WHAT WOULD AN ALTERNATIVE TO ETSU-R-97 LOOK LIKE?

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1 INTRODUCTION

The currently recommended method for the assessment and rating of wind farm noise in the UK is that specified in ETSU-R-97[1]. The ETSU-R-97 report was developed by a dedicated Noise Working Group (NWG) which had been set in the early 1990s. Whilst this NWG was facilitated and chaired by the DTI, it is noted in the document that their output should not be considered a report of Government capable of replacing advice contained within relevant Government Guidance. Notwithstanding this position, Government planning advice has since recommended the adoption of the ETSU-R-97 methodology.

The NWG responsible for the drafting of the ETSU-R-97 document comprised interested persons from a cross-section of backgrounds, including three Environmental Health Officers, two independent acoustic consultants, five developers, a lawyer, the chair of the BS4142[1] committee from the National Physical Laboratory and a representative from ETSU itself.

ETSU-R-97 provides a discursive review of the deliberations of the NWG, including the need for a separate assessment methodology for wind turbine noise, and the recommended adoption of an approach which uses the relative to background approach of BS4142 as its starting point, but with fixed absolute lower noise limits overriding this approach in very low background noise environments.

Thus ETSU-R-97 is a document that has remained unchanged for nearly two decades, despite being heavily criticised by some throughout its life. Identified shortcomings concerning the consistency of its application have been tackled through the publication of additional good practice guidelines[2], as opposed to the ETSU-R-97 document itself being updated. Over this same twenty year period much else has changed:

- the maximum size of commercial scale wind turbines has increased;
- the maximum size of wind farms has also increased;
- more traditional on shore rural locations for wind turbine installations have evolved to increasingly include other areas (for example suburban regions, industrial regions, transport corridors and off shore);
- the possibility for closer adjacencies between neighbouring wind farms has increased, leading to the need for greater consideration of cumulative noise effects;
- the approach to wind turbine control has evolved from previously dominant ‘stall regulated’ technology to the now dominant ‘variable speed’ technology, thereby enabling much more control flexibility over the noise output characteristics of wind turbines;

- the planning policy and guidance landscape has changed;
- acoustic standards which were extant in the early 1990s (and which formed the basis of discussion for the ETSU-R-97 document) have been updated;
- understanding into the effects of noise on people has advanced; and
- knowledge and understanding in a number of areas has increased through experience.

The present paper aims to pose the question as to what form an assessment framework for wind turbine noise could take if developed from scratch (and so not as a development of the current ETSU-R-97 document) in the light of current knowledge, acoustic standards and guidelines, and in the context of the current planning framework. It should be stressed that the deliberations contained herein should not be interpreted as representing the views of the authors concerning the adequacy of ETSU-R-97, nor the authors' recommendations for any future developments of that document. Rather, this paper is intended to promote discussion amongst those members of the acoustics community interested in looking to the future of wind energy development in the UK.

2 CHANGES OCCURRING SINCE PUBLICATION OF ETSU-R-97

2.1 Planning Guidance

At the time of writing of ETSU-R-97 there existed two relevant Planning Policy Guidance (PPG) Notes: PPG 22 'Renewable Energy' and PPG 24 'Planning and Noise', both of which have now been removed from circulation. The current planning system relies on a revised raft of relevant guidance, comprising:

- National Planning Policy Framework (NPPF);
- National Planning Practice Guidance (NPPG);
- National Policy Statements (NPS) EN-1 and EN-2; and
- Noise Policy Statement for England (NPSE).

Due to the need to be brief in this paper these documents are not reviewed in detail, nor is a point by point comparison undertaken against the documents extant at the time of writing of ETSU. A number of pertinent comments at a more general level are, however, useful.

Extant guidance in both the NPSE and the NPPG (see the table referenced within paragraph 5 of the Noise Section of the NPPG) relates the assessment of noise impact to various so called 'Effect Levels'. These Effect Levels range from 'No Observed Effect' (which is the case when the noise is not noticeable), through 'No Observed Adverse Effect' (this being the case even though the noise may be perceptible) and then on through the 'Lowest Observed Adverse Effect', 'Significant Observed Adverse Effect' and finally to 'Unacceptable Adverse Effect' (which relates to the very highest levels of impact and the most extreme outcomes). The latter two categories are classed as being required to be 'avoided' and 'prevented' respectively.

