whichever consenting regime the application is to be determined. However, when considering cumulative assessments, in some instances, small turbines should be excluded from cumulative assessment as discussed in 2.40.

Periodic updates

1.11 It is recognised that wind turbine technology evolves and therefore there is a need for guidance that adequately reflects current wind turbine characteristics and the latest knowledge and practice. As such, it is anticipated that this technical guidance will be reviewed/updated as necessary.

Interaction with policy

1.12 Reference to ETSU-R-97 in UK planning policy or guidance should be interpreted to mean a reference to this technical guidance, which replaces ETSU-R-97.

Specific considerations relating to Policy in England and Northern Ireland

1.13 The Noise Policy Statement for England (NPSE [4]) (2010) introduces the principles of a LOAEL (Lowest Observed Adverse Effect Level) and a SOAEL (Significant Observed Adverse Effect Level) for noise. A similar approach is also taken in the Noise Policy Statement for Northern Ireland (NPSNI [5]) (2014). The LOAEL identifies the exposure level where adverse effects of noise on health and quality of life can be detected (which should be mitigated and minimised). The SOAEL identifies the exposure level above which significant effects on health and quality of life occur (which should be avoided). The NPSE however notes that both of these general aims should be interpreted within the context of Government policy on sustainable development. The explanatory note to the NPSE also explains that the aim is to 'minimise' non-significant adverse noise impacts as far as reasonably practicable.

1.14 Since the publication of ETSU-R-97, wind turbine technology has advanced, leading to improvements such as variable speed operation[1], power regulation through turbine

[1] The sound power output of a variable speed turbine varies considerably with wind speed, being quieter at the lower wind speeds when the blades are rotating more slowly. Older turbine models would operate at one or two fixed rotational speeds and therefore produce much more uniform noise at most wind speeds.

pitch[2], and use of Serrated Trailing Edges[3]. With these technologies applied, further reductions of noise from the wind turbines can generally only be achieved through design or operational changes that result in losses in renewable energy generation. For example, modern turbine models often allow the use of noise-reduced operation modes, but at the cost of some loss of electrical power generation. Increased setback distance from noise-sensitive receptors, when considering other design constraints or planning considerations, can often only be achieved through reduction in the number of proposed wind turbines, which also reduces the overall electrical generation potential of a development.

1.15 ETSU-R-97 recognised the specific nature and operation of wind turbines and the noise they produce, and how this differs to many other sources of noise. The ETSU-R-97 guidance also identified the need to balance the environmental impacts from a wind farm with the benefits that arise through the development of renewable energy sources. These same principles remain relevant for these guidelines.

1.16 Defining LOAELs and SOAELs for wind turbine noise, in the context of the NPSE guidelines in England or the NPSNI in Northern Ireland, is outside the scope of this technical guidance. However, based on the current state of knowledge, the noise assessment criteria derived in this document are not expected to exceed the SOAEL, although they may be above the LOAEL in some cases.

1.17 When adverse but non-significant effects (above the LOAEL and below the SOAEL) are predicted following assessment and compliance with this technical guidance, further noise minimisation is not required as a matter of policy in the context of sustainable development. It is recognised that noise minimisation is likely to be achieved through iterative layout design and the selection of appropriate wind turbine technology, with the outcome of this process ultimately tested and constrained by the assessment process set out in this guidance.

Considerations relating to Scottish and Welsh policy

1.18 Like in England, there are references to ETSU-R-97 in planning policy and guidance for Scotland and Wales, however the concepts of LOAEL / SOAEL are not included in national policies within these administrations. Nevertheless, national policies in these administrations are broadly similar, in that they support renewable energy generation (including from onshore wind) provided there are no unacceptable adverse impacts including from noise. Current Welsh policy [6] encourages consideration of the effects of different developments on the soundscape in each location-specific context, and in relation to wind turbine developments, makes reference to the ETSU-R-97 guidance subject to the review set out in reference [2].

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2 The alternative, power regulation through blade stall, would generate increasing levels of noise at higher wind speeds.

3 Blade additions which reduce noise emissions from the turbines at little or no energy cost.

1.19 The same general comments as in paragraphs 1.13 to 1.17 therefore apply, and compliance with the present technical guidance is considered a way of satisfying these requirements.

Potential effects which do not require assessment

1.20 There are a number of aspects of wind turbine noise that do not require assessment at the planning stage because their effects on humans can be considered negligible or suitably controlled by the criteria set out in this guidance. These include infrasound, ground-borne vibration and low frequency sound, which are considered in turn below.

Infrasound

1.21 The term infrasound refers to sound at frequencies below 20 Hz, and for wind turbines is often related to the blade passage frequency. Research has shown that, for modern upwind turbines (i.e. turbines where the rotor is positioned upwind of the tower when in operation), the levels of infrasound at typical receptor distances are well below the threshold of perception. The scoping review [2] (p. 114) concluded that *'the findings from the existing evidence base indicate that infrasound from wind turbines at typical exposure levels has no direct adverse effects on physical or mental health'*.

Ground-borne vibration

1.22 The term ground-borne vibration refers to mechanical vibration from the operation of the wind turbine that is directly transferred to and propagates through the ground. Levels of ground-borne vibration from modern upwind turbines are very low and, although ground-borne vibration from wind turbines can be measured at large distances using sensitive equipment, these levels are significantly below the human perception threshold and therefore do not result in adverse effects on human receptors.

Low frequency

1.23 The term low frequency sound refers to sound occurring predominantly in the frequency range from approximately 20 to 200 Hz. Noise-sensitive receptors are considered to be suitably protected from low frequency sound by the proposed noise criteria (which are based on A-weighted noise levels, see glossary for definition). In the absence of specific low frequency tonal noise (which is covered by the tonal assessment methodology of Appendix B), no specific low frequency limits are necessary to control wind turbine noise.

2 Assessment method

Noise Assessment Criteria

Summary

Operational wind turbine total noise assessment criteria (TNAC)[4] for noise-sensitive receptors are defined as the greater of:

- a Lower Limiting Value (LLV); or
- 5 dB above the typical background sound levels determined in accordance with these guidelines.

Separate noise limits apply to the day and night periods for standardised wind speeds up to 10 metres per second (m/s). The LLV is set in the range of 35 – 40 dB[5] for day periods (07:00 to 23:00). The actual value used within the range specified depends on several site-specific factors which are discussed at paragraphs 2.18 to 2.29. For night periods (23:00 to 07:00), the LLV is set to 43 dB.

Background sound levels for the day (derived from the “quiet day” periods) and night, are related to standardised wind speeds determined from hub height wind speeds on the proposed wind farm site being assessed.[6]

Alternatively, a simplified noise criterion of 35 dB (up to 10 m/s) can instead be applied in the absence of background sound level measurements, during both day and night.

At noise-sensitive receptor locations where the occupiers are financially involved with the wind farm development (see paragraph 2.29) the criteria can be increased to the greater of:

- 45 dB; or
- 5 dB above typical background sound levels.

Where cumulative noise levels can be shown to comply with the TNAC at each receptor, site-specific noise limits (SSNLs) relating to noise attributable solely to the specific development under consideration are then derived.

[4] The TNAC apply to the cumulative noise from all relevant wind turbines.

[5] The assessment and measurement of wind turbine noise is based on the L_{A90} and all references to dB in this document are dB L_{A90} unless explicitly stated. For the purposes of the prediction of turbine noise, the L_{A90} is assumed to be 2 dB lower than the predicted L_{Aeq}.

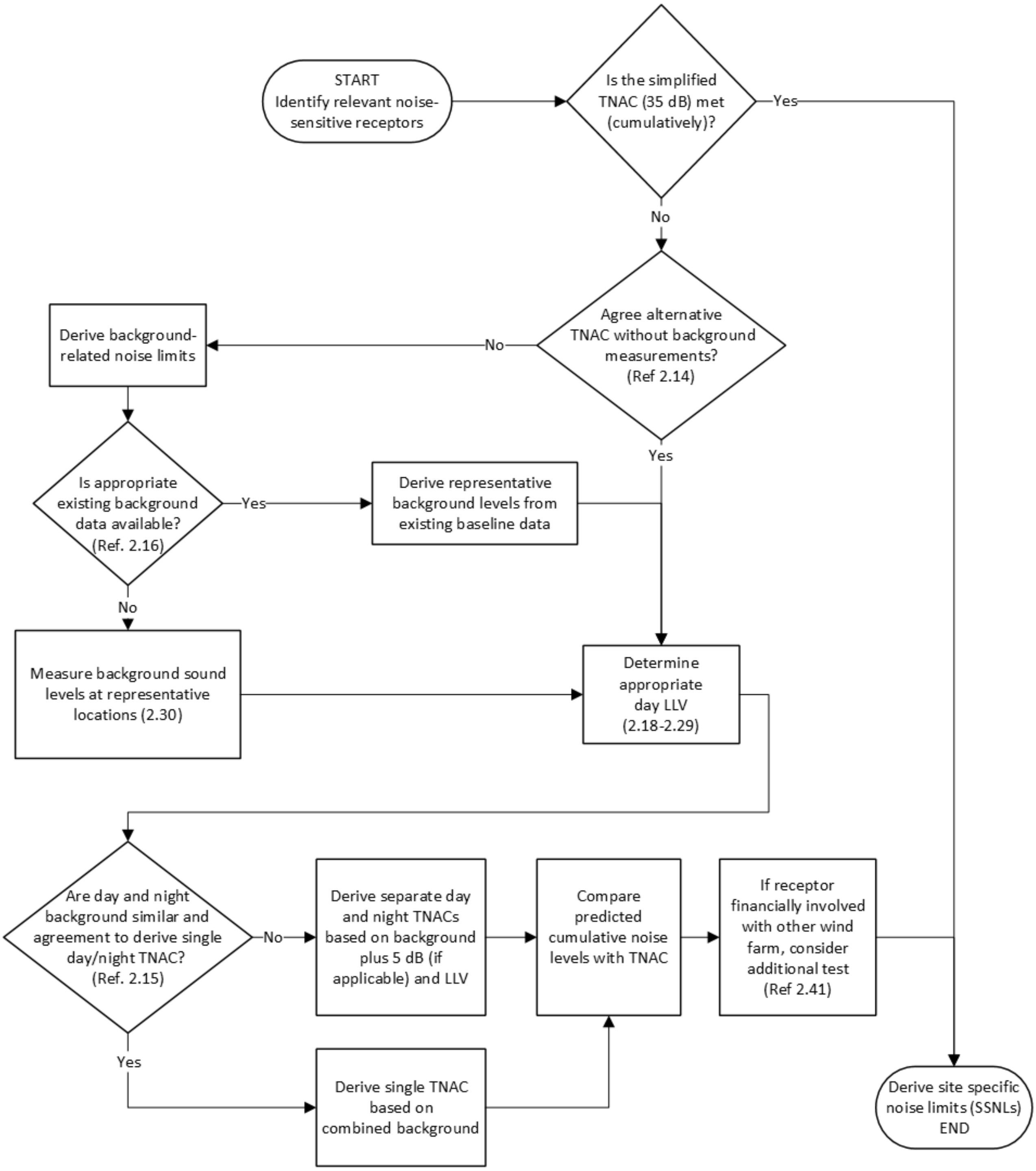
[6] Definitions of ‘quiet day’, ‘day’ and ‘night’ periods are provided in Appendix A – Glossary of Terms.

Assessment process

2.1 The assessment of a proposed wind turbine development follows these steps based on details set out subsequently in this document, as illustrated in Figure 1:

- Relevant noise-sensitive receptors around the proposed development are identified (see 2.2), accounting for cumulative impacts, unless the proposed development has a negligible contribution at the receptor (2.40).
- At some or all of the noise-sensitive receptors identified, the TNAC could be defined based on the simplified fixed level of 35 dB(A) (paragraph 2.17).
- For other noise-sensitive receptors, more detailed noise limits are derived: more commonly from measurements of background sound levels taken at a representative number of properties (2.30) specifically for the purposes of assessing the development under consideration (unless exempted as set out in paragraph 2.14), or from existing measurements (2.16).
- The day LLV is then determined based on a range of site-specific factors as set out at 2.18 to 2.29.
- The TNAC are then determined based on a combination of LLV and background sound levels (or on the basis of LLVs alone according to 2.14). Separate TNACs apply for day and night periods (unless a single day and night TNAC is otherwise agreed as set out at 2.15).
- Predicted wind turbine noise levels, including relevant cumulative contributions (see 2.39-2.40) can then be compared to the TNAC to determine compliance. Financially involved receptors may need additional consideration in some cases: see 2.41. If non-compliance is predicted, noise mitigation measures should be identified.
- Assuming compliance with the TNAC, site-specific noise limits (SSNLs) that apply to noise solely from the development being considered are then determined, in line with the principles of paragraphs 2.45-2.47. This can be secured in practice by following guidance set out in Section 4.

Figure 1: Flow chart showing noise assessment process



Noise-sensitive receptors

2.2 Noise sensitive receptor locations will normally comprise residential dwellings only. In some cases, additional receptors with sensitivity to noise, such as healthcare buildings providing inpatient services, nursing/retirement homes, educational establishments with residential elements (e.g. boarding schools), etc. should also be included in the assessment; these additional receptors should be identified at the initial scoping stage of the assessment, in consultation with relevant stakeholders such as the relevant Planning Authority. It is not necessary to consider every potential noise-sensitive receptor within any study area provided that the receptors considered are representative of all relevant noise-sensitive receptors identified.

