The Social and Economic Impact of Rural Wind Farms

Submission to the Senate Community Affairs Committee by

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The subject of the enquiry is particularised by invitation to comment on the following:

1. Any adverse health effects for people living in close proximity to wind farms;
2. Concerns over the excessive noise and vibrations emitted by wind farms, which are in close proximity to people's homes;
3. The impact of rural wind farms on property values, employment opportunities and farm income;
4. The interface between Commonwealth, state and local planning laws as they pertain to wind farms; and
5. Any other relevant matters.

The following submission relates primarily to noise which is the area of my expertise.

HEALTH EFFECTS – ITEM 1

Assessment using the dB(A) frequency weighting

The World Health Organisation (WHO) Guidelines for Community Noise was adopted by the WHO in 1999. The guideline summarises the health effects of noise on man and makes certain recommendations to protect health. The recommendations are based on sound levels inside a bedroom to allow for undisturbed sleep. The internal sound levels are then approximated to an equivalent outdoor sound level using a simplistic attenuation factor of noise from outside to inside a dwelling of 15 dB. It should be remembered that it is the indoor sound level target that matters and that lower sound attenuation from outside to inside of 5 to 7 dB may apply.

Since that time 'The health effects of environmental noise – other than hearing loss' published by the Commonwealth of Australia enHealth Council, May 2004 recommends adoption of the World Health Organisation's 'Guidelines for Community Noise'. The Environmental Health Committee (enHealth) is a subcommittee of the Australian Health Protection Committee (AHPC).

The following extracts are from the WHO Guidelines for Community Noise 1999 pertaining to sleep disturbance, consideration of vulnerable groups and the derivation of outside noise levels that correctly reflect the indoor sound level target.

> *10.4 Consideration of Vulnerable Groups*
> The evaluation of noise effects and related protective standards are virtually based on data from "normal", "average" people. They are usually adult participants of investigations, selected as representative samples of the general population, or sometimes because of availability. However, people having less abilities and/or possibilities to cope with the impacts of noise exposure, and thus being at greater risk for harmful effects, might be

underrepresented or insufficiently considered in noise protection necessities.

Examples of vulnerable groups are: people with particular diseases or medical problems (e.g., high blood pressure), people in hospitals or in rehabilitation, people dealing with complex cognitive tasks, the blind, people with hearing impairment, babies and young children and elderly in general.

For every noise protection guideline the issue of vulnerable subgroups of the population has to be considered. This is valid for types of effects (communication, recreation, etc.) as well as for places of exposure (home, workplace, public institutions, etc.).

10.6.3 Sleep Disturbance

Sleep disturbance due to continuous, as well as intermittent noise, has been demonstrated by electrophysiological and behavioral methods. The more intense the background noise is, the more disturbing is its effect on sleep. Measurable effects start from about 30 dB LAeq. Physiological sleep effects include changes in the pattern of sleep stages, especially a reduction in the proportion of REM-sleep. Subjective effects have also been identified such as difficulties in falling asleep, perceived sleep quality, and adverse after effects like reported headache and tiredness. The sensitive groups are believed to include mainly elderly persons, shift workers, persons who are especially vulnerable due to physical or mental disorders, and other individuals who have sleeping difficulties.

The probability that sleep will be disturbed by a particular noise depends on a number of factors including the interference criterion used (e.g., awakening or solely EEG changes), the stage of sleep, the time of night, the character of the noise exposure, and adaptation to the noise. Individual differences in sensitivity are pronounced. Although systematically collected field data on sleep disturbance are limited, there is some consensus of opinion that where noise exposure is continuous, the equivalent continuous sound pressure level indoors at night should not exceed approximately 30 dB LAeq if negative effects on sleep are to be avoided.

Low frequency noise, for example, from ventilation systems, can disturb rest and sleep even at low intensity. In the presence of a large proportion of low frequency sounds a still lower value than 30 dB LAeq would be needed. It should be noted that the adverse effect on sleep partly depends on the nature of the noise source.

Sleep disturbance increases with increased maximum sound pressure level. Even if the total equivalent continuous sound pressure level is fairly low, a small number of noise events with a high maximum level will affect sleep adversely. Therefore, guidelines for community noise to avoid sleep disturbance should be expressed not only in terms of equivalent sound pressure level but as maximum levels, and number of noise events during night, as well.

If the noise exposure is not continuous, the maximum sound pressure level is best correlated to sleep disturbances. Effects have been observed at individual exposures of 45 dB LAmax, or even less. It is especially important to limit the noise events exceeding 45 dB LAmax especially where the background sound pressure level is low; in fact, to protect sensitive persons a still lower guideline value would be preferred. Measures reducing disturbance during the first part of the night can be predicted to be most cost effective. In the first place, efforts should be made to reduce the sound pressure level of noise maxima and the number of noise events before focusing on reducing the equivalent level.

Sleep disturbance is the critical effect in bedrooms, in dwellings and preschools. Recommended guideline values inside bedrooms are 30 dB LAeq for steady-state continuous noise, and for a noise event 45 dB LAmax, preferably even lower, about 40 dB LAmax. Lower sound pressure levels may be annoying depending on the nature of the noise source. The maximum level should be measured with the instrument set at ”fast”.

At nighttime outdoors, sound pressure levels should not exceed 45 dB LAeq, so that people may sleep with bedroom windows open. This value has been obtained by assuming that the reduction from outside to inside with the window open is 15 dB; note that the actual reduction may be less in some cases, maybe only 5-7 dB, which then would mean that the sound pressure level outdoors needs to be kept at or below 35-37 dB LAeq.

10.7 Summary
..... Inside bedrooms the sound pressure level should not exceed 30 dB LAeq for steady-state continuous noise, and for a noise event not exceed 45 dB LAmax, preferably even lower (maybe 40 dB LAmax). Still lower levels may be annoying depending on the nature of the noise source. At nighttime, sound pressure levels outdoors should not exceed 45 dB LAeq, so that people may sleep with bedroom windows open. Even lower levels may be required pending the design of the window opening, maybe 35-37 dB LAeq outdoors.

In 2009 the WHO published an update to the Guidelines for Community Noise that summarised recent research on the health effects of noise. The update is called “Night Noise Guidelines for Europe” (NNGE). Its relationship to the WHO Guidelines for Community Noise is stated in the Abstract as follows: “These guidelines are applicable to the Member States of the European Region, and may be considered as an extension to, as well as an update of, the previous WHO Guidelines for community noise (1999).” Furthermore, it states in the Executive Summary that “The 1999 guidelines are based on studies carried out up to 1995 (and a few meta-analyses some years later). Important new studies (Passchier-Vermeer et al., 2002; Basner et al., 2004) have become available since then, together with new insights into normal and disturbed sleep. New information has made more precise assessment of exposure-effect relationship. The thresholds are now known to be lower than LAmax of 45 dB for a number of effects.”