Helpful descriptions are provided in the aforementioned NPPG table as to example outcomes that may arise from people being exposed to noise at the various effect levels. For perceptible noise these outcomes range from it being audible *'… but does not cause any change in attitude or behaviour …'* (at the No Observed Adverse Effect Level), through the noise causing *'… small* *changes in behaviour and/or attitude …'* (at the Lowest Observed Adverse Effect Level, with example outcomes also being provided), to *'extensive and regular changes in behaviour and/or an inability to mitigate the effect of noise leading to psychological stress or physiological effects …'* (at the Unacceptable Adverse Effect Level).

The approach adopted by ETSU-R-97 is essentially an acceptable/unacceptable criterion, with discussions appearing to indicate that the noise limits recommended in the document have fully accounted for other factors which may require consideration when setting the noise limits in accordance with extant guidance. Whilst a reasoned discussion is presented within ETSU-R-97 for the noise limits provided, and whilst some flexibility is provided for the choice of limits based on factors that it could be argued to take some other planning merits into account, it has been argued that the factors considered are by no means comprehensive. The factors comprise:

- the number of dwellings in the neighbourhood of the wind farm;
- the effect of noise limits on the number of kWh generated;
- the duration and level of exposure; and
- financial involvement.

2.2 Turbine Technology

At the time of writing of ETSU-R-97, large scale commercial turbines were typically up to around 0.5 MW generating capacity, with hub heights and rotor diameters up to around 50 m. They were also typically fixed speed (be this single or two speed) machines, with a mix of control mechanisms divided between more traditional 'stall regulation' and more modern (for the time) 'pitch regulation'. Current large scale commercial turbines are more typically up to around 3.0 MW generating capacity, with often 70 m plus tower heights and 80 m plus rotor diameters. With the increase in turbine size, minimum separation distances between turbines and residential dwellings has typically increased from around 500 m at the time of writing of ETSU-R-97 to 1 km or 2 km for larger wind farm developments comprising current large scale turbines. The combination of the foregoing factors has led to a systematic trend towards wind farm noise experienced at dwellings having a lower frequency biased spectral balance.

Another important development for modern turbines is the inclusion of more advanced control mechanisms, meaning that their noise output characteristics may be varied as a function of, amongst other factors, wind speed. The consequence of this technology is that the noise output of modern turbines can be controlled to enable noise limits to be met for certain wind speed and direction conditions rather it simply being a question of shutting turbines down or reducing numbers of installed turbines. In extreme circumstances the turbine noise profile, as it varies with wind speed, can be 'shaped' such that it closely follows any derived noise limit curve without providing the reduction in noise under lower wind speed or upwind propagation conditions which would otherwise be expected.

2.3 Likelihood of Cumulative Noise Effects

Not only have trends in wind farm locations and layouts changed over time, as previously discussed, but the tendency for multiple wind farms to be developed in acoustically close proximity to one another has also significantly increased. In some areas this is due to planning policy, and in others it is purely due to the availability of relatively large areas of land which share similar potential wind resource, and therefore for multiple landowners and developers alike to seek to maximise the potential for wind energy development on that land.

The potential problem with this situation from an acoustic perspective arises from the derivation of noise limits in ETSU-R-97 that are specifically stated as applying to the cumulative effects of all wind energy developments that may affect a given noise sensitive receptor. Once one development has ‘used up’ the allocated noise limit then it is not possible, theoretically at least, for other wind farms to be developed as they can be given no allocation of a noise limit because none is available. At the very least, if different developments are subject to the planning application process at the same time, the total derived ETSU-R-97 noise limit, which itself simply cannot be exceeded, must be appropriately apportioned between the various developments. It is understood that noise is the only environmental factor having such a lack of flexibility in the application of limits. All other environmental factors are allowed some degree of flexibility and judgment in deriving what is acceptable.

One particular consequence of the above is that increasing efforts are being expended on demonstrating the actual noise contributions of a particular wind farm development at a given noise sensitive receptor location under different propagation conditions; for example for differing wind directions. Traditionally, demonstrating that a wind farm could meet its ETSU-R-97 derived noise limits was done on the basis of the calculated noise levels under worst case downwind propagation conditions. However, under cumulative scenarios it is normally impossible for the various contributing wind farms to be simultaneously downwind of a given noise receptor. In fact it is frequently the case that when a noise receptor is downwind of one wind farm, then it is upwind of another. The two scenarios of upwind and downwind noise propagation would produce quite different noise immission levels at the receptor location. It would therefore seem only ‘fair’ that any such effects should be properly accounted for in order to derive a calculated noise immission level at the receptor location which will properly reflect what occurs in practice, rather than simply assuming that all wind farm developments simultaneously contribute to their individual maxima.