2.3 Although the total noise assessment criteria in this technical guidance are defined to protect both the indoor and outdoor environment of the noise-sensitive receptor locations, the assessment criteria are defined at free-field[7] external locations close to the noise-sensitive building. These locations should be representative of areas that are frequently used for relaxation or for activities for which a quiet environment is highly desirable and use of which are directly connected with the noise-sensitive receptor location (and typically no further than 30 m away from the residential property). Control of noise in these external areas provides suitable control of indoor noise levels (whether windows are considered open or closed) without necessitating specific indoor noise control. No criteria for control of indoor noise levels from wind turbines are therefore provided in this guidance.

2.4 The criteria should not be applied at positions around a property which are likely to be affected by reflections from acoustically reflective surfaces (such as locations near to walls of the dwelling) or unusually sheltered (such as enclosed spaces, courtyards etc.).

Noise criteria overview

2.5 **Noise limits vs noise assessment criteria**: the noise assessment criteria summarised above are the total noise assessment criteria (TNAC) which apply to cumulative operational noise levels of all acoustically relevant wind turbines (see Cumulative Noise paragraphs 2.39 to 2.43 below for further guidance) at a given receptor location. Wind turbine noise is controlled by the application of site-specific noise limits (SSNLs) at relevant noise-sensitive receptor locations. These SSNLs apply to the wind farm being considered through the application of these noise limits in planning conditions. The SSNLs will be lower in some instances than the total noise assessment criteria (see paragraph 2.44).

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7 For the purposes of this guidance, free-field locations are those which are not significantly affected by acoustically reflective surfaces (except the ground), located at least 3.5 m from reflecting surfaces with a measurement height of 1.2 -1.5 m.

2.6 **Wind speed references**: All wind speeds in this technical guidance refer to standardised[8] wind speeds. Noise limits apply for a range of standardised wind speeds from zero up to 10 m/s. Guidance is provided in section 3 on assessing noise effects at higher wind speeds in specific situations.

2.7 **Character corrections**: All criteria set out in this guidance assume that noise levels from wind turbines are 'rated' by adding, where appropriate, a character correction to the measured wind turbine noise levels when assessing compliance with the SSNL for an operational wind farm. Character corrections are to be applied for the presence of tones and elevated amplitude modulation (AM) when determined through compliance measurements.

2.8 It is generally not possible to predict the occurrence of such noise characteristics at the planning stage. Tonal noise from wind turbines, when it occurs, is usually associated with a specific design or a component malfunction (combined with operational characteristics), rather than being an expected general characteristic of all wind turbines. All wind turbines generate AM (or blade swish, to a limited extent), but the occurrence of elevated levels of AM is a complex phenomenon that is likely to be related to a combination of turbine and site characteristics; the current consensus is that AM cannot be predicted. Tonal noise and AM are therefore best controlled through enforcement of planning conditions which include the application of character corrections as described in section 4. The approach set out in this technical guidance is formulated on this basis, and consequently, character corrections should only be applied to compliance measurements and should not be added at the planning/application assessment phase, unless there is strong evidence to do so.

Noise assessment criteria definition

2.9 Different total noise assessment criteria (TNAC) normally apply to the control of operational noise during the day (07:00 to 23:00) and night (23:00 to 07:00) periods. These noise assessment criteria are either based upon a combination of a Lower Limiting Value (LLV) or, optionally (see paragraph 2.14), a margin above typical background sound levels. Background sound levels and wind turbine noise both vary with wind speed, and therefore the TNAC will generally be derived as values which change with wind speed, to reflect the variation in typical background sound levels.

2.10 The $L_{A90,10min}$ measurement index is used when determining background sound levels, determination of TNAC, setting of noise limits, and measurements taken during an assessment of compliance with noise limits. This is because compliance measurements at receptor locations made using the L_{A90} index provide a more reliable metric for wind turbine noise than indices such as the L_{Aeq}, which can be affected by relatively loud, transitory noise events from other sources. In addition, it is considered

[8] The standardised wind speed V_s is based on the wind speed measured or extrapolated/interpolated at a height H_{hub} representative of the wind turbine hub height: V_{hub}, using the formula set out in the IEC 61400-11 standard[8] with a notional height of 10-metres and a reference roughness length of 0.05 metres.
$V_s = V_{hub} \log (10/0.05) / \log (H_{hub}/0.05)$. This is consistent with the way wind turbine noise emissions levels as a function of wind speed are commonly reported according to the IEC 61400-11 standard.

desirable to use the same measurement index for both the criteria forming the basis of assessment and for compliance measurements, in order to avoid unnecessary conversion between metrics.

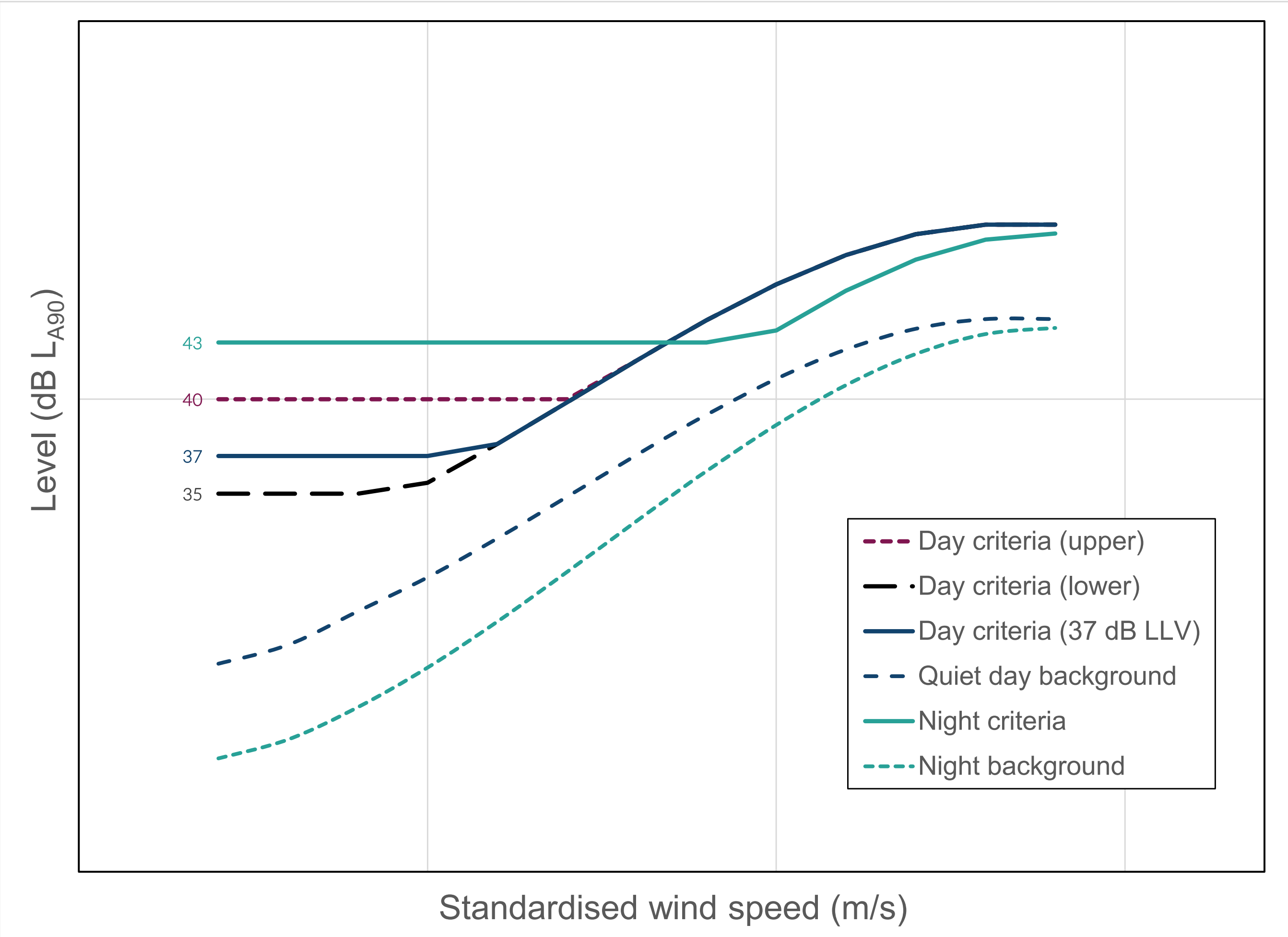
2.11 Wind turbine TNACs during both day and night periods are to be determined as the greater of either:

- 5 dB above typical background sound levels; or
- the relevant Lower Limiting Value (LLV) (see below).

2.12 The TNACs for day and night are normally derived separately based on the typical background sound levels during those periods (see section paragraphs 2.30 to 2.38 on background sound levels).

2.13 Figure 2 below represents an example where the TNAC is determined from the results of background sound measurements where the day and night assessment criteria are set relative to typical background sound levels.

Figure 2: Diagram illustrating the determination of the total noise assessment criteria (example shown assuming a 37 dB LLV for illustrative purposes)



2.14 It may be acceptable, where agreed between the developer and the relevant authority, to complete the above assessment process in the absence of a survey of background sound levels. The assessment would then be based only upon the LLVs, which would apply at all relevant wind speeds for the day and night periods separately, without also relating the assessment criteria to a margin above typical background sound levels. Although some of the factors given at paragraph 2.26 for justifying the choice of LLV during the day are to some extent assessed by consideration of background sound levels, this can be determined based on the expected character of the area in a manner agreed with the relevant authority.

2.15 When determining TNAC based on background sound levels and those background sound levels do not vary significantly between the quiet day and night periods, a single TNAC can be imposed (applying during both day and night periods), provided this is agreed with the Planning Authority. This combined TNAC should be based upon the greater of the relevant day LLV and 5 dB above typical background sound levels obtained during both quiet day periods and night periods, analysed together.

2.16 Where existing background sound surveys have already been completed (for adjacent schemes for example) it may be acceptable to use these data, provided they have been gathered and appropriately corrected for the reference wind speed height in accordance with good practice.

2.17 Alternatively, a simplified total noise assessment criterion (TNAC) of 35 dB (up to a wind speed of 10 m/s) can be set without relating the assessment criteria to a margin above background sound levels. This applies during both day and night. This would not require the measurement of background sound levels. This criterion is particularly suitable for single or smaller scale turbines or cases where a large setback distance exists between turbines and neighbouring properties.

Choice of LLV

2.18 Determination of the appropriate LLV is generally approached on a project-level basis. The only exceptions to this are: where, for a specific receptor, predicted cumulative noise levels are below 35 dB, in which case a simplified TNAC of 35 dB can be applied (see 2.17); or where a receptor is financially involved.

2.19 Different lower limiting values (LLVs) apply during the day and night for noise-sensitive receptors without a financial involvement in the wind farm development:

- For day periods, the LLV is set in the range from 35 to 40 dB.
- For night periods, the LLV is set to 43 dB.

2.20 The chosen LLV is applied to all noise sensitive receptors in the vicinity of the development without a financial involvement in the development, and not derived on a property-by-property basis, as described in 2.18 above.

2.21 The choice of the LLV for day periods within the range of 35-40 dB is to be determined based on the following factors, which represent the planning impacts and merits of the wind farm scheme(s) in relation to noise:

- The generating capacity of the wind farm and the likely consequence that the choice of LLV would have on the energy generation of the wind farm(s).
- The number of dwellings in the neighbourhood of the wind farm(s) and the magnitude of the levels to which these are exposed.
- The duration and level of exposure to wind turbine noise of dwellings in the neighbourhood of the wind farm(s).

2.22 The factors considered in determining the day LLV are presented in priority order, i.e. the largest weight should be given to the overall generating potential of the wind farm, with the number of dwellings and the duration and level of exposure being secondary and tertiary considerations respectively.

2.23 The different day LLV considerations should be evaluated where relevant within a national context (i.e. within the context of England, Scotland, Wales or Northern Ireland as relevant to the project), as the range of wind energy projects, national policy priorities, and population density in practice can vary in each case.

2.24 **Energy generation:** the energy generation potential of the proposed site, evaluated in terms of the proposed generating capacity, should be considered in the context of the range of existing and proposed wind farm schemes.

- The higher the generating capacity of the project is, in the national context (see 2.23), the more the LLV should tend towards the upper end of the range.
- The lower the generating capacity is in the national context (see 2.23), the more the LLV should tend towards the lower end of the range.
- When determining a cumulative TNAC for several wind farms or the extension of an existing project (see cumulative noise section paragraphs 2.39 to 2.43), the total generating capacity from the relevant sites included in the assessment should be considered.
- The effect of the choice of LLV on energy generation should also represent a consideration. If the choice of LLV does not impact on energy generation of the wind development, for example because the nearest noise-sensitive receptors are relatively distant, then a lower LLV should be applied.

2.25 **Number of noise-sensitive receptors:** the more dwellings that are in the neighbourhood of a wind farm, the lower the limits should be, as the total environmental noise impact on sensitive receptors will be greater.

