Complaints from noise of wind turbines – Australian and New Zealand experience

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ABSTRACT

Wind farms are a growing form of energy supply in Australia and New Zealand. Wind farm development in Australia has grown significantly since 1999. From 2003 to 2005, there were several proposals submitted for approval with numbers of turbines ranging from 30 to over 100. Noise impacts from wind farms remains a contentious issue for the community and statutory authorities in the planning stage, but there is no nationally agreed approach to assessment. A recent Swedish study identified a dose-response relationship for noise from wind farms that was significantly higher than that obtained for general industrial noise. This paper attempts to compare the incidence of complaints in Australia and New Zealand, about noise from wind farms and complaints about noise in general. Data on complaints or objections from planning and approval stages is compared with those from the operating phases of wind farms. Understanding of any dose response to wind farm noise is likely to be a key factor in their future approval conditions, siting and operation.

INTRODUCTION

Australia currently has 738 MW of installed wind turbine power and 5818 MW proposed (AUSWEA 2006). Figure 1 shows the locations of existing Australian wind farms (AGO, 2006). The rate of development of wind energy is controlled to some extent by responses to government policy such as Mandatory Renewable Energy Targets (MRET). However, it is clear that there will be a significant increase in the number of wind farms in the coming years. This has implications for community and environmental noise, and whenever a new wind farm is proposed, there are concerns in the community about how noisy they will be, amongst other environmental issues. So it is considered to be a reasonable item for an acoustics conference to examine.

Source: Australian Greenhouse Office, 2006
Figure 1: Location of Australian Wind Farms

A paper presented at the Wind Turbine Noise Conference 2005 (Pedersen 2005) reported on a Swedish study of community annoyance from exposure to noise emissions from wind turbines and farms. A dose response relationship was determined which showed a higher dose response than previously determined for industrial noise. In that study, the proximity of residents to the wind turbines was as little as 300m. Some wind farms in Australia have similar distances to residences.

The prevalence of complaints against operating wind farms in Australia and New Zealand has not been considered in detail and this paper was intended to be an attempt to obtain some statistics and report on them. This has been more difficult than expected, as there are few sources of public information about noise complaints from wind farms. Operators with complaints for high or higher than expected sound levels don't want to discuss their problems, and most regulators don't collect statistics on the subject.

This paper discusses (in brief), the following:

- the number of objections based on noise, to typical wind energy projects in Australia (NSW and Victoria);
- the number of cases of complaints of annoyance from wind farms in Australia;
- a comparison with the number of complaints about noise from other environmental noise sources;
- some information about the nature of complaints and sound levels from the Swedish study;
- what sound levels are acceptable in Australia, based on regulatory approaches and what is likely to be required to ensure low levels of potential for noise annoyance; and,
- typical distances likely to be required from the currently available commercial wind turbines, to achieve acceptable sound levels.

The need for industry and regulator support for the conduct of dose response studies, along with community annoyance studies, after the installation of wind farms, is discussed. Improvement of the regulatory approach to allow a more simplified assessment of noise aspects, and setting of reasonable sound level objectives to ensure low potential for annoyance, are also considered.

OBJECTIONS TO PROPOSED WIND FARM DEVELOPMENTS BASED ON NOISE

The regulatory approval process of a proposed wind farm involves an environmental impact assessment process. For the noise aspects, the assessment in Australia and New Zealand is guided either by the NZ Standard NZS 6808: 1998 (Standards NZ, 1998) or the South Australian EPA Guideline (SA EPA 2003). These are used in different states, so there is no nationally agreed approach to assessment of noise from wind farms as yet (Tickell 2006).

The approach to environmental assessment is similar in all areas. There is a requirement to undertake baseline assessment of noise and other environmental parameters in the area of the proposal and at potentially affected receiver sites. This involves site work in the area of the proposal, so it is expected that the community in general, beyond the property owners, becomes aware of the proposals at a fairly early stage of the development. Unfortunately this can lead to opposition to the proposals before detailed studies have been completed. Assessment of community response to the proposals is a requirement of the assessment studies. In some cases resident action groups are formed to oppose the developments or individual citizens launch their own objections. Their opposition to some projects has also been active enough to encourage national television and radio articles about their opposition (ABC, 2006).