2.4 Increased Awareness of Factors Affecting 'Derived Prevailing Background Noise Level'

Integral to the process of the setting of noise limits in line with ETSU-R-97 is the derivation of the 'prevailing background noise' for the 'quiet day-time' hours and the ‘night-time’ hours for, or representative of, each assessment locations. The quiet day-time hours are defined as 1800-2300 every day plus Saturday afternoons and all day Sunday, and the prevailing background noise for this period is used to define the day-time noise limits. The prevailing background noise is defined as a best fit regression line through a plot of the multiple 10 minute L_{A90} background noise levels measured over the relevant quiet day-time or night-time periods which are plotted against the site measured wind speeds (usually by way of the simultaneous measurement of the corresponding 10 minute averaged wind speed at a single location on the site). This process effectively averages the background noise level at each integer hub height wind speed for these two time periods over the survey period. If the IoA Good Practice Guide recommendations are adopted, which they should be in most cases, then the wind speed is measured at, or derived for, hub height and 'standardised’ to 10 metres height. This latter ‘standardised’ process involves converting the hub height wind speed to a wind speed at 10 m height assuming a wind shear profile (i.e. variation in wind speed with height) corresponding to a reference roughness length of 0.05 metres. In such cases the effects of different wind shear conditions (which in reality also depend on atmospheric stability as well as roughness effects) over the survey period are also averaged in producing these prevailing background noise curves.

The final outcome of the derived prevailing background noise curves, which are used to set the value of the ETSU-R-97 limits except where background noise levels are very low, can depend to a greater or lesser extent on a number of factors. Such factors include the precise measurement location and the extent to which that location is affected by noise from trees and foliage and/or other noise sources, including the effects of any sheltering both from wind and other noise sources. The extent to which an optimum position (i.e. that giving the most conservative result, which equates to the lowest background noise curve) may be different for different wind speeds and directions and may also be affected by constraints imposed by residents. Although guidance is given in the IoA Good Practice Guide it is always going to be a matter of professional judgement of the equipment installer.

The results may also be influenced by the selected time period for the noise measurements. Such effects may include seasonal factors including, for example, leaf cover, running water courses, increased holiday traffic, agricultural activity or boiler flue noise. As above, although advice is provided in the Good Practice Guide, the significance of these factors will vary from location to location. The effect of wind direction and wind shear is effectively averaged over the survey, so questions often arise as to the ‘true’ representativeness of the chosen survey period.

The location at which the site wind speed is measured can also be crucial to the derivation of prevailing background noise, particularly if it is measured at 10 metres height. Even if it is measured at the optimum location (i.e. the mast for a site which is being assessed) this process can easily result in different limits being applicable to other potential sites in the same area, even for the same set of background noise measurements, due to the relative wind exposure of masts installed at the different sites. This has particular implications for cumulative assessments.

The choice of polynomial used for the curve fitting can also affect the results, as can the way 'outliers' are defined and dealt with. All of these factors should be judged by the person carrying out the assessment to give the most conservative result. However, there may not always be an optimum solution so again the need to exercise a degree of professional judgment may be required.

3 ALTERNATIVE APPROACHES TO ASSESSMENT

3.1 Max Noise Level Approach

3.1.1 Alternative 1 - No Baseline Measurements

Many of the uncertainties which arise with ETSU-R-97 are due to background noise in rural areas being related to the effects of wind on trees and foliage. This is because such environments are essentially quiet for much of the time, with increases in background noise only occurring when the wind blows. However, how much of this increase is reflected by the derived prevailing background noise curves for each location can be influenced by one or more of the factors identified above. A solution to this would be to dispense with such baseline monitoring in rural areas and to simply limit the maximum noise level generated by wind turbine sites to an agreed, set level.

The above option of a single fixed noise limit is made possible by the way noise from modern pitch regulated turbine designs remains constant above rated power. This was generally not the case when ETSU-R-97 was published. At that time the noise output of the more common stall regulated machines kept on increasing with increasing wind speed, regardless of whether or not rated power had been reached. It was primarily for this reason that the masking effects of higher (wind dependent) background noise levels at higher wind speeds were relied upon to set noise limits. Indeed, even with the application of the ETSU-R-97 process, and particularly as turbine height increases, it is sometimes a fact that the predicted turbine noise at wind speeds above rated power is in any event compared with the lower limiting values of the noise limits. In such cases the existing background noise level isn't actually taken into account in the assessment at all, but rather is only used for the purpose of setting the limits in any planning conditions on noise.