- When the turbines considered are located near a relatively large number of noise-sensitive receptors, for example a town or a village, the LLV should reduce or remain towards the lower end of the range.
- Conversely when located near a low number of noise-sensitive receptors, for example isolated individual dwellings, the LLV could increase or remain towards the upper end of the range.

- The neighbourhood of the wind farm can be considered for the purpose of this clause as the region where predicted (cumulative) wind turbine noise levels are at or above 35 dB (see 2.34).
- The magnitude of the predicted levels to which the different noise-sensitive receptors are exposed is also a material consideration.

2.26 **Duration and level of exposure:** the proportion of the time and extent to which wind turbine noise may be above existing typical background sound levels should be considered.

- Factors which will suggest the LLV would increase or remain high:
    - Most noise-sensitive receptors tend to be downwind of the turbines for a low proportion of the time, for example if located upwind of the turbines under the prevailing wind conditions.
    - Predicted noise levels tend to be comparable to or lower than typical background sound levels, for example due to elevated background sound from other sources or an exposed location.
- Factors which will suggest the LLV would decrease or remain low:
    - Most noise-sensitive receptors tend to be downwind of the turbines for a majority of the time (e.g. under prevailing wind conditions);
    - Predicted noise levels tend to be particularly higher than typical background sound levels, for example due to relatively low background levels.

2.27 The different LLV considerations may also be inter-related and should therefore be evaluated holistically. For example, if a larger number of noise-sensitive receptors were located such that they would be exposed to the wind turbine noise for a minority of the time, this would attract less weight than if these were located such that they would have a higher duration of exposure. Some illustrative examples are set out in Appendix C.

2.28 The LLV should be evaluated in the prescribed range defined at 2.19 based on site-specific criteria that are considered in each case. A general presumption that a certain "standard value" should be used for all projects would be contrary to this principle.

2.29 The LLV used to define the noise assessment criteria can be increased to 45 dB for both day and night periods where the occupier (whether owner-occupiers or tenants) of the property has a financial involvement in the wind farm. Detailed guidance on appropriate arrangements for financial involvement is beyond the scope of this technical guide, however case law[9] suggests this should be where the occupier

[9] High Court of Justice Queen's Bench Division (2014), CO/347/2014, The Queen on the Application of Joicey vs Northumberland County Council.

receives a profitable (not merely compensatory) financial benefit associated with the wind farm over the life of that scheme.

Background sound levels

2.30 Where typical background sound levels are to be determined, these are measured at noise-sensitive receptors and related to wind speeds experienced on the wind farm site being assessed. Wind speeds need to be representative of those experienced at the hub height of the wind turbines being considered and standardised to 10-metres height (see paragraph 2.6). Turbine noise predictions are also referenced in terms of standardised wind speeds so that they can be compared with typical background sound levels and TNAC at a dwelling in comparable conditions, on a like-for-like basis.

2.31 The range of wind speeds to be included in the survey of background sound levels needs to encompass a range from lower wind speeds (where the wind turbines begin to operate) up to higher wind speeds (where noise emission levels from the wind turbines considered are no longer increasing), and within the range of wind speeds considered in these guidelines (see paragraph 2.6). For wind turbines currently in common use in existing onshore wind energy developments, which utilise variable speed operation and power regulation through blade pitch, this may only need to include standardised wind speeds up to 8 or 9 m/s, since modern wind turbines are likely to have reached their maximum noise output at around these wind speeds. Where a survey of background sound levels includes wind speeds up to a maximum which is less than 10 m/s, the maximum derived noise assessment criterion is applied up to 10 m/s.

2.32 Periods of rainfall should be monitored, and data affected by rainfall should be excluded from the representative background sound dataset. Other atypical or unrepresentative periods should also be excluded from the analysis in line with good practice.

2.33 Measurements of background sound should not include noise from any operational wind turbines (including small wind turbines which are excluded from assessment within these guidelines), as these are not considered part of the baseline when determining the assessment criteria that applies to noise from all wind turbines. Where there remains a need to determine background sound levels that could be influenced by operational wind turbine noise, a suitable method needs to be selected to determine background sound levels without a substantial contribution from operational wind turbines, through reference to good practice guidance and in consultation with the Planning Authority. It may be possible to reference historical background sound data provided it is suitable, representative, and accords with good practice.

2.34 Measurements should normally be undertaken at a representative sample of noise-sensitive receptor locations where predicted wind turbine noise levels exceed the lowest LLV (35 dB) at any wind speed in the wind speed range considered. This area of study should include potential contribution of cumulative wind turbine sites, unless their influence is considered negligible (2.40). It is recommended to discuss the choice of representative background survey locations with the relevant Planning Authority where possible and invite a representative of the Planning Authority to witness the installation of the measurement equipment if reasonably practicable.

2.35 Typical background sound levels during the day (07:00 to 23:00) are determined from data for “quiet day” periods which are defined as comprising: all evenings from 18:00 to 23:00, plus Saturdays from 13:00 to 18:00 and Sundays from 07:00 to 18:00. Typical background sound levels during the night are determined from data for the period 23:00 to 07:00 on every day of the week. All times are defined in terms of local time including daylight savings adjustments where applicable.

2.36 The variation in typical background sound levels with wind speed is determined by relating multiple $L_{A90,10min}$ noise measurements with the average wind speeds measured over the same 10-minute intervals and then determining the average sound level as it varies with wind speed (by fitting a best fit curve to the data using a linear or polynomial regression, in accordance with good practice guidance). This process should be completed separately for the day and night and represent the relationship of the change of typical background sound levels with wind speed for both periods.

2.37 The aim of the monitoring is to determine reasonably representative data in conditions under which the noise-sensitive receptor locations would be exposed to noise from the wind turbines being assessed. For example, if some wind directions result in a noise-sensitive receptor location being relatively sheltered while downwind of the proposed wind turbines, consideration should be given to noise data collected for these wind conditions. Background sound measurements need to be carried out at locations representative of the nearest affected noise sensitive receptor locations (see paragraph 2.3) in a free field position, with the microphone mounted between 1.2 m to 1.5 m above ground. Whenever possible, the measurement position should be more than 3.5 metres from potentially significant acoustically reflective surfaces (except the ground).

2.38 Good practice guidance is to be referenced to consider aspects of the background sound monitoring not covered in this technical guidance. For example, suitable equipment to use, including suitable windshields to undertake measurements in potentially windy conditions, placement of equipment, data analysis, use of best-fit lines/curves, survey duration and the exclusion of atypical sounds affecting the measurements.

Cumulative noise

2.39 The total noise assessment criteria (TNAC) derived above apply to the cumulative effect of all wind turbines in the area contributing to the noise received at the noise-sensitive receptor locations in the vicinity of the proposed development.

2.40 Where noise levels from the proposed development are lower than 25 dB, or 10 dB or more below both the day and night TNAC, a cumulative operational noise assessment is not necessary at that noise-sensitive receptor. In addition, the noise impacts of small wind turbines are generally localised and could represent a disproportionate constraint on larger wind energy developments. In such cases, the contribution of these turbines should be excluded from the cumulative noise assessment. For the purposes of this guidance, turbines with generating capacities of 50 kW or less can be considered to have localised noise impacts and can therefore be excluded from cumulative noise assessment. Turbines with generating capacities above 50 kW and less than (for example) a few hundred kilowatts can be excluded from cumulative assessment where it can be demonstrated that noise impacts from these turbines are localised and where including these turbines in a cumulative assessment would result in disproportionate constraints on larger developments. All other wind farm developments must be considered in the cumulative assessment where their individual noise level contribution is within 10 dB of the TNAC.

2.41 For the purposes of cumulative noise assessment, financial involvement (see paragraph 2.29) is specific to the wind farm in which the receptor has an interest. Accordingly, there are two tests that should be undertaken at each financially involved noise-sensitive receptor:

- Total cumulative noise from all relevant developments including the one which it is financially involved with must not exceed the financially involved TNAC.
- Total cumulative noise from all relevant developments excluding the one which it is financially involved with must not exceed the non-financially involved TNAC.

2.42 In some situations, a receptor may become exposed to noise from several different wind farm sites in different wind directions thereby increasing the duration of exposure, which is one of the factors relevant to determining the LLV. When assessing cumulative noise effects, if the contributions from each individual wind farm are combined assuming that the assessment location is downwind of all wind turbine developments simultaneously, this represents a suitable way to implicitly account for the increased duration of exposure. If predictions of wind turbine noise levels are carried out which account for the reduction in predicted noise levels due to wind direction, the duration of exposure must be considered when determining the LLV to be used as the basis of the cumulative noise assessment.

2.43 Assessment results (predicted noise levels, TNAC, SSNLs etc.) should be presented to one decimal place. This is important because small changes in level can have consequences when calculating appropriate limits and can affect the noise headroom of future developments. It is acknowledged that changes of a fraction of a decibel would not be perceptible, and it is considered that changes of less than 0.5 dB are considered to be negligible. This is in line with the premise that where a development is 10 dB below an existing development its contribution is considered to be negligible but mathematically would result in a 0.4 dB increase[10] in total noise level.

Site-specific noise limits

2.44 Operational noise from wind turbine developments should be controlled through the application of site-specific noise limits (SSNLs) that apply to noise solely from the development being considered. These SSNLs are usually derived for each relevant noise sensitive receptor location and incorporated into planning conditions for the wind farm development under consideration.

2.45 Where there are no other wind turbine developments included in the assessment, the SSNLs should normally be set below the TNAC unless doing so would mean the site cannot operate without unreasonable restriction. SSNLs should only be equal to the TNAC where it is necessary, with supporting justification for this provided in the assessment. This approach is needed in order to not unduly restrict other potential future wind farm development in the local area, i.e. by a wind farm being consented and using up the entire available TNAC when it is not necessary to do so, thereby leaving minimal or no additional margin for future schemes. This approach is also necessary to meet the stated aim of this guidance, *i.e.* to provide wind farm neighbours with a reasonable degree of protection from wind turbine noise without placing unreasonable restrictions on wind farm development.

2.46 Where there are other wind turbine developments included in the assessment, the first stage in determining the SSNL is to calculate the available SSNL by logarithmically subtracting the contributions from other wind turbine developments from the TNAC. If the contribution from other wind turbine developments is equal to, or above, the TNAC, the SSNL would usually be set at 10 dB below the TNAC.

2.47 The following guidance shall be followed when setting appropriate SSNLs:

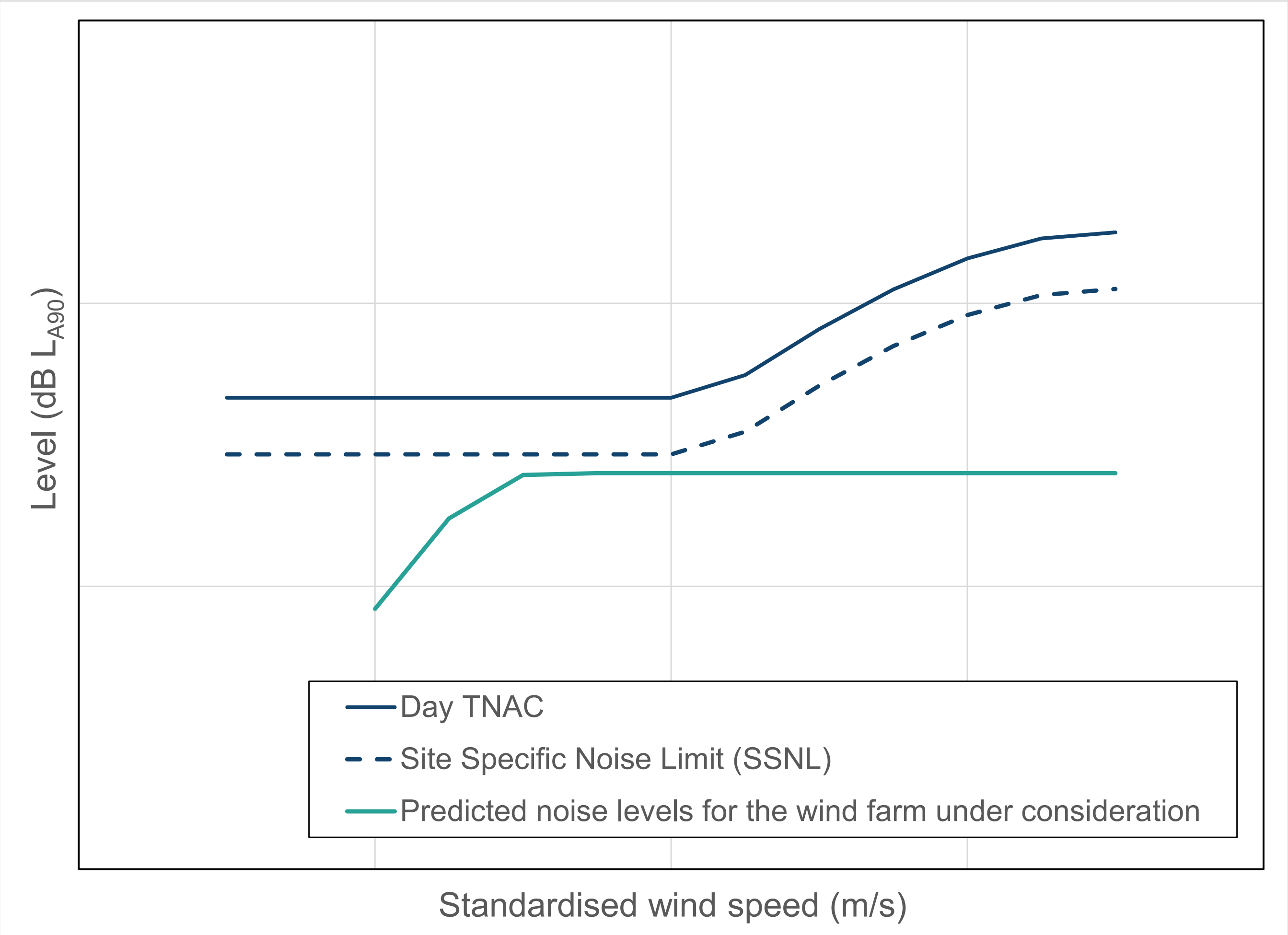
- The SSNL should not be higher than the TNAC that would apply to the proposed development in the absence of other wind turbine developments.
- The SSNLs should normally follow a profile (variation with wind speeds) closer to the TNAC, rather than the profile of predicted noise levels (see illustration in Figure 3);
- The SSNL may be calculated using the ‘remaining noise budget’[11] principle, but the applied SSNLs should normally follow a profile closer to the TNAC;

[10] Although the contribution of several wind farms at 10 dB below the relevant noise limit could in theory add up to cumulative levels around 1 dB above that noise limit, this is considered unlikely to occur in practice and would be considered an acceptable marginal noise increase (in the context of the assessment of cumulative operational wind turbine noise only).