Section 1.3.5 of the NNGE discusses the attenuation of sound from outside to inside for the average year. There are no attenuation values described that are representative of rural dwellings in Australia and I see this as a key area warranting research. With this information it will be possible to set outside noise level targets that meet the WHO recommendations that are accepted by enHealth.

The full NNGE is attached for reference.

Another related effect on health is noise nuisance. The commonly used noise impact assessment approach of “Background plus 5dB” is regularly applied to noise from wind farms. A summary of the use of this approach is described in my paper “Review of the Application of NZS6808 to wind farms in Australia.” L Huson & Associates Pty Ltd, Victoria, Australia, published in proceedings of Acoustics 2006, Joint Conference of the NZ and Australia Acoustical Societies, Christchurch, November 2006.

The principal behind the “Background plus 5dB” assessment approach of the NZS6808 wind farm standard and AS4959 is that it is assumed that small increases above the ambient soundscape is tolerable and that sounds below ambient sound levels are masked. This assumption can be very wrong for the current assessment methodology used for wind farms in Australia. By way of illustration the following is found in the NNGE in section 1.3.6

> “A simple definition of background level or “ambient noise” level is the noise that is not targeted for measurement or calculation. Background noise can interfere with the target noise in a number of ways. It can:
> • mask the signal
> • interact physically
> • interact psychologically.
>
> As this report is often dealing with low-level target noise, masking is an important issue. The other two interactions are more important in the domain of annoyance. Masking, however, is a complex process. The human auditory system is uncannily good at separating signals from “background”.Microphones (and the software behind them) have been slow to catch up, as the unsatisfactory results show when it comes to automatically recognizing aircraft in long-term unmanned measuring stations.
> The rule of thumb that a noise can be considered masked if the signal is 10 dB below the background is only valid if the noises have the same frequency composition and if they actually occur at the same time. This is particularly important to stress where LAeq levels are compared: even a relatively continuous motorway of 50 dB cannot mask aircraft noise of 30 dB, because this may be composed of five aircraft arriving at an LAmax of 57 dB. Neither can birdsong, because the frequency domains do not overlap.”

The problems encountered with reference to masking above, when LAeq levels are compared, is exacerbated when LA90 levels are compared. For example, continuous sound from crickets in the evening in the 2kHz to 3kHz frequency range will have no masking effect on noise from wind turbines and this type of noise can easily be identified at sound levels below the ambient LA90 caused by crickets. Another problem arises when using LA90 to assess wind turbine noise emissions is the characteristic of sound from the blade movement and the gearbox in the nacelle. The swish – swish sound level of the rotating turbine blades occurring at a repetition rate of typically 1 Hz will be underrepresented in the LA90 measurement parameter since the resulting sound level is that level exceeded for more than 90% of any measurement period. Therefore, the maximum sound level from any ‘swoosh’ will be higher than the reported LA90 level.

In contrast to the “Background plus 5dB” approach, Denmark has chosen a simpler assessment methodology. The advantage of this approach is that the assessment does not take weeks to complete and the foibles of the “Background plus 5dB” are removed in preference for only two measurement results at 6m/s and 8m/s (which is normally the region of operation known to cause the most compliance problems for Australian wind farms). The full Danish directive is shown in Appendix A.

RECOMMENDATION 1

Irecommend the adoption of an assessment methodology similar, if not identical, to that operating in Denmark. The target noise levels for compliance at rural Australian dwellings would be different to those in Denmak if a study to determine the correct outside to inside noise attenuation value is at variance with the 15 dB default value suggested in the WHO Guidelines for Community Noise.

INFRASOUND AND LOW FREQUENCY NOISE

The NNGE does not refer to infrasound research and associated health effects. However, research by Castelo Branco et al. (2003) is referenced in the Appendix as follows:

> "Castelo Branco et al. (2003) studied Wistar rats born under low frequency noise exposure. The third octave level of the applied broadband noise was > 90 dB for frequencies between 50 and 500 Hz. The broadband level was 109 dB(lin). The exposure schedule was chosen as a model for occupational noise: 8 hours per day, 5 days per week, and weekends in silence. Third generation rats born in low frequency noise environments were observed showing teratogenic malformations including loss of segments.

The frequency range for this experiment covers the typical wind farm dominant noise emission around 500 Hz. However, the sound levels used in the experiment were some 40 dB above anything likely to be observed from wind turbines at typical dwelling distances when measured in dB(A). The reference shows that high low frequency noise levels can have effects on health.

If we were to investigate lower frequency sound levels from wind farms we cannot use the C-weighting or the A-weighting since these attenuate low frequency sound <20 Hz significantly. The G-weighting is designed to quantify infrasound below 20 Hz.

The following chart is an extract from a UK DTI report prepared by Hayes Mckensie Partnership in their report on low frequency noise in 2006. It shows that a significant amount of infrasound energy can be generated from a wind farm (in this case some 35 dB(G) above ambient at higher wind speeds).