What would need to be determined for this approach is, of course, the relevant value of such a maximum limiting level for the turbine noise. Given the flexibility already embedded in the ETSU-R-97 process for the selection of a fixed lower absolute noise limit, such a limt could be in the range from 35 dB L_{A90} to 40 dB L_{A90} (or even 45 dB L_{A90} for involved properties) without deviating significantly from the current ETSU-R97 approach, although clearly the assessment index to be used would have to be given due consideration. A similar flat limit is currently being considered as an alternative to the existing approach in Ireland[3] with a study being carried out to determine the effect of different limits, within a specified range, on energy generation from wind power.

Although this approach is principally aimed at variable speed pitch regulated turbines, consideration would have to be given to how this would affect stall regulated turbines, possibly with such a limit only applying up to 12 m/s as this the case with the current ETSU-R-97 limits. A possible issue arises with the Environmental Impact Regulations requiring consideration of baseline, but this is often side-stepped already when the ETSU-R-97 'simplified' noise limit of 35 dB L_{A90} is applied to the assessment irrespective of baseline for single turbines and more remote sites.

3.1.2 Alternative 2 - Incorporating a Correction for Non-Wind Related Baseline

Although the approach identified in Alternative 1 could be deemed to be valid in rural areas, some dispensation might be appropriate for developments in urban areas or close to transport corridors. Non-wind related background noise is likely to be less susceptible to precise measurement location, and any masking effects of turbine noise could be more significant. This is the approach used to assess non-wind related generators of noise, such as those assessed using the recently revised BS4142[4], where low wind speed conditions represent the most conservative baseline conditions.

This requires a definition of determining a non-wind related baseline noise environment, such as possibly rejecting baseline data for ground level (microphone height or similar) wind speeds above a certain speed, such as the <5 m/s recommendation of BS4142.

Given the high likelihood of the variation of a non-wind related baseline noise environment with time of day, consideration would need to be given to what measurement periods would be used. It may be appropriate, for instance, to determine the baseline for hourly periods with different limits to apply to each hour of the day.

To be very robust, the baseline could be a combination of an average minus one or more standard deviations for each measurement period, especially if these covered longer periods (e.g. night, evening, day-time, day-time with weekend day-time periods being considered separately, etc.). It may be observed that the two periods used by ETSU represent times when the baseline in more populated areas or along transport corridors are most changeable, a feature which can result in large amounts of scatter in the background noise charts.

Finally, if the non-wind related baseline noise characteristics were determined in this way, then consideration would need to be given to the method for setting noise limits relative to the baseline, possibly in the first instance by reference to the considerations of latest edition of BS4142.

3.2 Noise Dose Approach

3.2.1 Alternative 1 – Noise Dose (No Baseline Measurements Required

Following on from the noise dose approach adopted by the World Health Organisation[5] for quantifying noise at night, it could be a much more useful approach to assessment of impact to assess a yearly noise dose, probably quantified as L_{den} in line with the European Noise Directive[6], as a residential property in the prevailing wind direction receives potentially greater impact than one in the opposite direction. Also, a wind farm where there is relatively low wind resource has less impact than one where there is a high wind resource. This is the approach now taken in the Netherlands[7], although that approach doesn't include wind direction effects.

Such an approach would require an 'acceptable' dose to be set which would, of course, be different to the L_{A90} limits set in accordance with the approach of ETSU-R-97. The limits could take the form of the aforementioned L_{den} levels, or for the night-time the current WHO criterion of 40 dB $L_{night,outside}$ could be readily adopted. One issue is that such a noise dose based approach could lead to practical problems relating to compliance measurements at noise-affected receptor locations. Such measurements would require the collection of long term noise data, but with no real chance of correcting that data for the influence of non-wind farm noise. An alternative, which is already adopted in some countries, could be to undertake compliance measurements of the sound emissions of the installed wind turbines ‘at source’, and to then apply these data (coupled with long term wind distribution data) to an agreed sound propagation model capable of determining the annual L_{den} noise dose.