[11] Remaining noise budget: calculating the available headroom within the TNAC for a proposed wind farm by logarithmically subtracting the SSNLs which apply to adjacent development(s) from the TNAC. Alternatively, where the adjacent sites have SSNLs which equal the TNAC or where there are large margins between predicted

- The SSNLs should not normally be set substantially higher than predicted noise levels for the wind farm under consideration at wind speeds where the wind turbines reach their maximum noise levels;
- SSNLs shall not be set lower than 10 dB below the TNAC;
- SSNLs that apply to noise sources outside of the control of the operator/owner of the development (i.e. cumulative limits) should not be used;
- The difference between the SSNL and the TNAC may vary at different noise sensitive receptor locations to account for the relative contribution of other cumulative sites considered, ensuring that cumulative levels remain below the TNAC;
- In some cases, it may be appropriate to define a single value SSNL that applies at all wind speeds within a defined range (for example where the lowest applicable LLV is met at all wind speeds).

Figure 3: Diagram illustrating the determination of the SSNL derived from TNAC for a single proposed wind farm



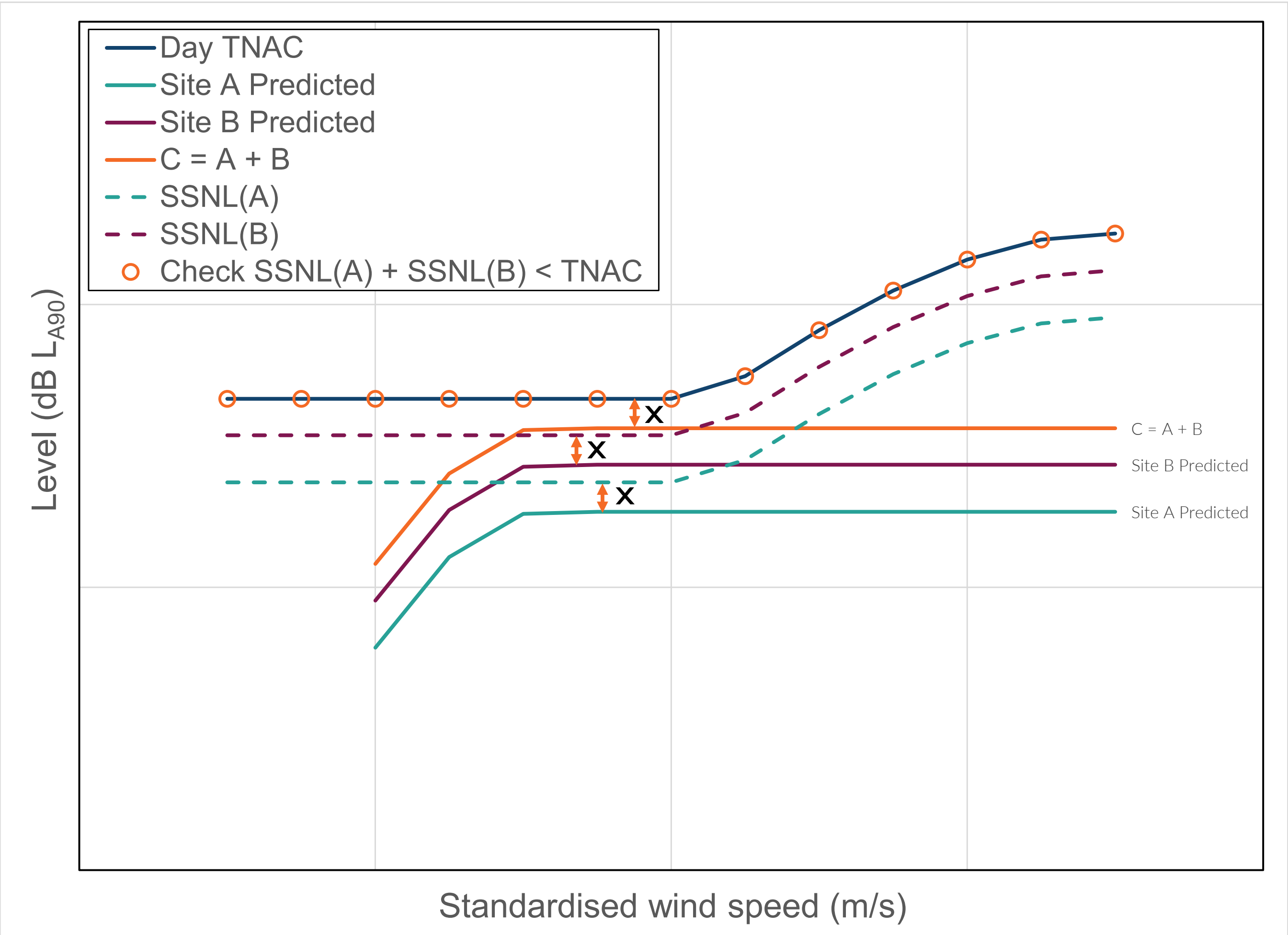
2.48 An example of a suitable approach is set out in the case of a property exposed to noise from two proposed wind farms A and B with a similar noise emission profile

noise levels and their SSNLs, this calculation can be completed by logarithmically subtracting the adjacent development(s) predicted noise levels from the TNAC, provided a reasonable allowance is included in the predictions for operational noise levels to be higher in practice whilst remaining within the SSNL.

(assuming concurrent applications). The SSNLs for both wind farms could initially be obtained with the following process, for each relevant receptor, as illustrated in **Figure** 4:

- Determine the minimum margin (x) between the cumulative predictions and the TNAC.
- Adjust the TNAC curve by reducing it by a constant amount at all wind speeds, until the minimum margin between this reduced curve and the predicted levels for wind farm A is x. This is then set as the SSNL for wind farm A.
- The same process is done for wind farm B using the same margin (x).
- Check that the logarithmic addition of the SSNLs for A and B does not exceed the TNAC, or adjust as necessary.
- In the example of **Figure** 4, the TNAC was fully allocated to the wind farms A and B. In some cases, for example where there is a large margin between cumulative predictions and the TNAC, the SSNLs could be further reduced to allow for future developments. This would be achieved by reducing the value of x before calculating the SSNLs for wind farms A and B.

Figure 4: Diagram illustrating the **process set out in paragraph 2.48**



3 Operational noise monitoring

3.1 Noise from wind farms should be controlled through planning conditions (or equivalent requirements) which direct the wind farm operator, at any time during the operation of the development, to undertake measurements at one or more specific properties following justified complaints[12] related to noise. A condition requiring periodic monitoring, or post-completion monitoring at residential properties in the absence of complaints, is not required under this technical guidance.

3.2 Measurements should focus on periods where background sound levels are minimised (such as night periods, if the turbines being assessed operate in the same way during the day and night) and with regard to specific conditions in which complaints occurred and/or where noise from the wind farm is maximised (typically, downwind conditions in which the wind blows from the wind turbines towards the noise-sensitive receptor). This will define one or more data subset(s) in which the analysis will be undertaken.

3.3 Where it has been identified (e.g. through complaint records) that complaints specifically relate to operational wind turbine noise at wind speeds which are above those considered in the noise assessment and contained within the planning conditions, appropriate noise limits can be determined as part of the initial compliance assessment protocol to be submitted and agreed with the relevant Planning Authority.

3.4 Good practice guidance from the Institute of Acoustics is to be referenced to consider aspects of the monitoring not covered in this technical guidance, for example, equipment to use, including suitable windshields to undertake measurements in potentially windy conditions, placement of equipment, data analysis, survey duration and the exclusion of atypical noise sources affecting the measurements.

3.5 Values of the $L_{A90,10min}$ measurement index and other related data (wind speed, wind direction etc.), for each 10-minute interval, are separated (or ‘binned’) into 1 m/s wide wind speed bins centred on integer values of wind speed (i.e. 3, 4, 5 etc.). It should be noted that typical baseline background sound levels are derived using a best-fit curve through the data to determine the typical background sound levels as they vary with wind speed, whereas operational noise measurements are concerned with defining noise levels under specific conditions (i.e. in wind speed and direction bins). It should also be recognised that the TNAC and SSNLs set out in section 2 of this document and the example noise condition set out in section 4 only define noise criteria / noise limits at integer wind speeds. It is therefore appropriate to demonstrate compliance with the appropriate SSNLs at relevant integer wind speeds.

3.6 Data should also be filtered by wind direction, which may involve filtering data for only conditions where the assessment location is downwind of the wind turbines or

[12] A justified complaint would typically relate to a noise that, on their review, the relevant Planning Authority considers likely to be sufficiently audible or significant, and attributable to the specific wind farm under consideration.

separated into narrower wind direction data subsets (for example, separating data into multiple 30° wind direction sectors). The relevant approach should reflect the following:

- Weather conditions in which complaints were received;
- Weather conditions contained in the request from the relevant Planning Authority[13];
- Downwind conditions, unless this necessitates an unreasonably extended monitoring period due to these wind conditions being uncommon.

3.7 Where data are to be filtered to include only downwind conditions, the downwind sector is often considered to be the arc between the most dominant wind turbines at the property considered and the noise-sensitive receptor position. This downwind direction arc may be expanded by up to +/- 45° to provide a suitable data subset size but can be left more narrowly defined where considered appropriate.

3.8 Where a correction for the residual noise (i.e. any noise not associated with the wind turbine(s) being assessed) is required, this is typically done by repeating the measurements including periods where the assessed wind turbines are shut down to determine a residual level. The wind turbine average residual noise level should normally be calculated for the relevant bins/subsets as described above; however, it may be appropriate for this correction to use an alternative method which must be justified, and any comparison should be undertaken on a like-for-like basis.

3.9 For every wind speed bin in every data subset (the total noise bins), an arithmetic average of the overall L_{A90} noise level readings is calculated to represent the single value 10-minute L_{A90} noise level in that bin. If applicable, a parallel procedure is carried out with wind turbines turned off to derive the residual noise level in each parallel bin. Where required, the wind turbine noise corrected for residual noise is obtained separately, for each pair of bins, by logarithmically subtracting the value of the residual bin from the value of the total bin (see 4.20). Where relevant (see paragraphs 3.11 to 3.22), for each 10-minute interval, for every noise bin, a character correction is determined. The wind turbine rating level for each bin is then the arithmetic sum of the bin noise level (corrected for residual noise where appropriate) and the bin character correction, where applicable. It should be noted that, where the residual noise level is higher than, or within 3 dB of, the measured overall noise level it may no longer be appropriate to use the residual noise correction. This indicates that the wind turbine development noise level is equal to, or lower than the residual noise level.

3.10 Where it is not possible to determine compliance with the limits through measurements at the receptor locations (for instance where access to carry out measurements is refused or where residual noise levels are high relative to the total measured levels), it may be acceptable to determine compliance through alternative approaches. For example, proxy measurements (either at an alternative free-field location or through a

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[13] As the Planning Authority can request site data from the operator, this could be used to identify any patterns of weather / operational conditions when complaints occur.

sound power level measurement) and modelling, with agreement from the Planning Authority. However, it is not appropriate to apply character corrections from proxy measurement locations distant from the receptor location (see paragraph 3.13 below).

Correcting measured noise for character

3.11 In cases where the character of the noise is likely to include specific character components that require assessment, based either on the description of the complaints, the opinion of the relevant authority or observations made at noise sensitive receptors in the vicinity of the wind farm site, then any required compliance monitoring should assess these characteristics. Where no such descriptions or observations of the presence of these characteristics are made, the compliance assessment does not normally need to assess these characteristics.