These can be found in a web-search fairly easily, and noise is often quoted as a major issue for the residents in the region of the development. It is difficult to identify the number of objections to wind farm developments using internet searches, as you could spend weeks sorting through results and examining pages and reports thrown up from various search engines. Some are discussed in published papers and conferences. For example, Watts has described the public response to a proposed wind farm on the Awhitu Peninsula coast in New Zealand, covering both the community opposed to the project and those in support of it (Watts 2005).

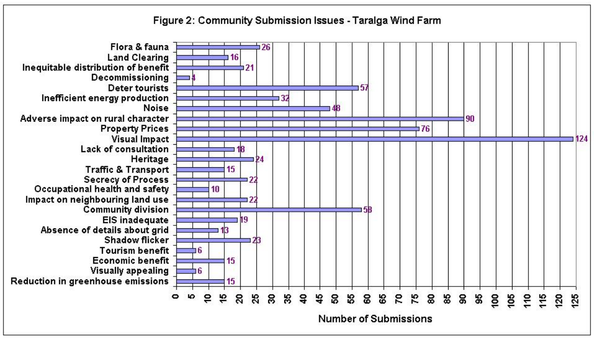
One way to obtain some statistics is to examine the regulatory assessment reports for the developments, and this has been done for two proposed projects in NSW, using information available from the NSW Department of Planning website. These are for the proposed Capital Wind Farm and the Taralga Wind Farm (Griffin, 2006 and Department of Planning, 2006).

For the Capital project near Canberra, there were 79 submissions made with 94 questions asked. Of these, there were 39 questions related to noise, the largest number of questions relating to an environmental aspect. One other question was related to the effects of noise from the wind farm on property values. The types of questions asked about noise included the following:

- distances to residences;
- the potential use of noise easements;
- infrasound and health effects;
- management methods of noise in operation if objectives are exceeded;
- background measurement methods, locations and seasons;
- noise source data used (which turbine);
- cumulative effects; and,
- prediction software and its use of meteorological conditions.

For the Taralga Project, in central rural NSW, Department the report notes there were 228 submissions during and after the public consultation period that were considered. 171 submissions were against the proposal and 30 were in support. Two petitions were submitted, with 168 signatures in a supporting petition and 113 signatures in an opposing one. A further survey undertaken of 154 people in the area, showed that 102 were against the project and 52 for it.

The highest number of submissions (122) was related to visual impacts. Noise was ranked sixth in the number of submissions with 48, after adverse impact on rural character (90), property prices (75), community division (58) and deter tourists (56). These are shown graphically in Figure 2 below, from the report.



Source: (NSW Department of Planning 2006)
Figure 2: Issues raised by submissions to Taralga Project

Issues related to noise impacts in the submissions were collated in the report. They are listed as:

- construction noise.
- low frequency noise and associated health problems.
- noise impacts at nearby residences and workplaces will result in loss of sleep, health problems and loss of amenity.
- the ability of the noise modeling to predict overnight noise levels due to low ground level wind speeds and overnight temperature inversions (in particular the practice of using 10m wind speed measures to extrapolate speed at turbine height).
- noise levels are not appropriate for a rural setting. Concern was also raised about noise impacts on animals.
- inaccuracies in the Environmental Impact Statement, including the absence of a number of properties in the noise modeling in the Environmental Impact Statement.

The issues of low-frequency/infrasound and health effects are often raised, despite many studies by regulators. See for example Leventhall (Leventhall 2005).

The above list is typical of many identified in other reviews of community concerns related to wind farm proposals. The proportion of submissions related to noise in the above two discussed projects is also typical, with noise often being one of the most significant items of concern. The issue for developers, regulators and the acoustical profession is how to reduce this rate of concern.

Organised opponents of wind farms often provide evidence of high noise levels from wind farms and on-going complaints from them. But what is the real experience? This is discussed in the next section.

COMPLAINT HISTORY FROM WIND FARMS

The approach taken in this paper to identifying actual complaint history for operating wind farms in Australia was perhaps too simple to obtain a satisfactory result and could be considered as an initial attempt. At present only regulatory officers in each state have the power to force operators to report on complaint history. EPA officers involved in noise regulation in all States of Australia were either telephoned or sent emails requesting information about noise complaints from wind farms and whether overall statistics were kept about noise complaints. Most people contacted were helpful, and those who did respond advised that there was little evidence of complaints.

The same questions were also sent to some operators of several wind farms, either private industry or state owned enterprises. However not all were approached and that is one shortcoming of this review. The response from operators was less helpful and most did not respond. Responses are discussed below.