3.2.2 Alternative 2 - Noise Dose Change

A possible variation on the above might be to evaluate the noise dose change, as discussed in Reference 8. This option presents an ideal situation from the point of view of Environmental Impact Assessment as it precisely quantifies the noise dose change. However, the method does go back to the requirement for comprehensive baseline noise measurements correlated with wind speed. The results at specific wind speeds and for different wind directions would still be taken into to account, but individual data points are likely to have a less significant effect than in the ETSU-R-97 procedure. The procedure would involve quantifying the noise dose received with and without the wind farm. Whilst consideration would additionally need to be given to what constitutes an acceptable noise dose change, this might be easier to quantify than what an acceptable noise dose (as opposed to the change in noise dose) might be. Consideration would have to be given as to how to deal with existing wind farms to prevent the creeping background effect: if assessments were only based on an acceptable level of change, then the noise dose could keep increasing with every new development in area. A possible solution might be to identify an appropriate change in noise dose but only up to the point at which an acceptable overall noise dose would be exceeded.

3.3 Variable Noise Limit with Wind Speed

3.3.1 Alternative 1 - Based on Assumed Background Noise Curve (No Baseline Measurements Required)

A further approach worthy of review is one based on an assumed baseline/background noise curve. This is an approach which has been used in the State of Ontario, Canada[9]. A similar approach has also been used, to a certain extent, in some UK Planning Authority assessments where there has been doubt about the validity of the measured background noise data[10].

Essentially this would result in noise limits that are the same or similar to those in ETSU, possibly with further consideration being given to the lower limiting value applicable at night and the value selected in the 35-40 range for daytime, but the same background noise curve is applied at every site for every location. This background noise curve would be selected to be generic for the type of area being considered. The choice of background noise curve could depend not just on the remoteness of the area being considered, but also on the topography. For example, for a flat site with minimal height change between the housing and the height of the turbine bases there is likely to be more change in baseline noise with wind speed than for housing in a valley overlooked by a ridge with turbines on it. This would, however, require clear criteria/parameters to determine which curve to apply in specific circumstances.

3.3.2 Alternative 2 - Variable Noise Limit with Wind Speed based on Average Baseline Across the Site

One further approach which has been used or agreed to on occasions is, as above, to base the limits on ETSU-R-97, with the caveats in respect of the lower limiting values, but based on average (or even minimum) baseline data measured across the whole site. To formulate this, measurements would be carried out at an agreed number of locations across the site with the results averaged for each wind speed and then used to form the site noise limits. In common with the noise dose change approach discussed above, this would reduce the criticality of noise levels at specific locations, with particular approaches being put in place to either screen out clear outliers or to incorporate them in some other way.

4 APPROACH TO LEVEL OF IMPACT

With all the alternative methods discussed above it might be preferable to incorporate a graded approach to assessment, more in line with the recent changes to planning guidance discussed above, rather the current acceptable / unacceptable criterion of ETSU-R-97. As an example, a change in noise dose of less than 1 dB could be classed as negligible, 1 - 3 dB could be minor, and greater than 3 dB a major change. Likewise a noise dose of less than 40 dB L_{den} could be classed as negligible, 40-45 as minor and greater than 45 dB as major. These are not recommendations and not informed by considerations of any particular effects, but merely intended to be illustrative etc.

In a similarly illustrative manner, exceedance of the maximum and variable noise limits discussed above by 0 dB to 5 dB could be classed as minor, 5 dB to 10 dB as major or, for the variable noise limit approach some account of the percentage of time predicted exceedances of the limits would occur might need to be taken into account. It should be noted that this approach is essential if the ‘planning balance’ is taken out of the setting of any noise limits insofar as only inaudibility is a guarantee of no noise issues arising, and anything above inaudibility incorporating a judgement of reasonableness must constitute an element of planning balance.

Acoustic character corrections would need to be considered, but it is recommended that these are separately addressed.

Cumulative issues would, however, have to be considered, especially with regards to duration of exposure. The noise dose approaches above could assist with this, but the fixed noise limit approach may need to include some consideration of duration.

5 APPROACH TO LIMITS AND ‘COMPLIANCE’

Because of the difficulty of measuring turbine noise in the environment due to its comparability, in many circumstances, to background noise levels, but also as a consequence of the general agreement over the noise prediction methodology recommended in the IoA Good Practice Guide, consideration could additionally be given to desk based assessments of compliance using agreed standards. This option has already been discussed in 3.2.1 above where it was discussed how any such assessments would need to be supplemented by measured sound power levels from at least a selection of installed turbines using an agreed noise quantification methodology, such as that of IEC61400-11[11].