3.12 Noise should be ‘rated’ by adding a character correction which can be applied during assessment of compliance of a particular wind farm with its site-specific noise limits. These character corrections are to be added due to the presence of tones or discrete frequencies in the noise (tonal character correction) as well as amplitude modulation (AM character correction). During a compliance assessment, values of the $L_{A90,10min}$ measurement index will be determined for each 10-minute interval for one or more data subset(s) in which the analysis will be undertaken. For relevant subsets, values of the character corrections should be calculated for both tones and AM and the higher of these individual character corrections should be applied (on the basis that it is the most dominant feature being considered). If both tones and AM are being investigated, results are reported separately (for each data subset) as well as reporting the applicable (highest) character correction.

3.13 Character corrections can only be determined at, or close to, the location being assessed, as character and audibility can vary significantly between locations. Character corrections from one measurement location cannot normally be applied to another location.

3.14 Incidences of character not related to the wind turbines being assessed should be excluded from the analysis. The presence of noise character may usefully also be assessed where relevant during shut-down periods, as this can allow identification of character in sounds not related to the wind farm being considered.

Tonal analysis

3.15 The tonal audibility should be calculated for each 10-minute interval using the method shown in Appendix B. It should be noted that in order to perform narrowband analysis according to the method, it will be necessary to record audio data with a suitable resolution and sampling frequency to cover the frequency range of interest.

3.16 If the 10-minute interval analysed is not considered valid[14], that data point is removed from the character analysis (no character correction calculated) and the data is not included in the bin averaging described below.

3.17 The associated character correction is calculated for each 10-minute interval. Where the tonal audibility is less than 2 dB the character correction is 0 dB, and where the tonal audibility is greater than or equal to 6.5 dB the character correction is 5 dB. Otherwise, the character correction is calculated using the following formula (as shown in Figure 5):

$$\text{Tonal character correction} = \begin{cases} 0 & \text{where } Tonal\ audibility < 2 \\ 5 & \text{where } Tonal\ audibility \geq 6.5 \\ Tonal\ audibility \times \dfrac{5}{6.5} & \text{where } 2 \leq Tonal\ audibility < 6.5 \end{cases}$$

Figure 5: Tonal character correction curve

Amplitude modulation analysis

3.18 The AM rating level (dB) is calculated for each 10-minute interval using the method set out in the Institute of Acoustics document *A Method for Rating Amplitude Modulation in Wind Turbine Noise* [7]. The method is directly applicable to amplitude modulation (AM) for turbines with a blade passage frequency of between 0.3 Hz and 1.6 Hz,

[14] This may be due to corruption from other sources of noise during the 10-minute interval or where the apparent tonality detected can be shown to be unrelated to the wind turbines being assessed.

corresponding to rotational speeds of 6 to 32 rotations per minute (rpm) for a three-bladed turbine. It should be noted that in order to carry out the analysis, it is necessary to record A-weighted 1/3 octave data at 100 millisecond time resolution.

3.19 The Institute of Acoustics AM methodology requires the analysis to be undertaken in three frequency ranges (50 to 200 Hz, 100 to 400 Hz or 200 to 800 Hz) with one band chosen from these three. This choice should be determined by analysing the frequency range which tends to give the highest results, separately for each data subset (where relevant) and in each bin, excluding outliers, as this provides the best representation of modulation associated with specific site and propagation characteristics.

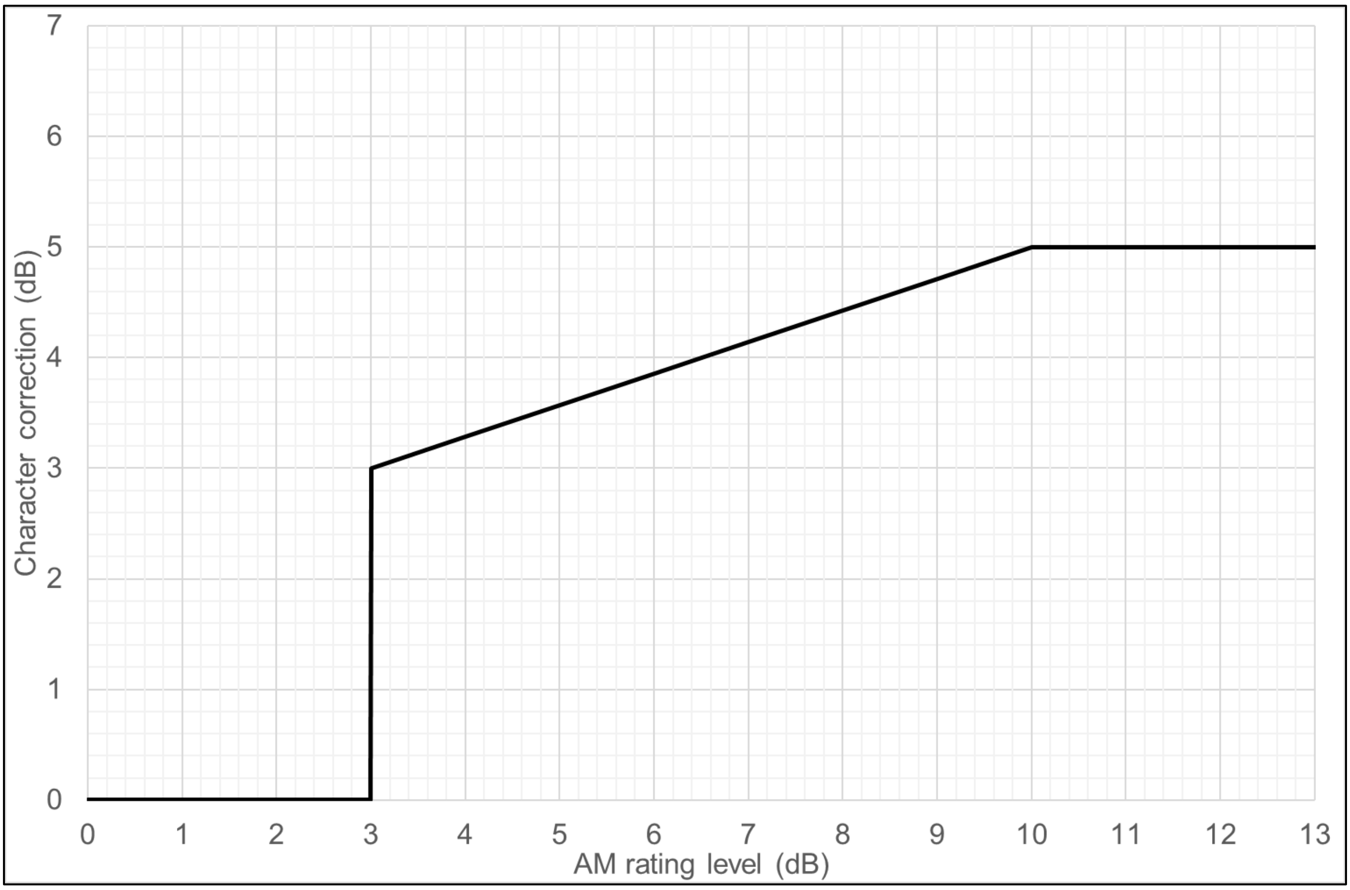
3.20 If the 10-minute interval analysed is not considered valid, i.e. when corrupted due to other sources or the apparent modulation detected is not related to the wind turbines being measured but to other sources, that data point is removed from the character analysis (no character correction calculated and the invalid ten-minute period not included in the bin averaging described below).

3.21 Where valid (uncorrupted) data allow the analysis to be undertaken, an AM rating level (M) is calculated in accordance with the Institute of Acoustics AM methodology for each 10-minute interval. Where M is less than 3 dB, or no modulation was detected, the character correction is 0 dB, and where M is greater than or equal to 10 dB the character correction is 5 dB. Otherwise, the character correction is calculated using the following formula (illustrated in Figure 6):

$$\text{AM character correction} = \begin{cases} 0 & \text{where M} < 3 \\ 5 & \text{where M} \geq 10 \\ 3 + \dfrac{2M - 6}{7} & \text{where } 3 \leq M < 10 \end{cases}$$

Where *M* is the 10-minute AM rating level.

Figure 6: Amplitude Modulation character correction curve



Combined character corrections and bin averaging

3.22 The tonal and AM character corrections for each 10-minute period (where relevant) are averaged separately for each bin/subset. A total character correction for that bin/subset is then obtained as the highest of the tonal and AM correction within that bin/subset.

4 Planning conditions

Introduction

4.1 This section describes how noise limits should be applied to wind turbine developments and includes the technical data that should be recorded by the operator of the development and the way in which complaints should be investigated.

4.2 Where a complaint is made to the relevant Planning Authority about operational noise from the wind turbine(s), this can trigger a procedure for assessing compliance with the noise limits, which would normally involve measurements carried out at the expense of the operator of the wind turbine development at the complainant’s property. This can be secured via standard planning conditions.

Setting limits

4.3 Operational noise from wind turbine developments should be controlled through the application of site-specific noise limits (SSNLs) that apply to noise solely from the development being consented.

Example planning condition

4.4 The following section provides example text forming a suitable basis for inclusion in a planning condition (or similar requirement) to control operational noise levels. Planning Condition Technical Guidance Notes are also included in the following section, and it is the intention of this technical guidance that planning conditions could reference these guidance notes without needing to include them in full, in the interest of conditions being concise. The text in square brackets in the following example is to be replaced by the appropriate text for the specific development being considered (e.g. references to noise limit values would be replaced by the appropriate noise limits for the specific development).

> The rating level of noise from the combined effects of the wind turbines hereby permitted (including the application of any tonal and/or amplitude modulation (AM) character correction), when determined at any residential properties lawfully existing or with planning permission at the time of the consent [and non-residential receptors listed in the tables attached to this condition] in accordance with the [Assessment and Rating of Wind Turbine Noise 2026 Planning Condition Technical Guidance Notes (“ARWTN Technical Guidance Notes”) or any relevant guidance notes which might replace these in due course], shall not exceed [either XX dB L_{A90} or] the values for the relevant integer wind speed set out in or derived from the Tables attached to this condition. In the event that a complaint is made, the following steps shall be carried out:

A) Within 28 days from receipt of a written request of the Local Planning Authority, following a justified complaint[15] to it alleging noise disturbance at a specified residential property [or specified non-residential receptor], the wind farm operator shall, at its own expense, employ an appropriately qualified and experienced acoustician and provide a written protocol (“the Protocol”) to be approved in writing by the Local Planning Authority. The Protocol shall confirm the applicable noise limit, describe the procedure to assess the level and character of noise from the wind farm at the specified property in accordance with the procedures described in the [ARWTN Technical Guidance Notes] and set out a timescale within which the assessment described in the Protocol will be completed. The written request from the Local Planning Authority shall set out as far as possible the time or meteorological conditions to which the complaint relates and whether the character of the noise is likely to include tonal noise or AM components if applicable. Measurements to assess compliance with the noise limits shall be undertaken in accordance with the agreed Protocol. If the Local Planning Authority or acoustician determine the character of noise is likely to include tonal or AM components, the Protocol needs to consider the assessment of these characteristics.

B) The wind farm operator shall provide to the Local Planning Authority the acoustician's assessment of the rating level of noise at the specified property. The assessment shall include, if requested by the Local Planning Authority, all data collected for the purposes of undertaking the compliance measurements and analysis, such data to be provided in a format to be agreed with the Local Planning Authority. Certificates of calibration of the equipment shall be submitted to the Local Planning Authority with the acoustician's assessment report.

C) Where a further assessment of the rating level of noise from the wind farm at the specified property is required to correct for other noise sources pursuant to the [ARWTN Technical Guidance Notes], the wind farm operator shall submit a copy of the further assessment within 21 days of submission of the acoustician's initial assessment unless otherwise agreed by the Local Planning Authority. The wind farm operator shall facilitate wind turbine shut-downs as suitably justified by the acoustician to allow the contribution from other sources to be determined, if suitable data is not already available.

D) Wind farm operational and wind data logged by the operator, as defined in the [ARWTN Technical Guidance Notes], shall be supplied to the relevant Local Planning Authority on its request, within 14 days of receipt in writing of such a request.

Table [X]: Operational noise limits at properties (dB L_{A90}) – day (07:00-23:00)

Receptor Location (easting, northing)	Standardised Wind Speed (m/s)									
	1	2	3	4	5	6	7	8	9	10

[15] A justified complaint would typically relate to a noise that, on their review, the relevant Planning Authority considers likely to be sufficiently audible or significant, and attributable to the specific wind farm under consideration.

Table [Y]: Operational noise limits at properties (dB L_{A90}) – night (23:00-07:00)

Receptor Location (easting, northing)	**Standardised Wind Speed (m/s)**									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**

Planning condition technical guidance notes

4.5 These planning condition technical guidance notes are referenced in the planning condition, but do not need to be reproduced within the planning conditions attached to a development consent notice.

4.6 Values of the $L_{A90,10\ minute}$ noise index should be measured following good practice guidance issued and maintained by the Institute of Acoustics in terms of measurement positions and equipment used. Measurements shall be undertaken in such a manner to enable both a tonal and AM character correction to be calculated for selected periods where a tonal or AM assessment is required in the assessment Protocol, in line with the applicable assessment methods defined in Section 3 of this technical guidance.