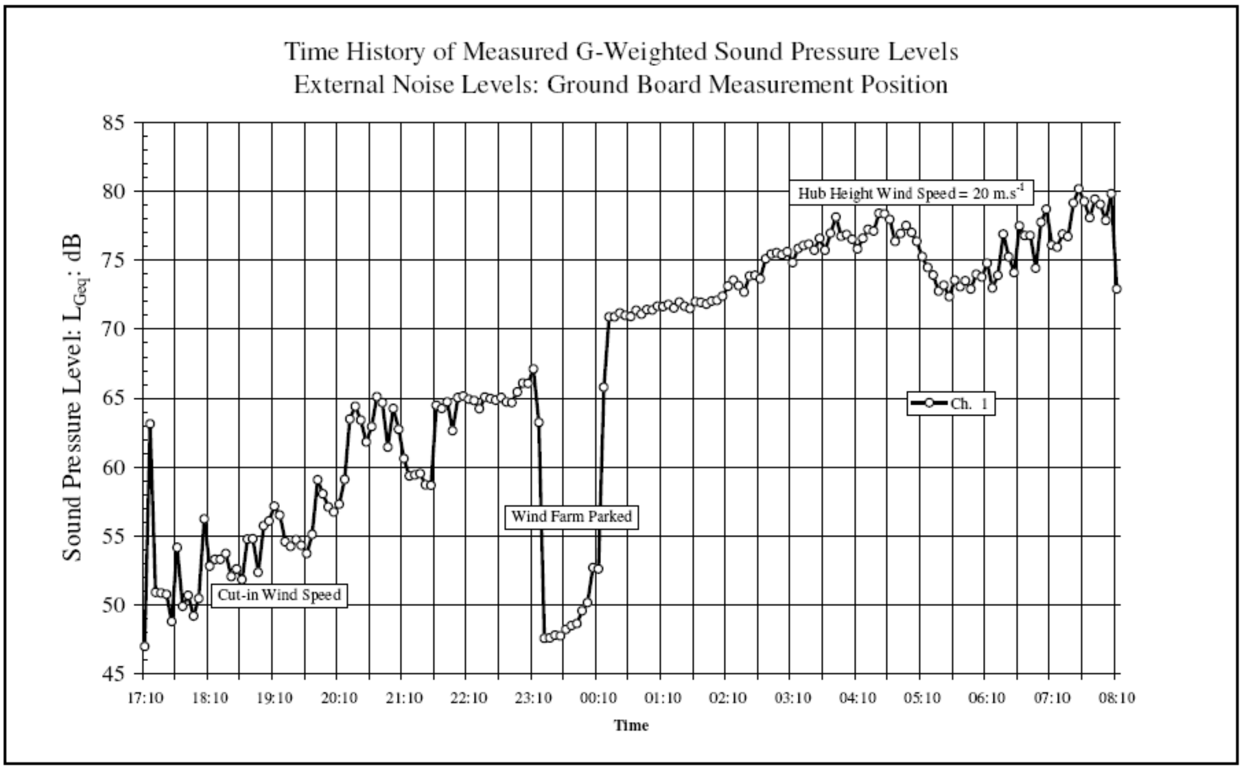

Figure 12: Time History Figure of G-Weighted Sound Pressure Levels for a Wind Farm
Extract from UK DTI Low Frequency Noise Report by Hayes Mckensie 2006

The measurement data was obtained >360m from modern wind turbines operating in the UK. A statement that I regularly see is that 'infrasound is not a significant feature of modern wind farms ‘(e.g. SA wind farm guidelines, NZS6808 and noise impact assessment reports in Australia) is clearly not true.

Another fallacy is that infrasound attenuates from a wind turbine at the rate of 6 dB per doubling of distance. Work by the German Federal Institute for Geosciences and Natural Resources is described in an attached presented at the Infrasound Workshop, November 28 – December 02, 2005, Tahiti. Their analysis and predictions of infrasound propagation are shows with the conclusion that infrasound propagation is such that the sound pressure level is inversely proportional to distance from the wind turbine. This means an attenuation of only 3 dB per doubling of distance, not 6 dB as commonly assumed. The German research relates only to sound frequencies below about 9 Hz, which is the upper frequency limit of their equipment. The equipment used is well proven for detecting both the direction and amplitude of infrasound. The ANU operates a similar infrasound monitoring station in Australia for detection of nuclear explosions via triangulation with other world wide monitoring sites.

The spectra and time history plot in the German presentation clearly show pressure pulses from each blade rotation. Spectral peaks dominate at blade passing frequency and harmonics.

A recent publication “ Infrasound Measurements from Wind Farms and Other Sources” prepared by Sonus for Pacific Hydro can be found on their web site.

I have reviewed the data presented in the Pacific Hydro commissioned report and find that the report draws very questionable conclusions.

The report is based on hub height wind speeds between 6m/s and 8m/s, which will be unrepresentative of higher wind speeds. The Low frequency noise report for the UK DTI in 2006 (referred to above) has in Figure 12 a measurement of dB(G) 360m from a wind farm (does not state if the distance is that to the nearest turbine or just the wind farm boundary) where 80 dB(G) is measured for a hub height wind speed of 20m/s. This is about 15 dB(G) higher than the 6 - 8 m/s result.

The novel infrasound measurement methodology proposed and used in the Sonus report has not been verified as being an alternative to the method described in IEC614000-11, despite the claims that it has. The report states that a Svantek 957 sound level analyser was used, yet that concurrent measurements were taken for the verifications. Concurrent / simultaneous measurements can only be taken if there are two microphones (the Svan 957 accepts one microphone input only).

The Svan 957 does not calculate dB(G) directly, it has to be calculated from summation of 1/3 octave band measurements.

The 1/3 octave band sound levels measured inside and outside a dwelling are interesting (Tables 8 and 9). Blade passing frequencies are typically in the 1Hz 1/3 octave band and at this frequency the results show that the indoor sound level was 13 dB higher than outside the dwelling. Harmonics of blade passing are typically up to 5 Hz and the data from these tables show that indoor sound levels up to the 2.5 Hz 1/3 octave band are consistently higher indoors than outdoors, even though the overall dB(G) level is lower indoors than outdoors.

I am very surprised by the simplistic approach taken and used incorrectly in the Sonus report to describe the reduction of sound with distance from a sound source. For a point sound source on the ground the decrease in sound pressure level with distance from the sound source decreases by 6dB with each doubling of distance. This is under perfect conditions with no wind or other influences. A 100m diameter turbine blade does not represent a point source. In this situation you consider the near field and far field effects together with the significant height of the sound source. Plane waves do not attenuate at the rate of 6dB per doubling of distance and I question the validity of the 'in box' measurement results presented in the Sonus report at distances of 85m, 165m and 360m from the turbine tower.

Contrary to the conclusions drawn in the Sonus report I strongly suspect that the adverse human responses reported by many people (those surrounding the Waubra wind farm, for example) relate to the lower frequency end of the dB(G) infrasound scale in the sub 5Hz range.

Infrasound audibility or perception

Adverse, null or indeed beneficial effects from low frequency sound and infrasound from wind farms have yet to be experimentally demonstrated. However, this does not mean that research will not uncover adverse effects in the future. It is reasonable only to say at this time that clinical evidence is currently unavailable to demonstrate adverse effects from infrasound generated by wind farms. Remember that the link between smoking and lung cancer took 25 years to prove. Numerous literature reviews (e.g. Leventhall) cite the fact that infrasound levels from wind farms are at inaudible pressure levels. Just because they are ‘inaudible’ does not mean that the brain does not perceive and respond to such stimulus.