In Western Australia, Verve Energy (Verve, 2006), operator a wind farm at Esperance, advised they were unaware of any complaints for since the development of their current wind farm in 2002. An earlier wind farm at Salmon Beach, closer to Esperance, built in 1987 (six 60kW turbines) and decommissioned in 2002, had some complaints. This was investigated in the late 1980's and further complaints were not known to have been received. That plant was decommissioned due, in part to noise issues from the exposure to potential noise complaints that may arise from encroaching urban development with very expensive housing – see Figure 3.

Source: Verve Energy, 2006-08-05
Figure 3: Salmon Beach wind farm (decommissioned 2002), Esperance, W.A.

Urban expansion took housing to within a few hundred metres of the operational turbines. This left no buffer for noise and the risk of a noise complaint was too high to justify ongoing maintenance. They were decommissioned in 2002 and replaced with six larger 225 kW turbines at a new wind farm distant from potential encroachment. The closest noise sensitive boundary to the new wind farm is 500m.

A proposed development at Albany received objections on the basis that they would be discernible in the town's main street, 12km distant. Verve Energy advised it is often able to allay fears of wind noise by getting objectors to visit a wind farm and experience the noise.

In Queensland, there was some recollection in the EPA of complaints about the Windy Hill wind farm near Cairns, in its early days but that had since died down. No response was received from the operators to the emailed questions. The web site provides a tourist type brochure of how to get there, but no annual monitoring type data. The experience of neighbouring farmers exposed to noise at Windy Hill was given in a Victorian based article objecting to a development in that State. EPA annual reports give overall statistics of complaints about different pollutants – air, water, noise, but don't break them into source types.

In NSW, the EPA publish statistics in their annual report about complaints made to the Pollution Line, a 24-hour phone number for complaints about any type of pollution. Only one complaint about a wind turbine was known to the DEC noise officers, but this was for a residential-sized unit.

In Victoria, information about complaints of the Toora wind farm was contained in information of objectors to and planning appeals tribunals reviews of other wind farms proposed for the Gippsland region. Toora is an operating wind farm in Gippsland, Victoria, where there have been complaints about wind farm noise. Toora Windfarm is operated by Stanwell Corporation near Toora in South Gippsland. It has 12 turbines each of 1.75MW capacity. Distances between turbines at Toora and non-landowner residences are from 400m to 730m and beyond (VCAT 2001). The South Gippsland Shire Council commissioned a review of the environmental noise-monitoring program at Toora (Fowler, 2005). This will be discussed in the next section.

No statistics or information was available from Tasmania, other than there was a potential for complaint from one site.

In South Australia, the EPA advised:

> "… given there is limited wind farm development in the proximity to housing in SA, there are correspondingly few complaints … the limited numbers would not be sufficient to come up with a meaningful sample size." (EPA SA. 2006)

One SA operator advised they were not aware of anyone amongst owner/operators who might have been collating noise complaints, and suggested contact with the EPA. (Tarong Energy, 2006). One of the other major operators in SA advised me to contact AUSWEA (Babcock & Brown 2006). Earlier contact with AUSWEA on a similar type of project to compare reported measured sound levels with model predictions had not been successful.

In New Zealand, there is no single EPA type of organisation. The Ministry of Health funds the provision of specialist acoustical advisory services to Public Health Services through the Environmental Noise Analysis and Advice Service. They advised that there is no central government control and no central collation of statistics on complaints. Local authorities, city and district councils, have responsibility for control of noise. Most wind farm locations are in sparsely settled areas and affected persons per site are very few, probably less than five for most sites and often only one or two. Their expectation was that the total exposed population in NZ which could be said to be affected (where turbine levels exceeded 30 to 35 dB(A), would be less than 20 households. This does not include a prototype location in Wellington. Some of these would be receiving benefits from allowing wind farms on their land and none would be anywhere near industrial zones.

One NZ wind energy project was reported to have had tonal noise problems on commissioning. Henderson (Henderson, 2005) has provided a detailed report of the problem, which was related to a gear noise problem. While 40 dB(A) was the local council's noise limit requirement) the project agreed to a particularly low sound level (30 dBA including any tonal penalty at the house of the nearest objecting neighbour) as part of their resource consent. They agreed to do this for three main reasons:

> "a) the nearest objector lived 1.4 km away and we believed we would easily meet that standard
> b) the neighbour in question experienced very low background sound levels in a sheltered valley (sometimes as low as 20 dBA or lower) and expressed the strong value that she placed on that sound quality
> c) the turbine was a prototype. Therefore we accepted the need to "go the extra mile" for the local community. We also knew that if the

> sound levels exceeded 30 dBA at that distance, we would have a serious marketing problem with the turbine."