4.7 The wind farm operator shall continuously log arithmetic mean power output, mean nacelle anemometer wind speed, mean nacelle orientation, mean wind direction as measured at the nacelle, arithmetic mean rotor rotational speed for each wind turbine, and whether each wind turbine is running normally during each successive 10-minute interval for each wind turbine on the wind farm. The wind speed at wind turbine hub height shall be standardised to a reference height of 10 metres as defined in paragraph 2.6. The resulting standardised wind speed data are synchronised with the noise measurements. All 10-minute intervals shall commence on the hour and in 10-minute increments thereafter synchronised with a common time reference such as Coordinated Universal Time (UTC). Data provided to the relevant Planning Authority in accordance with the noise condition shall be provided in electronic format using a widely accessible file specification such as comma separated values or, in the case of audio recordings, WAV files (or similar accessible formats). The assessment Protocol will define the wind speed reference to be used for the assessment of each location and how this will be determined from the wind turbine data recorded and/or any other suitable anemometry data available during the measurements.

4.8 Where a property to which a complaint is related is not listed in the tables attached to the planning condition, the applicable noise limits included in the Protocol are to be justified by the acoustician. The limits should be taken from the nearest listed location or, if the limits are set relative to background sound levels, based on the location likely to experience the most similar background sound environment to that experienced at the specified property. In some cases, the noise limits for properties not listed in the noise limit table attached to the planning condition may require some adjustment to account for cumulative considerations that were accounted for within the original noise assessment. In these instances, the associated calculations should be clearly set out in the Protocol.

4.9 The Protocol should specify an analysis of character (tonality and/or AM) if the description of the complaint, indications from the Planning Authority regarding the character of the noise, the opinion of the acoustician or site observations, suggest that the noise may potentially include specific tonal or AM components.

4.10 The assessment shall identify a subset of data having had regard to:

- the conditions (including time of day and corresponding wind directions and speeds) at times in which complaints were recorded;
- the nature/description recorded in the complaints if available;
- information contained in the written request from the relevant Planning Authority;
- likely propagation effects (downwind conditions or otherwise);
- the results of the tonality/AM analysis where relevant.

4.11 In cases where it is possible to identify patterns of clearly different conditions in which complaints have arisen, additional subsets may be considered provided this does not introduce unreasonable complexity in the analysis and can be justified by the acoustician.

4.12 The $L_{A90,10\text{-minute}}$ measurements shall be synchronised with measurements of the 10-minute wind and operational data logged in accordance with paragraph 4.7. Within each of the subset(s) of data identified, data shall be placed into separate 1 m/s wide wind speed bins centred on each integer wind speed.

4.13 A data logging rain gauge shall be installed for the duration of the noise measurements. The gauge shall record over successive 10-minute intervals synchronised with the noise measurements. Data affected by rainfall shall be excluded from the analysis.

4.14 The L_{A90} sound pressure level for each data subset and wind speed bin is the arithmetic mean of all the 10-minute sound pressure levels within that data subset and wind speed bin except where data has been excluded for reasons which should be clearly identified by the acoustician.

4.15 The noise measurements shall be made so as to provide sufficient valid data points in each data subset(s) assessed.

4.16 Where relevant, in accordance with the Protocol or based on the opinion of the acoustician or site observations, an assessment of tonality and/or amplitude modulation shall be undertaken for each 10-minute interval of the data subset(s) considered. The analysis shall be undertaken in accordance with the character analysis methodologies set out in in Section 3.

4.17 Where data for a 10-minute interval are affected by non-wind turbine noise sources such that the character rating is considered unlikely to be associated with the wind turbines being tested, that interval should be removed from the character analysis. For all other valid data, the value of the tonal audibility and/or AM rating (if relevant) for each 10-minute interval shall be converted to separate tonal and AM character corrections in decibels in accordance with the procedure of Section 3 (Figure 5 and Figure 6).

4.18 The resulting tonal and AM character corrections shall be placed in the appropriate data sub-set and wind speed bin. Where a character correction is zero it should be placed in the bin in the same way. For each data subset considered, the individual tonal and/or AM character corrections (where relevant) shall be arithmetically averaged separately within each bin to obtain a tonal and/or AM character correction for the bin. The assessment level in each bin is the arithmetic sum of the bin L_{A90} and the maximum of the tonal or AM character correction for the bin. *For example, if the bin average tonal character correction is 4.9 dB and the bin average AM character correction is 3.2 dB, the penalty applied to the bin L_{A90} shall be 4.9 dB.*

4.19 If the rating level in every bin lies at or below the limit(s) defined in the assessment Protocol then no further action is necessary. In the event that the rating level is above the limit(s) defined in the assessment Protocol in any bin, the acoustician shall undertake a further assessment of the rating level to correct for other noise sources so that the rating level relates to noise only from the wind turbine(s) being assessed. Correction for other noise sources need only be undertaken for those wind speed bins where the rating level is above the limit.

4.20 The residual noise level (L_3) without the wind turbines operating is normally obtained through shut down of acoustically relevant wind turbines[16]. If such data is required, the wind farm operator shall facilitate the switch-off of acoustically relevant wind turbines in the development as agreed with the acoustician to enable the further assessment to be undertaken. The further assessment shall then be undertaken by repeating the steps in paragraphs 4.12 to 4.14, with the relevant turbines switched off, and determining a residual noise level (L_3) at each integer wind speed within the wind speed bins and data subsets defined in paragraph 4.18. The corrected wind farm noise level (L_1) in each of these bins shall then be calculated as follows, where L_2 is the measured level with wind turbines running but without the addition of any character correction:

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

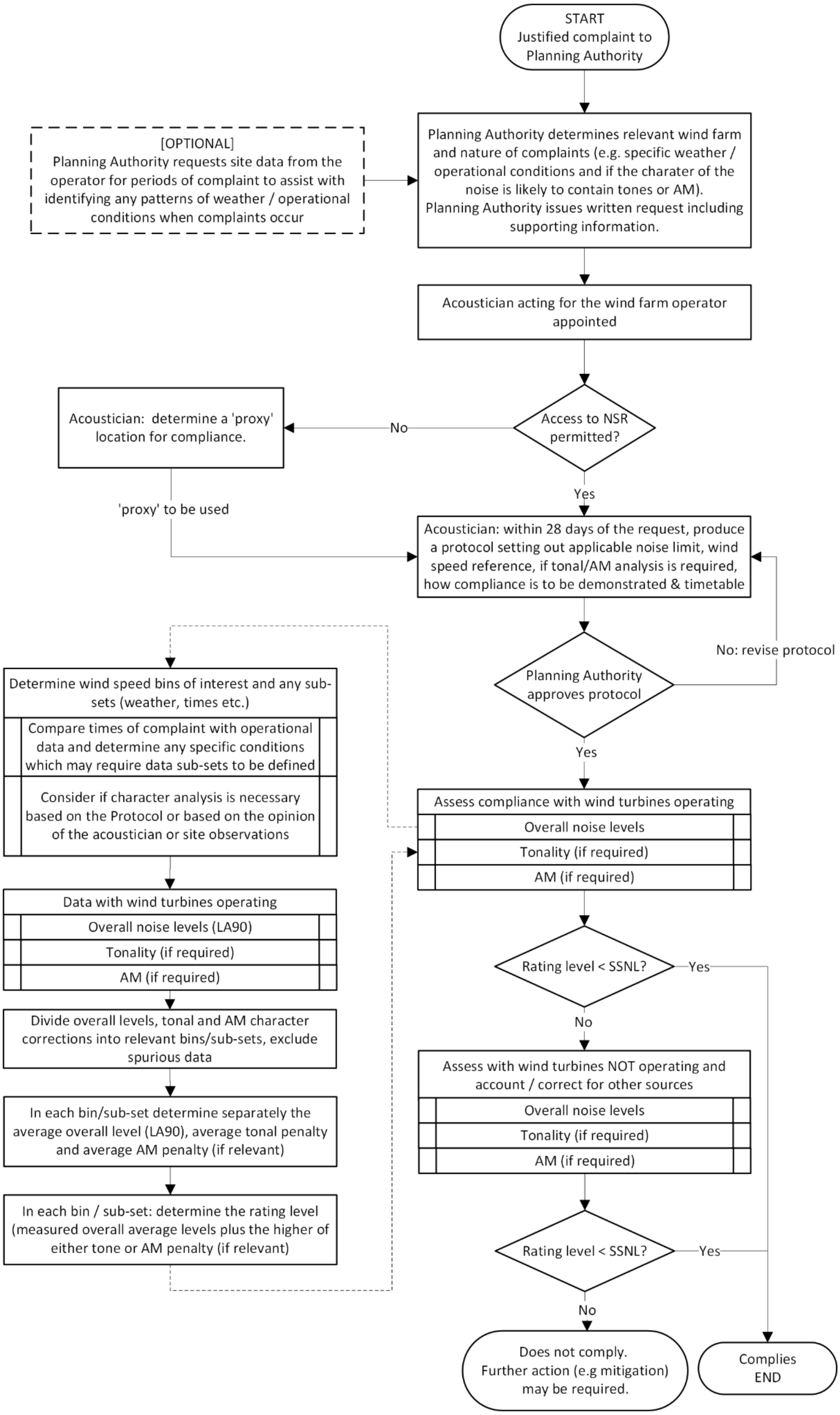
4.21 Where the residual noise level is higher than, or within 3 dB of, the measured overall noise level it may no longer be appropriate to use this correction. This indicates that the turbine development noise level is equal to, or lower than the residual noise level. In these circumstances, an alternative method should be agreed with the relevant Planning Authority.

4.22 The corrected rating level shall be calculated by adding the character correction defined in paragraph 4.17 to the derived wind farm noise L_1 in that bin. If the corrected rating level in every bin lies at or below the limit(s) defined in the assessment Protocol then no further action is necessary. If the corrected rating level exceeds the limit(s) defined in the assessment Protocol in any wind speed, then the development fails to comply with the planning condition in the circumstances represented by that bin, and further action (e.g. mitigation of turbine noise levels or enforcement action by the Local Planning Authority) may be required.

4.23 The procedure for assessing compliance with the above planning condition is summarised in Figure 7 below.

[16] For large wind farm sites, the contributions of relatively distant turbines may be considered negligible and therefore shutting down these turbines would not be considered necessary. The relevant turbines and the method used (e.g. through predictive modelling) should be agreed as part of the Protocol if relevant.

Figure 7: Flow chart summarising the process for assessing compliance with the example planning condition



5 References

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Appendix A – Glossary of Terms

Term	Description
Amplitude modulation (AM)	A sound is modulated in amplitude when its level exhibits periodic fluctuations.
A-weighted	A filter that represents the frequency response of the human ear.
Acoustically relevant	When two environmental sound sources are present, if one source is 10 dB greater in level than the other, it is generally accepted the source with the lower level does not make an acoustically relevant contribution to the total noise level. In theory this results in an additional 0.4 dB (e.g. 40 dB + 30 dB results in 40.4 dB).
Background sound levels	The level of sound rarely fallen below in any given location over any given time interval, often classed according to day, quiet day, evening or night 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 m/s to 4.49 m/s.
Blade passage frequency	Rate or frequency at which the blade passes the tower during its rotation.
Critical Band	A range of audio frequencies that the human ear processes together, affecting how different frequencies of sound mask each other.
Day	07:00 to 23:00 local time, including daylight savings where applicable.
dB	Abbreviation for ‘decibel’: a logarithmic unit used to express sound level as perceived by the human ear'. The standard reference level for sound in air (0 dB) is defined as a pressure of 20 micropascals, which represents the threshold of human hearing.

Emission level	The noise level emitted by a source, often quantified as a sound power level.
Fast time weighting	An exponential time weighting applied to sound levels (defined in IEC 616721:2013 Electroacoustics - Sound level meters - Part 1: Specifications[9]).
Free field	A location that is not significantly affected by acoustic reflections (other than from the ground).
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.
Good practice	Detailed industry guidance on technical matters relevant to the implementation of these guidelines, such as that provided by the Institute of Acoustics[3].
Hertz (Hz)	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.
Hub height	The height of the centre of the rotor of a wind turbine above ground levels around the wind turbine.
Immission level	The level of noise at a receiver location quantified as a sound pressure level.
$L_{Aeq,T}$	The A-weighted energy average sound pressure level over the time interval, T
$L_{A90,T}$	A-weighted sound pressure level that is exceeded for 90% of a given time interval (T) measured using the fast time weighting, often used for the measurement of background sound. In the case of wind turbine noise assessment, the time interval T is 10 minutes.
LLV	Lower Limiting Value. This is the value of the fixed element of the noise limit and which is not related to a margin above background sound levels but is set at a fixed value irrespective of wind speed.
LOAEL	Lowest Observed Adverse Effect Level

ms	Millisecond.
Night	23:00 to 07:00 local time, including daylight savings where applicable.
Noise	Sound that evokes a feeling of displeasure in the environment in which it is heard and is therefore unwelcomed by the receiver. For the purposes of this guidance, sound from wind turbines is not considered desirable and is therefore considered to be noise. Conversely, general ambient sound (i.e. sound not associated with wind turbines) could contain desirable or undesirable elements and therefore is not assumed to be noise.
Planning Authority	The relevant council/body responsible for planning matters. This may include several authorities in some cases. May also be referred to as consenting authority where the Secretary of State is responsible for decisions.
Quiet day	Consists of periods of the day when background sound levels are often lower than other periods of the day. The quiet day consists of the following periods: evenings from 18:00 to 23:00, Saturdays from 13:00 to 18:00, and Sundays from 07:00 to 18:00.
Rated noise level	The level of wind turbine noise plus any adjustments (‘penalties’ or ‘corrections’) for the presence of tones or amplitude modulation characteristics.
Residual level	The level of sound measured at the assessment location not associated with the wind turbines being assessed.
Site specific noise Specific Noise Limit (SSNL)	The noise limit applicable to the development being assessed, accounting for the total noise assessment criteria (TNAC) and cumulative wind turbine effects.
SOAEL	Significant Observed Adverse Effect Level

Sound	Physically: a regular and ordered oscillation of air molecules that creates fluctuating positive and negative acoustic pressure above and below atmospheric pressure. Subjectively: the sensation of hearing excited by the acoustic oscillations described above (see also ‘noise’).
Standardised wind speeds	Standardised wind speeds are wind speeds at turbine hub height, converted to a height of ten metres for standardisation purposes with a formula using a ground reference roughness length of 0.05 metres (in accordance with the IEC 61400-11 standard[8]).
Tone	The concentration of acoustic energy into a very narrow frequency range.
Total noise assessment criteria (TNAC)	The criteria to be used when assessing total cumulative operational wind turbine noise, from which the site-specific noise limits SSNLs are derived.
Typical Background Sound Level	Describes the typical variation of background sound with wind speed, as is derived from a linear or polynomial regression analysis fitted to the measured 10-minute background sound levels (see 2.36).