Recent work on detecting neural activity caused by bone conduction vibration (Todd, 2008) indicates that the brain responds to low frequency levels 15 dB below the threshold of audibility caused by other bone conducting pathways. The report states that “These results extend our knowledge of vibration-sensitivity of vestibular afferents but also are remarkable as they indicate that the seismic sensitivity of the human vestibular system exceeds that of the cochlea for low-frequencies.” Further related research (Todd 2009) suggests high sensitivity to low frequency sound from the utricule. I have also spoken with Professor Ian Curthoys from the Vestibular Research Laboratory at the University of NSW (who has co-authored papers with Dr Todd) regarding infrasonic detection and low frequency sound below the threshold of hearing that has been regularly referenced to dismiss infrasound as a health issue. It appears that very little research, if any, has been done at very low frequencies but that the vestibulo-ocular reflex (VOR) technique used by Dr Todd could be a useful tool in future experimental research into the effects of infrasound.

The latest research in this area by Salt and Hullar (2010) provides further evidence of the mechanisms allowing the ear to perceive low levels of low frequency sound from wind turbines. Modern wind farms do contain readily measurable levels of infrasound, contrary to the opinion stated in the SA guidelines and NZS6808.

Whilst I accept that there has been no experimental demonstration of a link between low frequency sound and health effects, if those levels of exposure are below the threshold of audibility via the cochlea, we should keep an open mind in this regard. Absence of proof is not proof of absence.

Due to the number of people now living near to wind farms who report adverse health effects, a precautionary approach to this issue would be to set target noise levels indoors in terms of dB(G), similar to those applied in Denmark for industrial noise exposure, or simply sound pressure level in the frequency range below 9 Hz that can be readily measured with suitable equipment outdoors, even in the presence of high wind. There are currently no experimental data on the health effects from such sources and I would recommend further research into this area. Australia has the expertise to conduct such research and sleep research labs are available all over the country. It would not be too difficult to devise a suitable series of experiments testing exposure to wind farm noise emissions at low and higher frequencies.

In the absence of applicable research it may be appropriate to set target infrasound noise limits indoors, that are easily measured, at 75 dB(G). Wind farm proponents regularly espouse that modern wind farms do not cause such sound levels so there should be no complaints from that quarter if such precautionary target were to be set.

RECOMMENDATION 2

Implement laboratory tests to fill the gaps in our knowledge of the effects of wind farm noise emissions on health through sleep and relaxation human response monitoring in the laboratory.

Until such research produces a result, set a precautionary internal infrasound noise limit of 75 dB(G).

REFERENCES

Leventhall, G., 2003 "A review of Published Research on Low Frequency Noise and its Effects" Department for Environment, Food and Rural Affairs (DEFRA), May 2003

Salt AN, Hullar TE (2010). Responses of the ear to low frequency sounds, infrasound and wind turbines. Department of Otolaryngology, Washington University School of Medicine

Todd NPM, Rosengren SM, Colebatch JG. (2008). Ocular vestibular evoked myogenic potentials (OVEMPs) produced by impulsive translational acceleration. *Clinical Neurophysiology*, 119, 1638-1651.

Todd NPM, Rosengren SM, Colebatch JG. (2009). A utricular origin of frequency tuning to low-frequency vibration in the human vestibular system? *Neuroscience Letters*, 451, 175-180

POST CONSTRUCTION NOISE TESTING FOR A TYPICAL RECENT WIND FARM – ITEM 2

The Waubra wind farm in Victoria was recently approved on the basis of noise monitoring and modelling completed in accordance with NZS6808. Pre construction noise criteria charts were produced at that time which forms the basis of subsequent compliance assessments for a number of dwellings near the Waubra Wind Farm. Those charts are reproduced in the post construction compliance report.

Compliance with NZS6808: 1998 is required in the license conditions for the Waubra Wind Farm with an additional requirement to comply with night time noise targets.

General Observations

The post construction compliance report provides detail of only a Svan 953 noise logger that was operated by staff of the Waubra Wind Farm after training by an acoustical consulting firm. It appears that the consulting firm did not complete the noise measurements even though they are likely to have completed the data analysis and post compliance report.

I question if the assessment can be considered 'independent' as required by the approval conditions.

Wind speed data to correlate with the post construction noise measurements have been obtained from meteorological masts dissimilar to those locations used in determining the pre-construction noise compliance charts. A series of corrections have been applied to different met masts to determine the post construction chart data. This approach introduces serious errors and a better way would have been to obtain hub height wind speeds from the turbines operating nearest to the dwellings where post construction noise measurements were taken. This is common practice since each turbine records wind speed data and power output (the two are related by the power/wind speed curve for the turbine).

Scant information is provided on the post construction measurement locations. Only photographs from the pre construction measurements have been presented. Accordingly, it is not known if the siting requirements of NZS6808 have been met.

The noise charts showing pre and post construction noise data points clearly show that in the majority of cases the pre construction noise data was collected with equipment having a much higher noise floor than the post construction measurements. This can provide a higher pre construction target noise curve and give a lower post construction noise compliance curve.

Most of the noise charts have dissimilar trend curves applied. For example, the pre construction charts are fitted with third order trend curves, yet almost all of the post construction trend curves have been fitted with second order trend curves. This will reduce the trended sound level determined at higher wind speeds in the post construction case and make compliance easier to demonstrate.

The points above are examples of how data can be manipulated to show compliance or non-compliance, yet still pay lip service with the vague NZS6808 standard. Notwithstanding the best efforts of the dubious analyses, non compliance is still shown clearly for dwellings referenced H285 and H63. Other reports prepared by acoustical consultants in compliance with NZS6808 allow measurements in the area near to a dwelling, such as H285, even though access to this particular property was refused. I see no reason why measurements near to H285 were not considered valid in this case which is still in accordance with NZS6808: 1998, section 4.5.1.

Equipment used for the pre construction noise surveys we understand to be linear and approved for use by the manufacturer down to 30 dB(A). The specification for the Svan 953 shows linear data is valid down to 26 dB(A). Data below these limits has been included in the analyses and this will affect the trend curves produced from the data.

It is stated that data has been removed from likely rain affected points although the method of doing this has not been provided. The only way to do this properly is to have a rain gauge local to (within 5m) of the noise logger.

The correlation coefficients provided show poor correlation, generally around 0.5 or below. One would expect much higher correlation values for post construction noise/wind speed charts than preconstruction correlations but this is not the case in the analyses presented.

Many of the charts show that ambient noise levels have decreased when the wind farm is operational. This immediately raises questions over the data used in the analysis. Suggestions are made in the post compliance report regarding the possibility that post construction noise measurements were made in higher ambient noise environments than the preconstruction measurements, yet the report is silent on the situations where ambient noise levels have reduced when the wind farm is operational.

It is not possible to complete alternative analyses on the data presented in the post construction report unless the raw spreadsheet data is made available.