After commissioning, the prototype generated noise complaints from the neighbour in question. They measured a level of 31 dB(A) at that residence against a background of about 23 dB(A), with a clear tonal component at around 315 Hz. This added another 5 dBA to make the assessed level 36 dB(A). They voluntarily restricted operation to daylight hours, five days a week. Then in November 2003, shut down the turbine completely and took the time to get it right.

After modifications, the sound level was reduced from 36 dB(A) to 24 dB(A). Recent history of operating sound levels from that project and other wind farms in NZ is not known.

Overall, it appears that when wind farms are proposed, there are many objections to them based on noise. These objections often form the largest percentage of submissions. However, once operating, apart from Toora, for Australia there are few if any records of complaints or monitoring data made public, which EPA's or regulators are aware of, or that operators are prepared to talk about.

To improve public perception and awareness of the actual noise levels from wind farms, it is considered that it would be advantageous for the industry to openly report on complaint history and monitoring results in terms of achievement of noise level objectives for all operating wind farms. If the community is made aware that there are very few complaints and that objectives are being achieved, then their objections to new developments on the basis of noise may decline.

THE SOUND LEVELS AT TOORA

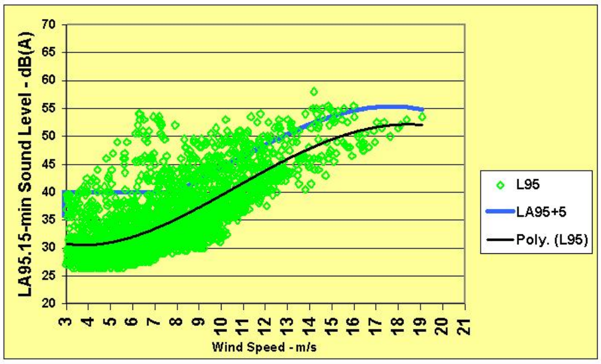
As noted earlier, Toora is a wind farm of 12 turbines of 1.75 MW on 70m towers. The local Council set a minimum distance between turbines and any dwelling of 300m. The distances between the non-landowner residents and the nearest turbines were 400m, 600m and 730m (VCAT 2001). Council commissioned a review of the environmental noise monitoring results undertaken on behalf of the operator. This review is one of the few publicly available with actual monitoring data for a site with known complaints.

This discussion comes completely from the review done by Fowler and only considers the results of the sound level and noise character analysis. The report reviewed noise measurement results for two sites made on 13 occasions of 4-week monitoring, between September 2002 and June 2004. The assessment was done for two sets of data – aggregate over a 24-hour period and for night-time only. It also included the assessment with and without a 5 dB penalty for special audible characteristics.

For one site, the objectives were exceeded on 7 of the 14 occasions for the night-time data, if no penalty was included. The exceedances ranged from 0.2 to 1.7 dB. If the special audible characteristic penalty was included, the exceedance occurred on all 13 occasions and ranged from 0.9 to 6.7 dB.

For the second site, higher sound levels were received. Night-time exceedances occurred on 11 of 13 occasions, from 1.3 to 4.8 dB, without including the 5 dB penalty. If the penalty was included, the exceedances occurred on all occasions and ranged from 5 to 9.8 dB.

The highest exceedances at both sites occurred in winter months, May to June being the highest. While the exceedance of objectives (without the penalty included) may not seem significant in comparison to our industrial or transport noise experience, the nature of the development of the objectives using the NZ Standard could result in sound levels being more than 15 dB above the background LA90 at the time. Figure 4 shows some real site data and the developed objectives.



Source: Tickell 2006
Figure 4: Development of Objectives using NZS:6808 (L95 + 5) for a set of real site data.

While the background could be as low as 25 dB(A), the allowable objective using the NZS is 40 dB(A). The highest exceedance occasion given in the report occurred at a wind speed of 6m/s. Whilst the data shown in Figure 4 is not the same site, it illustrates the potential problems of the difference between the objective and the range of background sound levels possible at sites.

COMPLAINTS FROM NOISE IN GENERAL

It is considered relevant at this stage to refer to statistics on general noise complaints registered with regulators. If people don't complain about noise from wind farms, is it because they don't complain about noise from other sources? New South Wales has the most readily available statistics on noise complaints, so their data is used here and is considered to be typical for other parts of Australia.