Appendix B – Tonal Analysis

B.1. There are three main steps in the procedure:

- Narrowband FFT frequency analysis of the noise at receiver locations;
- Line classification determination of the sound pressure level of the tone(s) and the sound pressure level of the masking noise within the critical band;
- Evaluation of the difference between the tone and the masking noise sound pressure levels (ΔL_{tm}) by comparison with a criterion curve to determine the audibility of the most prominent tone and any related tonal character correction.

Frequency analysis

B.2. The analysis for tones shall be completed on audio recordings of 2-minutes duration within each overall assessment 10-minute interval. These 2-minute audio recordings shall each lie within each of the overall assessment 10-minute interval considered.

B.3. For each 10-minute interval where an audio recording is available, a recording shall be processed to yield a multi spectrum of sequential and contiguous individual narrow-band spectra using Fast Fourier Transform (FFT), sampled using the Hanning window, with a 50% overlap, with an FFT frequency resolution (Δf) of 3 Hz ± 0.5 Hz and an analysis bandwidth of 2 kHz[17], with spectral line magnitudes in decibels. This will result in each individual short-term FFT having a window length of between 0.29 to 0.4 seconds. An overall average narrow-band spectrum of the same frequency resolution shall also be obtained for the whole 2-minute sample (‘average FFT’).

B.4. The tonal analysis shall be completed on ‘A’ weighted noise levels. This may be achieved using ‘A’ weighting applied when recording the audio, or post-processed to apply ‘A’ weighting to the audio before the FFT, or applied to the FFT spectra. Applying the A-weighting to the recordings as a post-processing step has the benefit of retaining the ability to listen to un-weighted recordings when interrogating the data.

Determination of tone and masking levels

B.5. The bandwidth of a critical band is 100 Hz for critical bands with a centre frequency of between 20 Hz and 500 Hz and 20% of the critical band centre frequency for critical bands with a centre frequency greater than 500 Hz. If a single tone is present within a critical band, the critical band is centred upon the tone. If two or more, closely spaced

[17] It may be necessary in some specific cases to identify tonality at higher frequencies and therefore consider a wider bandwidth, with the aim being to ensure the same window length and same frequency resolution. If a wider bandwidth is considered in this way, this should be clearly identified by the acoustician.

tones are present within a single critical band, the critical band is placed so that it maximises the amount of tonal energy.

B.6. The 2-minute average FFT is used to look for potential tones (using an initial search for local maxima or peaks) in the average spectrum. This can be done for example by:

- Identifying any FFT line that is higher than the two adjacent lines; or
- Using a threshold test, where lines are tested by detecting a specified increase above a threshold followed later by a decrease of more than this threshold (when scanning the spectrum moving from left to right). This is confirmed by undertaking the same analysis scanning the spectrum moving from right to left. This specified threshold would typically be set relatively low in level (~1 dB). The peak is then identified as the maximum level in the interval identified.

B.7. Although this initial search can result in 'false positives', the method then determines whether each peak is a tone with sufficient magnitude to be classified as such, as well as determining the masking energy within each critical band.

B.8. For each of the local maxima identified in the average FFT from the initial search, a peak is classed as a tone if its level is more than 6 dB above the logarithmic average of the sound pressure levels of the rest of the lines in the critical band centred on the peak, but excluding one FFT line each side of the peak (these are initially classed as neither tone nor masking).

B.9. An iterative procedure is undertaken to classify all other lines in the critical band. The general process is that if the peak line qualifies as tone, the adjacent lines are also classified as tone if their level is within 10 dB of the peak and greater than 6 dB above the logarithmic average masking level (excluding lines either side of the initial peak). If an FFT spectral line is more than 6 dB above the logarithmic average masking level and more than 10 dB below the peak level it is classified as neither tone nor masking.

B.10. Because classifying a line as a tone means it can no longer be counted as masking, an iterative procedure is required for the proper identification of tones and masking. This is described by reference to the two worked examples shown in Section B.22 to B.24. This classification process should be repeated and the logarithmic average masking level recalculated following re-classification of any spectral lines within the critical band. Once no lines are re-classified, the next peak in the average FFT is then considered and so forth. The process is repeated for every critical band centred around peaks in the spectrum. The result is that within each critical band every spectral line is classified as tone energy, masking energy or neither. Having identified the lines in the average FFT contributing to tonal levels, masking levels or neither, the tonal analysis can continue.

B.11. The masking energy within a critical band is calculated from the average FFT. Calculate the masking level in the critical band (L_{pm}) correcting for a reduction in the number of lines due to the exclusion of tones and for use of the Hanning window:

$$L_{pm} = 10\ Log_{10} \sum 10^{\frac{L_m}{10}} \ + \ 10\ \mathrm{Log}_{10} \left[\frac{critical\ bandwidth}{1.5\ N_m \,.\, \Delta f}\right]$$

Where: L_m = sound pressure level of each line classified as masking noise.

N_m = number of lines within the critical band classified as masking noise.

Δf = FFT frequency resolution

critical bandwidth = width (Hz) of the critical band (B.5)

B.12. Having identified the tonal lines, if several distinct tones are present in a critical band, the critical band should be adjusted to maximise the tonal audibility. This process may need to be repeated where there are multiple tones and different critical bands. Once all critical bands have been determined, the process can continue.

B.13. For each of the individual FFT spectra of 0.29 to 0.4 seconds duration, calculate the tone energy within each critical band, L_{pt}', using those lines classified as 'tone' from the 2-minute average FFT spectrum. Where more than one line in the average FFT is classified as 'tone' within a critical band then the tone level for each of these short-term spectra is calculated as the energy sum of lines classified as 'tone' to yield L_{pt}' for each short-term spectra.

$$L_{pt}' = 10\ Log_{10} \sum 10^{\left(L_t/_{10}\right)}$$

Where: L_t is the sound pressure level of each line containing tonal noise.

B.14. The tone level used in the assessment, L_{pt}, is the arithmetic mean of the top 10% of the tone levels (L_{pt}'), from all the individual short-term FFTs constituting the 2-minute average FFT.

Evaluation of the audibility of the tone(s)

B.15. The audibility of a tone is dependent upon the tone level difference (ΔL_{tm}) and the frequency (*f*) of the tone:

$$\Delta L_{tm} = L_{pt} - \ L_{pm}$$

B.16. The audibility criterion is defined as follows:

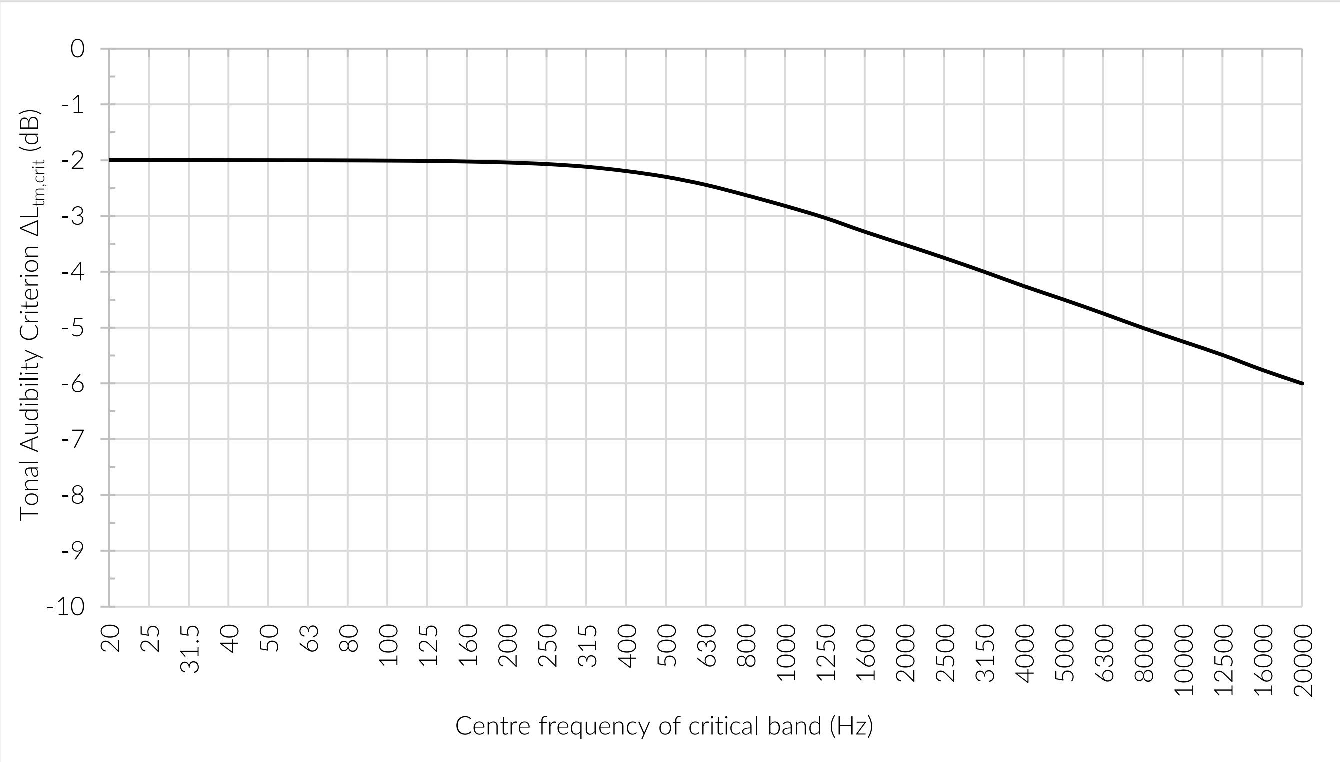
$$\Delta L_{tm,crit} = -2 - Log \left[1 + \left(\frac{f}{502}\right)^{2.5}\right]$$

B.17. This is the level at which the average listener will be just able to hear the tone. Figure 8 details the audibility criterion based upon the above equation. It can be seen from the figure that the audibility criterion is related to the frequency (*f*) which is the centre frequency of the critical band. For a single tone, the critical band centre frequency and the tone frequency will be similar. Where multiple tones are found within a critical band, the critical band centre frequency may differ from the frequency of the individual tones within the critical band.

B.18. The tonal audibility (ΔL_a) can be calculated from the audibility criterion as follows:

$$tonal\ audibility\ \Delta La = \Delta L_{tm} - \Delta L_{tm,crit}$$

Figure 8: Audibility criterion for tonal noise assessment



B.19. The resulting tonal audibility is used to calculate the associated character correction in the following section. The critical band with the greatest tonal audibility should be identified and used for calculating any related tonal character correction.

B.20. In cases where tones appear at low frequencies, it is advisable to investigate if the total tone level is above the average hearing threshold (e.g. BS EN ISO 389-7[10] or BS ISO 28961:2012[11]). If the total absolute tone level in a critical band, when correctly weighted and calibrated, is below the hearing threshold, this critical band is to be disregarded in the assessment of tonal audibility.

Tonal analysis outputs

B.21. Suggested analysis outputs for each 2-minute interval analysed are as follows:

- average FFT and classification of all lines (tone, neither or masking);
- each critical band containing tones and for this critical band, the centre frequency, total masking energy, total tonal energy, tone level difference, audibility criterion, tonal character correction, number of tones within critical band and the frequency and levels of the tone(s).

Tonal analysis worked examples

B.22. Figure 9 and Figure 10 show the stages in the tone identification and classification process. These are:

- Find peaks in the spectrum (line 23) using the initial search for local maxima.
- Calculate the average masking level in the critical band centred on each peak (28.8 dB), not including the peak and the two lines adjacent to the peak (line 22 & 24). This is the 'initial classification'.
- If the peak is more than 6 dB above the average masking level then the line is classed as 'tone' (line 23). Lines either side of the 'tone' are classed as 'neither' and the remainder are classed as 'masking'.