In summary: it appears that after the wind farm was constructed and became operational the ambient noise level at some dwellings REDUCED; despite the best attempts to implement noise management schemes to reduce noise emissions there is still non-compliance at some dwellings; the findings show that the prediction methodology of NZS6808 is suspect (predicted noise levels too low), and that; the process shows how poorly constructed and loose is the NZS6808.

RECOMMENDATION 3

The sooner the use of the "Background plus" approach described in the SA Guidelines, NZS6808, Draft National Guidelines for Wind Farm Development and AS4959 is abandoned, the better.

The assessment approach makes compliance testing a process extending over months and is not suitable for prompt complaints investigation. Even after the extended measurement regime and analysis is completed there are too many loose procedural variables that will allow non-compliance to be easily defended. Any extended monitoring should at least have a meteorological station near to the noise logger to allow bad data filtering caused by such things as rainfall to be removed.

ITEM 3

I cannot comment in detail on the aspect of property prices and income in rural communities except to say that the current adverse perception of noise from wind farms in the community will only be addressed if robust research is completed.

STATE AND COMMONWEALTH PLANNING REGULATIONS - ITEM 4

The Environment Protection Heritage Council (EPHC), July 2010, "National Wind Farm Development Guidelines - Draft "details the different criteria and planning instruments applied across Australia. The Draft is to apply for 12 months to allow different jurisdictions to "evaluate their effectiveness and provide the opportunity to assess how the Guidelines could best compliment existing planning and development processes, taking into consideration that these are best practice guidelines, and are not mandatory". Briefly, the current situation provides no consistency to planning for wind farm developments. Queensland, for example, does not have any suggested guidelines and treat each application as a 'one off' on its merits.

RECOMMENDATION 4

That enHealth prescribe acceptable noise targets for wind farm developments to protect health.

ITEM 5

No comment

ATTACHMENTS

The inaudible noise of wind turbines – Infrasound
WHO Night Noise Guidelines Europe 2009

PERSONAL EXPERIENCE

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QUALIFICATIONS

BSc (Hons) Applied Physics, UK 1975
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Member of the Environment Institute of Australia and New Zealand
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Australian representative for the International Institute of Noise Control Engineers (I-INCE) Technical Study Group 5 *A GLOBAL APPROACH TO NOISE CONTROL POLICY* (Now disbanded after completion of the scope of work defining this group – see http://www.i-ince.org/data/iince061.pdf)

My company, L Huson & Associates Pty Ltd, is a member firm of the Association of Australian Acoustical Consultants

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EXPERIENCE

Since graduating I have been involved in a number of scientific areas of research and development. My early experience was in constructing a microwave device to measure the temperature of plasma inside a nuclear fusion experimentation device at the UKAEA, Culham Laboratory in the UK. I then worked in research and development of thermal imaging devices prior to completing my Masters in Sound and Vibration Studies. My work since then (1977) has been primarily associated with acoustics and vibration both terrestrial and underwater.

For the past 20 years I have worked in Australia as a noise and vibration consultant and have operated through my own consultancy firm for the past 14 years. I am experienced in modelling acoustic propagation from a variety of sources such as railways, roads, aircraft, underwater ordnance, pile driving, blasting and numerous types of industry. With regard to industry, for example, I have prepared many noise sections of environmental impact statements for coal terminals and power stations (e.g. Tarong North, Callide C, Swanbank C) and have designed and installed long term noise and meteorological monitoring equipment to assess noise emissions for Kogan and Callide power stations that required analysis of data collected continuously over a period exceeding 5 years.

Of particular relevance to the evidence provided here is the work I completed for the Toora Wind Farm which involved detailed analysis of pre and post construction noise data using NZS6808 1998 to check compliance with license conditions. My experiences in the analysis of wind farm noise data led to a paper that was presented at the joint Australia and New Zealand Acoustics conference in 2006 titled "Review of the Application of NZS6808 to wind farms in Australia." This paper highlighted the sources of error that were implicit/allowed in the NZS6808, 1998 standard. The latest version of the NZS6808 standard (2010) addresses a number, but not all, of the data analysis error concerns described in my paper.

I have also provided expert evidence in Victorian Planning Panels for the Stockyard Hill Wind Farm, Moorabool Wind Farm, Yaloak South Wind Farm and the Allendale Wind Farm in South Australia.

APPENDIX A

Executive Order on noise from wind turbines

Pursuant to section 7(1), nos 1 and 2, section 7a(1), section 92 and section 110(3) and (4) of the Danish Environmental Protection Act, cf. Consolidation Act No 753 of 25 August 2001, as amended by Act No 475 of 7 June 2001, Act No 385 of 25 May 2005, Act No 569 of 24 June 2005 and Act No 244 of 27 March 2006, the following is laid down:

Part 1

Scope

Section 1. This Executive Order shall apply to the installation, modification and operation of wind turbines.

Part 2

Requirements for wind turbines

Section 2. Anyone who owns a wind turbine is responsible for it being installed, operated and maintained in such a way that the provisions of this Executive Order are complied with.

Section 3. The noise impact from wind turbines may not exceed the following limit values:
1) At the most noise-exposed point in outdoor residential areas, no more than 15 metres from the neighbouring dwelling in open countryside:
   a) 44 dB(A) at a wind speed of 8 m/s.
   b) 42 dB(A) at a wind speed of 6 m/s.
2) At the most noise-exposed point in outdoor residential areas, in areas for noise-sensitive land use:
   a) 39 dB(A) at a wind speed of 8 m/s.
   b) 37 dB(A) at a wind speed of 6 m/s.

(2) For the purposes of this Executive Order, the following definitions shall apply:
1) Neighbouring dwelling: any other dwelling than the wind turbine owner's private dwelling.
2) Noise-sensitive land use: areas which are used for or in district plans or town planning regulations have been assigned for residential, institutional, holiday home or allotment purposes or as recreational areas.

Section 4. The noise impact is determined in accordance with the guidelines in Annex 1 and is stated as the equivalent, A-weighted noise level at a height of 1.5 metres at wind speeds corrected to a height of 10 metres at 6 and 8 m/s respectively at a roughness length of 0.05 metres.

(2) Measurements are carried out as "Environmental measurements – external noise", cf. Executive Order on quality requirements for environmental measurements carried out by accredited laboratories, certified individuals, etc.

(3) Measurements of wind turbines which are fitted with several generators shall use the noise emitted from the noisiest generator as the basis for the noise measurement.

Part 3

Notifications etc.

Section 5. Anyone who wishes to install or modify a wind turbine shall submit notification to the municipal council of this.

(2) The notification shall include documentation that the wind turbines can comply with the noise limits in section 3.