Measurements of acoustic character features (ie. tones, amplitude modulation, impulsiveness) could however be made at affected properties as required and dealt with as necessary following agreed conventions.

6 CONCLUSIONS

The current recommended methodology for the assessment of noise from wind turbines in the UK is ETSU-R-97. Throughout its life of nearly two decades now, the ETSU-R-97 methodology has been the subject of various criticisms including the extent to which it truly delivers the balance intended between not unduly stifling the development of wind energy in the UK whilst at the same time providing the necessary noise protection to wind farm neighbours. Despite these attacks, ETSU-R-97 has remained unchanged, even though many factors which were considered to be pertinent during its development have changed to one degree or another in the intervening years. Such factors include: the increased physical size of wind turbines and wind farms; the construction of wind farms in ever more diverse areas; closer adjacencies between neighbouring wind farms leading to cumulative noise effects; changes to wind turbine control mechanisms to allow flexibility over the noise output characteristics of wind turbines; changes to planning policy, guidance and acoustic standards; greater understanding into the effects of noise on people; and increased knowledge and understanding in a number of areas through experience.

In light of the foregoing changes, the question posed in the paper is what form a methodology for wind farm noise assessment would take today, were this methodology to be developed from scratch in cognisance of today's knowledge and planning framework, and also unencumbered by the existence of a previous methodology in ETSU-R-97.

The discussion presented in the paper points to the possibility that a new assessment methodology would likely not have a simple pass/fail assessment criterion based on set noise limits. Rather, it would more likely aim to provide an assessment of likely impact in line with various noise impact effect levels that form the basis of current planning policy and guidance. The significance of these noise effect levels would then feed into the planning decision making process to be evaluated alongside all other relevant merits and/or adverse impacts of the proposed development.

The discussions also consider the possibility that any newly developed assessment methodology for wind turbine noise should not necessarily be based on a 'relative-to- background' approach. This debate has partly been based on changes in the noise output characteristics of wind turbines as a function of wind speed (which has fundamentally changed since ETSU-R-97 was written), and partly in recognition of the problems associated with agreeing the acceptability of background noise curves on which to base noise limits, and on testing compliance with such limits once a wind farm becomes operational. A number of alternative possibilities for the setting of noise limits which don't involve the measurement of existing wind speed dependent baseline noise levels are discussed. These include the adoption of fixed absolute noise limits, or noise limits set relative to non-wind related baseline noise levels or agreed generic background noise curves and noise 'dose' related limits.

Possibility is also raised of compliance with the chosen limits being established on the basis of measurements of sound power output on a sample of the installed turbines, coupled with the use of an approved noise prediction methodology to establish noise immission levels at wind farm neighbours, rather than requiring the actual measurement of noise immissions at those neighbouring properties.

7 REFERENCES

1. ETSU-R-97, The Assessment & Rating of Noise from Wind Farms, UK Department of Trade and Industry (1996)

2. A Good Practice Guide to the Application of ETSU-R-97 for the Assessment and Rating of Wind Turbine Noise, UK Institute of Acoustics (2013)

3. Proposed Revisions to Wind Energy Development Guidelines 2006 - Targeted Review in relation to Noise, Proximity and Shadow Flicker, Irish Government Department of Environment, Community & Local Government (2013)

4. BS4142, Methods for Rating and Assessing Industrial and Commercial Sound (2014)

5. Night Noise Guidelines for Europe, World Health Organisation (2009)

6. Directive 2002/49/EC of the European Parliament relating to the Assessment and Management of Environmental Noise (2002)

7. Netherlands Staatsblad 2010 Nummer 749, Decree amending the Decree on General Rules for Environmental Management and the Environmental Law Decree (Amendment environmental rules wind turbines) (2010)

8. A.R. McKenzie, Noise Dose Assessment of Wind Farm Noise, Acoustics Australia 40 (1) (2012)

9. Ontario Ministry of the Environment, Noise Guidelines for Wind Farms - Interpretation for Applying MOE NPC Publications to Wind Power Generation Facilities (2008)

10. Perth & Kinross Council, Supplementary Planning Guidance for Wind Energy Proposals in Perth & Kinross (2005)

11. IEC 61400-11, Wind turbines – Part 11: Acoustic noise measurement techniques, Edition 3 (2012)