B.23. Reclassify spectral lines:

Pass 1

- Calculate new average masking level centred around the peak, for those lines classified as 'masking'.
- Compare spectral lines above and below the peak to the average masking level.
- If a line is more than 6 dB above the average and less than 10 dB below the peak then it is classed as 'tone', therefore lines 22, 24 and 25 are also classified as 'tone'.

Pass 2

- Calculate new average masking level centred around the peak, for those lines classified as 'masking'.
- Compare spectral lines above and below the peak to the average masking level.
- If a line is more than 6 dB above the average and less than 10 dB below the peak then it is classed as 'tone', therefore line 21 is also classified as 'tone'.

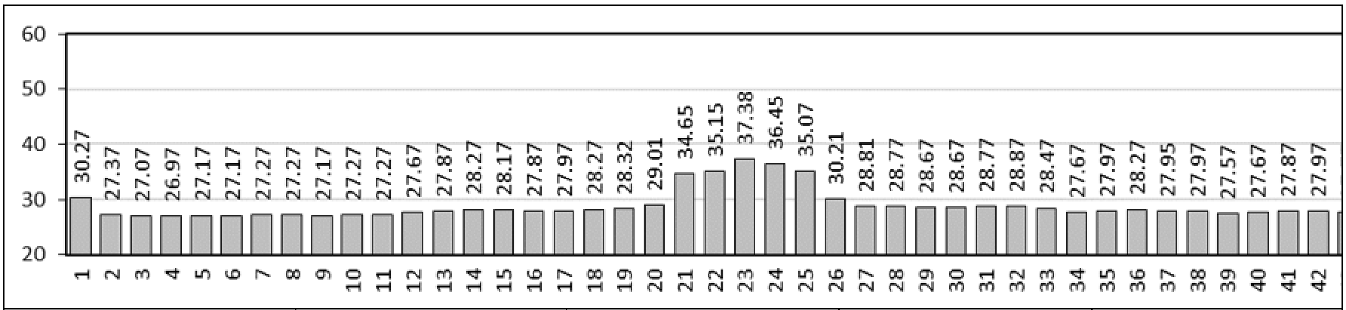
Pass 3

- Calculate new average masking level centred around the peak, for those lines classified as 'masking'.
- Compare spectral lines above and below the peak to the average masking level.

- If a line is more than 6 dB above the average and less than 10 dB below the peak then it is classed as 'tone'. There are no lines re-classified as 'tone' or 'neither' therefore the process stops.

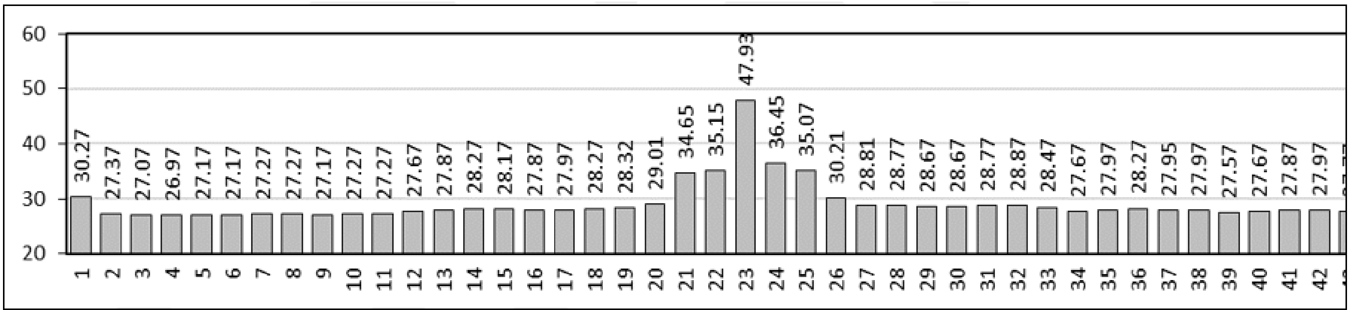
B.24. This process repeats for each pass until no lines are re classified and the process terminates. The number of passes required will vary depending on the spectrum shape. Figure 10 shows a further example of the stages in the tone identification and classification process using the same data as Figure 9 but where the tone is larger in magnitude leading to reclassification of adjacent lines as 'neither' in subsequent passes, terminating after the third pass does not identify any further lines to be 'neither'.

Figure 9: Tonal analysis worked example 1



	Pass:	Initial		1		2		3 (STOP)	
	Average Masking Level:	*28.81*		*28.46*		*28.10*		*28.10*	
Line	SPL	Class	Level above average masking	Class	Level above average masking	Class	Level above average masking	Class	Level above average masking
19	28.32	Masking	-0.49	Masking	-0.14	Masking	0.22	Masking	0.22
20	29.01	Masking	0.20	Masking	0.55	Masking	0.91	Masking	0.91
21	34.65	Masking	5.84	Masking	6.19	Tone	6.55	Tone	6.55
22	35.15	Neither	6.34	Tone	6.69	Tone	7.05	Tone	7.05
23	37.38	Tone	8.57	Tone	8.92	Tone	9.28	Tone	9.28
24	36.45	Neither	7.64	Tone	7.99	Tone	8.35	Tone	8.35
25	35.07	Masking	6.26	Tone	6.61	Tone	6.97	Tone	6.97
26	30.21	Masking	1.40	Masking	1.75	Masking	2.11	Masking	2.11
27	28.81	Masking	0.00	Masking	0.35	Masking	0.71	Masking	0.71
28	28.77	Masking	-0.04	Masking	0.31	Masking	0.67	Masking	0.67

Figure 10: Tonal analysis worked example 2



	Pass:	**Initial**		**1**		**2**		**3 (STOP)**	
Average Masking Level:		*28.81*		*28.46*		*28.10*		*28.10*	
Line	SPL	Class	Level above average masking	Class	Level above average masking	Class	Level above average masking	Class	Level above average masking
19	28.32	Masking	-0.49	Masking	-0.14	Masking	0.22	Masking	0.22
20	29.01	Masking	0.20	Masking	0.55	Masking	0.91	Masking	0.91
21	34.65	Masking	5.84	Masking	6.19	Neither	6.55	Neither	6.55
22	35.15	Neither	6.34	Neither	6.69	Neither	7.05	Neither	7.05
23	47.93	Tone	19.12	Tone	19.47	Tone	19.83	Tone	19.83
24	36.45	Neither	7.64	Neither	7.99	Neither	8.35	Neither	8.35
25	35.07	Masking	6.26	Neither	6.61	Neither	6.97	Neither	6.97
26	30.21	Masking	1.40	Masking	1.75	Masking	2.11	Masking	2.11
27	28.81	Masking	0.00	Masking	0.35	Masking	0.71	Masking	0.71
28	28.77	Masking	-0.04	Masking	0.31	Masking	0.67	Masking	0.67

Appendix C – Day LLV Examples

C.1 The following examples are intended to illustrate how the different factors affecting the appropriate choice of day LLV should be accounted for when determining the day LLV for a specific site. Note that the examples below are provided for purely illustrative purposes and are by necessity not exhaustive. Consideration of generating capacity may change depending on the evolving national context. The appropriate choice of day LLV needs to be determined by taking into account the relevant factors for the particular site under consideration and is therefore by definition site-specific.

Table 1: Case Study 1 – Small wind farm affecting low number of properties under prevailing conditions or with existing elevated noise levels

Case Study 1	Energy generation	Number of properties	Duration and level of exposure
Factor to be considered	1 MW generating capacity	2 non-involved properties where predicted operational noise levels are above 35 dB LA90	Both properties are upwind in the prevailing wind direction OR exposed to substantial existing water noise
Weight given to factor	Low generating capacity in the national context	Only 2 non-involved properties in relatively close proximity	Both properties unlikely to be downwind for a significant period of time

Resulting LLV	
A small-scale development with 2 properties in the vicinity and which are likely to be upwind for the majority of the time. The low generating capacity would strongly suggest an LLV towards the bottom end of the range, whereas the small number of properties and the relatively low duration of effect at these properties would increase the LLV. Considering all the factors in combination, a day LLV at the lower end of the range is appropriate.	Example resultant day LLV: 35-36 dB L_{A90}

Table 2: Case Study 2 – Small to mid-sized wind farm affecting relatively low number of properties under prevailing conditions

Case Study 2	Energy generation	Number of properties	Duration and level of exposure
Factor to be considered	10 MW generating capacity	8 properties where predicted operational noise levels are above 35 dB L_{A90}	Most of the properties are located such that they are downwind in the prevailing wind direction. No elevated background (rural).
Weight given to factor	Relatively low generating capacity in the national context	Moderate number of properties in relatively close proximity	Elevated proportion of the properties likely to be affected by noise under prevailing wind conditions

Resulting LLV	
A smaller scale (but not very small) development with several properties in the vicinity, mostly downwind for the prevailing wind direction. The relatively low generating capacity and the relatively frequent duration of exposure for the properties affected by noise would suggest a reduced LLV. Considering all the factors in combination, a day LLV at the lower end of the range is appropriate.	Example resultant day LLV: 35-36 dB L_{A90} (depending on site constraints)

Table 3: Case Study 3 – Moderate capacity wind farm affecting large number of properties under prevailing conditions

Case Study 3	Energy generation	Number of properties	Duration and level of exposure
Factor to be considered	20 MW generating capacity	One village with 30 properties where predicted operational noise levels are above 35 dB L_{A90} in addition to some isolated properties	The village is located in a direction which is downwind in the prevailing wind direction. No elevated background (rural).
Weight given to factor	Moderate capacity in the national context	Relatively high number of properties.	A village likely to be affected by noise under prevailing conditions

Resulting LLV	
A moderate scale development with a relatively large number of properties in the vicinity, downwind for the prevailing wind direction. The moderate generating capacity would indicate an increased LLV, but the relatively large number of properties affected by noise and the relatively high duration of exposure for these properties would indicate a reduced LLV. Considering all the factors in combination, a day LLV towards the lower end of the range is appropriate.	Example resultant day LLV: 35-37 dB L_{A90} (depending on site constraints)

Table 4: Case Study 4 – Moderate capacity wind farm affecting large number of properties under prevailing conditions

Case Study 4	**Energy generation**	**Number of properties**	**Duration and level of exposure**
Factor to be considered	40 MW generating capacity	12 properties where predicted operational noise levels are above 35 dB LA90	2 properties located downwind from turbines in the prevailing wind direction are close to a busy road. Other properties (lower background) are located upwind under prevailing wind directions
Weight given to factor	Moderate capacity in the national context	Moderate number of properties in relatively close proximity.	Low overall as properties with higher exposure duration have more elevated background.

Resulting LLV	
A moderate scale development, with a moderate number of neighbouring properties, some of which are downwind under prevailing conditions, but experience elevated background levels. The moderate generating capacity would indicate an increased LLV, the moderate number of properties affected by noise and the relatively high duration of exposure but for a small number of properties would indicate a reduced LLV. Considering all the factors in combination, a day LLV towards the middle of the range is appropriate.	Example resultant day LLV: 36-38 dB L_{A90} (depending on site constraints)

Table 5: Case Study 5 – Large wind farm affecting relatively low number of properties under prevailing conditions

Case Study 5	Energy generation	Number of properties	Duration and level of exposure
Factor to be considered	100 MW generating capacity	20 isolated properties where predicted operational noise levels are above 35 dB LA90	Most of these properties located such that they are downwind in the prevailing wind direction. No elevated background (rural).
Weight given to factor	Large generating capacity in the national context	Moderate number of properties in relatively close proximity, but not high considering the scale of the project.	Elevated proportion of the properties likely to be affected by noise under prevailing wind conditions

Resulting LLV	
A large-scale development with a handful of properties in the vicinity, mostly downwind for the prevailing wind direction. The large generating capacity and relatively small number of properties affected indicates a LLV towards the upper end of the range would be appropriate. However, the relatively frequent duration of noise exposure for the properties affected by noise would suggest reducing the LLV, unless this represented a disproportionate constraint. Considering all the factors in combination, a day LLV at the upper end of the range is appropriate.	Example resultant day LLV: 38-40 dB L_{A90} (depending on site constraints)

Table 6: Case Study 6 – Very large capacity wind farm affecting small number of properties under non-prevailing conditions

Casea Study 6	Energy generation	Number of properties	Duration and level of exposure
Factor to be considered	150 MW generating capacity	20 properties where predicted operational noise levels are above 35 dB L_{A90}	Most of the properties located such that they are not downwind in the prevailing wind direction. No elevated background (rural).
Weight given to factor	Very large generating capacity in the national context	Relatively low number of properties in relatively close proximity compared to extent of project	Most properties likely to be exposed to noise under infrequent weather conditions

Resulting LLV	
A large-scale development with a relatively small number of properties (relative to the scale of the development) in the vicinity which are not downwind under prevailing wind conditions. The large generating capacity, relatively low number of properties expected to be affected by noise and the relatively low duration of exposure would all indicate an increased LLV is appropriate. Considering all the factors in combination, a day LLV at the upper end of the range is appropriate.	Example resultant day LLV: 39-40 dB L_{A90} (dependant on site constraints)

This publication is available from: https://www.gov.uk/government/publications/assessment-and-rating-of-noise-from-wind-turbines-guidance