(3) Documentation shall take the form of:
1) A report of the noise emission readings from one or more specimens of the notified wind turbine type.
2) Maps of the area in which the applicant wishes to install the notified wind turbine(s). The maps shall feature a scale and North arrow as well as accurately indicate the location of the notified wind turbine(s), the location of existing wind turbines and of neighbouring dwellings and the distance to these and another noise-sensitive land use.
3) The calculation of the noise impact found at the points referred to in section 3 in accordance with the guidelines in Annex 1.

(4) For prototype turbines there shall be measurements and calculations under section 3(1) so that the likelihood of the turbine complying with the noise limits can be worked out.

Section 6. The notification is considered to have been submitted when the municipal council has received all the information specified in section 5(3).

(2) If the municipal council has not made any objections within four weeks of the date specified in subsection (1), the wind turbine may be installed or modified unless this is prevented by other legislation.

(3) Building and construction work may not commence before the expiry of this four-week deadline unless the municipal council announces before then that it will not object to the notification.

(4) In areas which, according to municipal or district land-use planning, are reserved for the installation of several wind turbines or assigned to be wind farms, and where notification of individual wind turbines takes place consecutively, the municipal council may on the basis of the calculations of the noise from the individual wind turbine set more extensive requirements for the noise contributed by the individual wind turbine than the noise limits set out in section 3, so that the total noise contribution from the wind turbines in the area can comply with the noise limits in section 3.

Section 7. When a wind turbine is put into operation the municipal council shall be informed of this.

(2) If a notified wind turbine is not put into operation within two years of the expiry of the deadline in section 6(2), a new notification containing the information specified in section 5(3) shall be submitted to the municipal council.

Part 4

Orders on noise measurements

Section 8. The municipal council may order the owner of a wind turbine to carry out noise measurements at their own expense, cf. section 4:

1) when a notified wind turbine is put into operation;
2) in connection with general statutory supervision, however no more than once a year; or
3) in connection with the processing of neighbours' complaints about noise, when the municipal council considers this to be necessary.

Part 5

Appeals and penalties

Section 9. With the exception of decisions pursuant to section 8 and all decisions relating to municipally-owned or municipally-operated wind turbines, decisions taken by the municipal council may not be appealed to another administrative authority.

Section 10. Unless a higher penalty is prescribed under other legislation, a fine shall be imposed on anyone who:

1) installs or modifies a wind turbine without notification or proper documentation, cf. section 5;
2) commences building and construction work or installs a wind turbine irrespective of any objections from the municipal council, cf. section 6(2) or (4);
3) commences building and construction work in contravention of section 6(3);
4) puts a wind turbine into operation in contravention of section 7; or
5) fails to comply with an order under section 8.

(2) The penalty may be increased to a prison sentence of up to two years should the infringement be committed intentionally or through gross negligence and if the infringement has

1) caused damage to the environment or resulted in the risk thereof, or
2) achieved, or was intended to achieve, financial gain for the person concerned or for others, including as a result of savings made.

(3) Criminal liability may be imposed on companies etc. (legal persons) under the rules of Part 5 of the Danish Penal Code.

Part 6

Entry into force and transitional provisions

Section 11. This Executive Order shall enter into force on 1 January 2007 and shall be repealed automatically on 31 December 2012, unless otherwise determined before this date, cf. the Danish Ministry of Justice's letter dated 28 February 2002 relating to a pilot scheme for the application of automatic expiration clauses in certain executive orders covering environmental and working environment issues.

(2) Section 6(4) also applies to areas which, according to district land-use planning, are reserved for the installation of several wind turbines or assigned as a wind farm, until this planning is changed or repealed, cf. section 3(1), (2) or (4) of Act No 571 of 24 June 2005 on amending the Danish Planning Act.

(3) Executive Order No 304 of 14 May 1991 on noise from wind turbines is repealed but shall still apply to wind turbines which have been notified or put into operation before 1 January 2007.

(4) If a wind turbine is notified before 1 January 2007 but not put into operation within two years of the municipal council's deadline for objections expiring, a new notification containing the information specified in section 5(3) shall be submitted to the municipal council in accordance with this Executive Order.

The Danish Ministry of the Environment, 14 December 2006

Connie Hedegaard

/ Karsten Skov

Annex 1

Part 1

1. General rules for measuring noise emission from a wind turbine

The method in sections A-C generally complies with IEC 61400-11 (2002). Measurements carried out in accordance with this standard can be used as the basis for the determination of $L_{WA,ref}$.

A. Land-based turbines

A turbine's noise emission (sound power level L_{WA} in 1/1 octave band) is measured at different levels of the electrical power produced by the turbine at a point on the leeward side of the tower. Measurements must be taken at a distance R from the base of the turbine, which must not deviate more than ±20% from the distance R_0 (see figure 1).

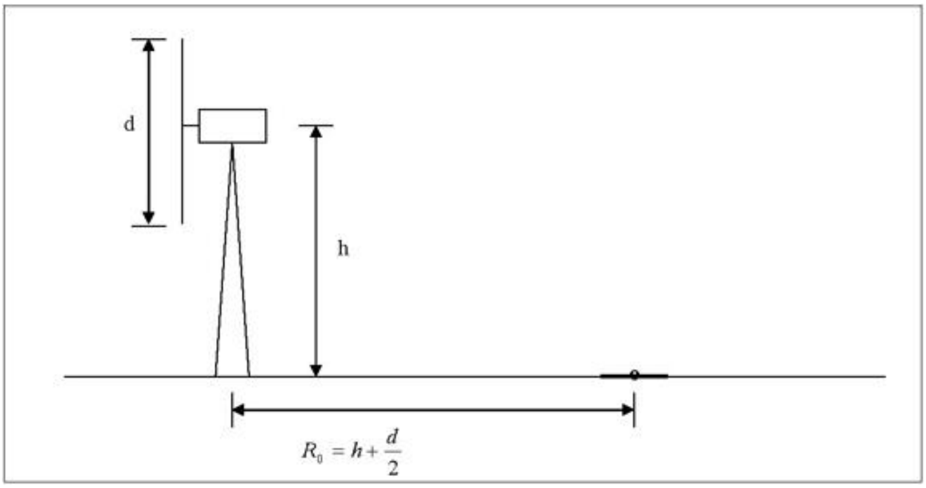

Figure 1

During the measurement the microphone must be positioned so that the direction from the tower of the turbine to the microphone does not deviate more than ±15° from the wind direction.

On the basis of sound measurements, A-weighted reference spectra are determined at wind speeds of 6 and 8 m/s respectively.