In the 2004-2005 annual report-year, a total of 9,696 calls were made to Pollution Line about incidents, this number being typical of the order of calls received for the past 6 years, ranging from 9,696 in 2004-5 to 13,747 in 2000-1. Noise calls were 15% of the total number of calls about incidents, third highest after odour (33%) and water (non-storm, 16%), but above air (11%). Noise was the highest number of calls (16%) to Pollution Line requesting information (NSW DEC 2005, 2006). So people will readily complain about noise if it exists. Next is to consider why they complain.

NOISE ANNOYANCE FROM WIND FARMS

As with any noise, the potential for annoyance from wind farm noise emissions depends on the sound level, sound characteristics such as the frequency content, tonality, modulation/variation in level, and psycho-acoustical issues such as previous experience with the noise and personal attitude to the source or operator.

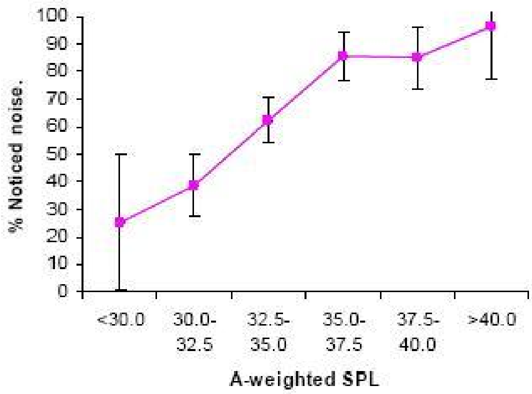
Assessment of annoyance from noise of wind farms appears to be a relatively recent field of interest, but has grown significantly since about 2003. One very early study was in 1993, of residents in Denmark, the Netherlands and Germany (Wolsink 1993). That study was of 573 people exposed to an average sound level of 35 dB(A) +/- 5dB. Only 6% were found to be annoyed and there was only a weak relationship between annoyance and A-weighted sound level. Variables related to annoyance were stress related to turbine noise, daily hassles, visual intrusion of wind turbines in the landscaper; and the age of the turbine site, the longer the operation, the less the annoyance (Pedersen, 2005 & Rogers, 2006).

A 2004 report on a study of residents near a 30MW, 17-turbine installation on the Dutch-German border, was of residents living 500m or more from the turbines. The residents were reacting strongly to the noise and residents up to 1,900m away expressed annoyance. Measured sound levels were higher than predicted by standard models because of higher night-time wind speeds at hub-height, and annoyance was increased by the impulsive, thumping nature of the sound at a distance of 1,500m but not noted at 500m. (Van den Berg 2004).

In 2005, Pedersen and Waye (Pedersen 2005) reported on two studies of residents in Sweden in 2000, exposed to different levels of noise from 16 wind turbines of 600kW. The first study had a total of 518 residents. There are' no references in the paper to distances, however distances were advised to be from 300m. The second study was from interviews with 15 of the residents in the first study. Responses were compared to sound levels calculated from Swedish guidelines.

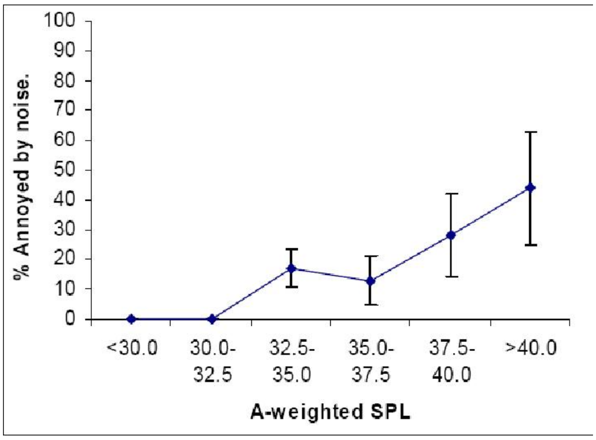
The results of the study included a dose response relationship – annoyance increased for increasing sound level, and the higher the sound level, the higher the percentage of respondents annoyed (see Figures 5 and 6 below). The annoyance from wind turbines was higher than the corresponding annoyance found for industrial noise of the same levels (See figure 7). However, the authors acknowledged the sample size was much smaller than those for similar studies of transportation and industrial noise annoyance, and further work was required to improve the dose-relationship data.