Half a wind protector is affixed to the microphone, which is positioned directly above a reflective plate on the ground in order to eliminate wind noise in the microphone as much as possible. The plate must not be smaller than one metre in any direction.

The noise from the turbine is measured as a number of A-weighted 1/1 octave sound spectra from 63 to 8,000 Hz, each determined over at least a one minute period. For each spectrum the average electrical power produced in the same period is measured, and the corresponding wind speed v_h at the turbine's hub height h can then be read from the turbine's power curve.

At least five spectra are measured at average electrical power, corresponding to the wind speed v_{ref} at a height of 10 metres under reference conditions in the range 5.5 m/s ≤ v_{ref} < 6.5 m/s, and at least five spectra where v_{ref} corresponds to the range 7.5 m/s ≤ v_{ref} < 8.5 m/s and where the relationship between v_{ref} and v_h is given in equation 1.1.1 (below).

There should be at least one of the abovementioned spectra for each of the following four ranges for v_{ref}:

5.5 m/s ≤ v_{ref} < 6.0 m/s

6.0 m/s ≤ v_{ref} < 6.5 m/s

7.5 m/s ≤ v_{ref} < 8.0 m/s

8.0 m/s ≤ v_{ref} < 8.5 m/s

The A-weighted reference spectrum at 6 and 8 m/s respectively is then determined as the average energy value of the measured sound pressure spectra for v_{ref} situated in the specified intervals at around 6 and 8 m/s respectively.

$$v_{ref} = v_h \cdot \frac{\ln \frac{z_{ref}}{z_{0ref}}}{\ln \frac{h}{z_{0ref}}}$$

h = the turbine's hub height in metres

z_{0ref} = reference roughness 0.05 metres (fixed value)

z_{reff} = reference height 10 metres (fixed value)

Equation 1.1.1. Correction of wind speed for turbines with known power curve

B. Turbines without known power curve

If in exceptional cases the turbine's power curve is unknown and v_h can therefore not be determined, the wind speed at the location can be measured at a representative, freely sited position on the turbine's headwind side at a height of at least 10 metres.

The distance between the anemometer and the tower of the turbine must be within two and four times the turbine's rotor diameter d, just as the perpendicular distance between the anemometer and the vertical plane on which the rotor's axis of rotation is situated must be no greater than d.

The measurements must be carried out at the same time as the noise measurements.

If the wind speed is measured at the height z, the relationship between v_{ref} and v_z is given using equation 1.1.2:

$$v_{ref} = v_z \cdot \frac{\ln \frac{z_{ref}}{z_{0ref}} \cdot \ln \frac{h}{z_0}}{\ln \frac{h}{z_{0ref}} \cdot \ln \frac{z}{z_0}}$$

The roughness of the terrain z_0 is estimated on the basis of table 1.

Equation 1.1.2. Correction of wind speed for turbines without known power curve

Type of terrain	**Roughness z0 [metres]**
Water, snow, sand	0.0001
Flat open countryside, bare soil, cut lawns	0.01
Agricultural areas with vegetation	0.05
Residential areas, small towns, areas of dense, tall vegetation	0.3

Table 1: Roughness for various types of terrain

C. Correction for background noise

With the turbine stopped, the background noise is measured off for at least five A-weighted 1/1 octave sound spectra, each of one minute's duration at wind speeds v_z, corresponding to v_{ref} being in the range 5.5 m/s ≤ v_{ref} < 6.5 m/s, and for at least five spectra when wind speeds v_z correspond to v_{ref} being in the interval 7.5 m/s ≤ v_{ref} < 8.5 m/s.

The relationship between v_z and v_{ref} is given in equation 1.1.2.

The value v_z is measured at the same time as the background measurements in a freely located position as described above.

The average energy value of the measured background noise spectra is determined at 6 and 8 m/s respectively and used to correct the turbine's reference spectrum, where the sound pressure levels $L_{A,\ ref}$ of each octave band in the reference spectrum are corrected in accordance with equation 1.1.3.

The total level $L_{A,\ eq}$ of the averaged background noise must be at least 6 dB lower than the total level $L_{A,\ eq}$ of the turbine noise. If this is not the case, a new measurement must be carried out when the background noise is lower. In connection with the checking of noise impact, measurements may, however, be used where the difference between total noise and background noise is less than 6 dB, provided that the calculated noise level after a background noise correction of -1.3 dB is no higher than the limit values.

$$L_{A,ref,k} = 10 \cdot \log(10^{\frac{L_{A,ref}}{10}} \div 10^{\frac{L_{A,b}}{10}})$$

where

$L_{A, ref, k}$ = the corrected reference sound pressure level in 1/1 octave band

$L_{A, b}$ = the averaged background sound pressure level in 1/1 octave band

Equation 1.1.3. Correction for background noise

The turbine's sound power level $L_{WA, ref}$ in 1/1 octave band is then found using equation 1.1.4.

$$L_{WA,ref} = L_{A,ref,k} + 10 \cdot \log 4\pi(R^2 + h^2) \div 6dB .$$

6 dB is a correction due to measuring close to a reflective plate on the ground

R = the actual measuring distance in metres between the microphone and the base of the turbine.

Equation 1.1.4. The turbine's sound power level

2. Determination of sound pressure level L_{pA}

At a point, e.g. by the nearest neighbour, the turbine's sound pressure level in 1/1 octave band at a height of 1.5 metres can be determined using equation 1.2.1:

$$L_{pA} = L_{WA,ref} \div 10 \cdot \log(l^2 + h^2) \div 11dB + \Delta L_g \div \Delta L_a$$

where

l = the distance in metres from the base of the turbine to the calculation point

11 dB = correction for distance, 10 x log 4п

ΔL_g = correction for the terrain (1.5 dB for land-based turbines and 3 dB for offshore turbines)

ΔL_a = luftabsorption ($\alpha_a\sqrt{(l^2 + h^2)}$), hvor dæmpningskoefficienten α_a fremgår af tabel 2.

Equation 1.2.1. Sound pressure level in 1/1 octave band

Octave band centre frequency in Hz	63	125	250	500	1000	2000	4000	8000
α_a in dB/m	0.0001	0.0004	0.001	0.002	0.0036	0.0088	0.029	0.1045

Table 2: Air absorption coefficients at a relative air humidity of 80% and an air temperature of 10ºC

The total A-weighted sound pressure level $L_{pA, tot}$ at the point is then found by adding the sound pressure levels $L_{pA, i}$ in the individual octave bands, cf. equation 1.2.2:

$$L_{pA,tot} = 10 \cdot \log \sum 10^{\frac{L_{pA,i}}{10}}$$

Equation 1.2.2. Total sound pressure level

The uncertainty of the calculated sound pressure level $L_{pA, tot}$ when using this method is ±2 dB.

3. Determination of tones and noise exposure L_r

In order to determine the noise impact L_r at a given point, the noise's content of clearly audible tones is assessed.

This assessment is carried out at the dwelling with the most noise exposure by objectively measuring in accordance with the guidelines in part 7 of the Danish Environmental Protection Agency's Guideline on measuring external noise, no 6/1984. The use of this method presupposes that the tones are stationary, i.e. that both the level of the tones and the level of the masking noise are determined by averaging a number of spectra which correspond to an analysis time of at least one minute.

The noise measurement must be carried out at a representative point close to the nearest dwelling, 1.5 metres above the terrain and selected in such a way that the wind noise has as little effect on the measuring results as possible.

There must be a tailwind ±45° from the wind turbine towards the measuring point, and the wind speed measured 10 metres above the terrain must be between 6 and 8 m/s. Measurement must take place in a time interval where the tone is clearest.

In this context there are no requirements for temperature gradient or cloud cover.

If a frequency analysis of the turbine noise measured close to the turbine as described in the procedures for measuring the A-weighted sound power level shows that no clearly audible tones occur near the turbine, the assessment at the neighbouring dwelling is unnecessary.

When processing a notification, the tone content can be determined on the basis of a measurement in the tailwind side of an equivalent turbine at a distance corresponding to the actual distance to the neighbour point.

If the noise contains clearly audible tones L_r is determined as specified in equation 1.3.1:

$$L_r = L_{pA,tot} + 5dB$$

Equation 1.3.1. Determination of clearly audible tones

Part 2

Special rules

1. Measuring noise from turbine groups

A turbine group is taken to mean a collection or three or more identical turbines, irrespective of whether these are installed on land or as offshore turbines.

The sound power level $L_{WA, ref}$ in 1/1 octave band is determined by measurements for at least three randomly selected turbines. The deviation between L_{WA} can typically be expected to be ±2-3 dB when the turbines are identical. For the other turbines in the group the average energy value of the three measured sound power levels is used.

The sound power level in 1/1 octave band at a point is found by adding the noise contributions from the individual turbines, calculated according to equation 1.2.1, as specified in equation 2.1

$$L_{total} = 10 \cdot \log(10^{\frac{L_p1}{10}} + 10^{\frac{L_p2}{10}} + ...)$$

Equation 2.1. Total sound pressure level from turbine groups

The same formula is used when the contribution from a new turbine is to be added to the sound pressure level generated by existing turbines close to the dwelling concerned.

The total A-weighted sound pressure level $L_{pA, tot}$ at the point is then found using equation 1.2.2.

If the wind speed must be measured during a noise measurement because it is not possible to measure the power produced by the turbine, the distance to this turbine from the anemometer, if it is placed on the tailwind side of the other turbines, must be at least 10 times the turbine's rotor diameter (d), see figure 1.

2. Measuring noise from offshore turbines

A. Microphone mounted on a reflective plate on the ship

Compared to measurements for land-based turbines, the measuring method is changed so that the reflective plate on to which the microphone must be directly affixed is positioned on the roof of the pilot house on the measuring ship or on some correspondingly large surface with an unobstructed view of the wind turbine from the microphone's location. The roof or surface must not be smaller than 4 metres in any direction.

The instructions in part 1.1 apply otherwise.

B. Microphone mounted on the ship without using a reflective plate

If the microphone cannot be mounted as specified under heading A, the microphone must be positioned 3-5 metres above sea level, free from reflective surfaces etc. and 1-2 metres out from the edge of the measuring ship with an unobstructed view of the wind turbine.

Measurements must be taken at a distance R from the base of the turbine, which must not deviate more than ±20% from the distance R_0 (see figure 1).

During the measurement the microphone must be positioned so that the direction from the tower of the turbine to the microphone does not deviate more than ±15° from the wind direction.

Measurements must then be taken as follows:

A wind protector should be affixed to the microphone and the microphone axis must point towards the hub of the turbine.

The noise from the turbine should be measured as a number of A-weighted 1/1-octave sound spectra from 63 to 8,000 Hz, each determined over at least a one minute period. For each spectrum the average electrical power produced in the same period is measured, and the corresponding wind speed (v_h) at the turbine's hub height (h) can then be read from the turbine's power curve.

At least five spectra are measured at average electrical power, corresponding to the wind speed v_{ref} at a height of 10 metres under reference conditions in the range 5.5 m/s ≤ v_{ref} < 6.5 m/s, and at least five spectra where v_{ref} corresponds to the range 7.5 m/s ≤ v_{ref} < 8.5 m/s and where the relationship between v_{ref} and v_h is given in equation 1.1.1.

There should then be at least one spectrum for each of the following four ranges for v_{ref}:

5.5 m/s ≤ v_{ref} < 6.0 m/s

6.0 m/s ≤ v_{ref} < 6.5 m/s

7.5 m/s ≤ v_{ref} < 8.0 m/s

8.0 m/s ≤ v_{ref} < 8.5 m/s

The A-weighted reference spectrum at 6 and 8 m/s respectively is then determined as the average energy value of the measured sound pressure spectra for v_{ref} situated in the specified intervals at around 6 and 8 m/s respectively.

When measuring the background noise, a measurement should also be taken of the wind speed v_z at a height of 10 metres above sea level with the anemometer positioned on the same vessel as the microphone.

Due to the sea level's low roughness value, $v_z = v_{ref}$.

With the turbine stopped, at least five A-weighted 1/1 octave band sound spectra of the background noise are measured, with v_z in the same two intervals as v_{ref}, before the A-weighted reference spectrum is then corrected as described for the measurements on land-based turbines.

The total level $L_{A,\,eq}$, of the averaged background noise must be at least 6 dB lower than the total level $L_{A,\,eq}$ of the turbine noise. If this is not the case, even when using the smallest possible measuring distance and largest possible microphone height, a new measurement must be carried out when the background noise is lower. In connection with the checking of noise impact, measurements may, however, be used where the difference between total noise and background noise is less than 6 dB, provided that the calculated noise level after a background noise correction of -1.3 dB is no higher than the limit values.

The turbine's sound power level $L_{WA,\,ref}$ in 1/1 octave band is then found using equation 2.2:

$$L_{WA,ref} = L_{A,ref,k} + 10 \cdot \log 4\pi(R^2 + h^2) \div 3dB$$

Equation 2.2. Sound power level for an offshore turbine