Factors other than sound levels were found to strongly affect annoyance in the Pedersen study, such as attitude to the source, sensitivity to noise, visual exposure (see Figure 8) and rural or city living experience. The first study obtained responses through a questionnaire, which was masked. The nature of the sound was often described as swishing, and in some responses as throbbing, resounding, rattling and howling.



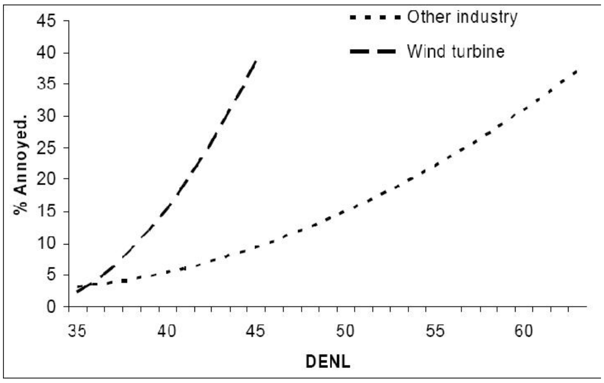
Source: Pedersen, 2005

Figure 5: The proportion of respondents who noticed noise from wind turbines related to A-wtd SPL's with 95% confidence intervals.



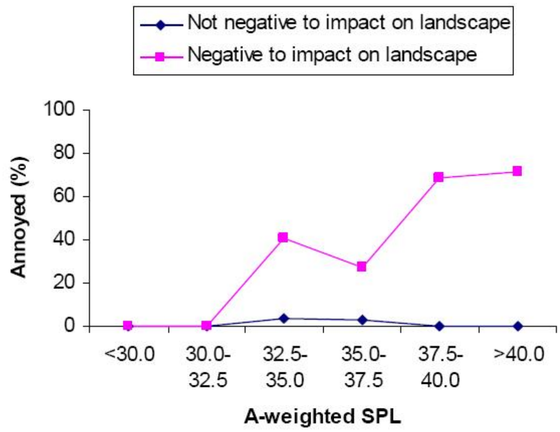
Source: Pedersen, 2005

Figure 6: Proportion of respondents annoyed by wind turbine noise related to A-wtd SPL's with 95% confidence intervals.



Source: Pedersen, 2005

Figure 7: The proportion annoyed persons as a function of DENL for noise from wind turbines and for noise from other industry (not shunting or seasonal industry).



Source: Pedersen, 2005

Figure 8: Proportion of respondents annoyed by wind turbine noise related to A-weighted SPL's comparing respondents not negative to wind turbines' impact on the landscape scenery (very positive, positive, neither positive nor negative) and respondents negative to wind turbines' impact on the landscape scenery (negative, very negative).

The annoyance was greater when respondents saw the rural setting as a place for peace and quiet, or they felt a lack of control over the project and felt subjected to injustice. As Rogers notes "*some of these factors can be influenced in the planning process*".

A 2006 report investigated low frequency and infrasound noise from three wind farms in the UK (Hayes McKenzie 2006). It noted: *"of the 126 wind farms operating in the UK, five have reports of low frequency noise problems which attract adverse comment concerning the noise. Therefore complaints are the exception rather than a general problem which exists for all wind farms."* To undertake the study, measurements were taken at three sites where low frequency noise has been identified by neighbours as a source of annoyance. The study concluded that:

- "Infrasound associated with modern wind turbines is not a source which will result in noise levels which may be injurious to the health of a wind farm neighbour;
- Low frequency noise was measurable on a few occasions, but below the existing permitted Night-time Noise Criterion ($L_{pA,LF}$ = 20dB). Wind turbine noise may result in internal noise levels within a dwelling that is just above the threshold of audibility, however at all sites it is always lower than that of local traffic noise;
- The common cause of complaint was not associated with LFN, but the occasional audible modulation of aerodynamic noise especially at night. Data collected showed that the internal noise levels were insufficient to wake up residents at these three sites. However once awoken, this noise can result in difficulties returning to sleep."

The distance between the turbines and the residences was only described for one site, with the closest turbine being 1030m, for three turbines of 1.3MW. A local road was 500 to 600m away and provided most of the local traffic noise.

In a presentation in Sydney in July 2006, van den Berg advised that annoyance had been expressed in sound levels below 35 dB(A) in some cases, especially where modulation is present (van Den Berg 2006). He commented that the frequency range of the modulation of sound levels was in the same range as speech, so it may be that humans are adapted to listen for sounds in this range and this adds to the annoyance. Modulation occurs when the wind speed varies over the rotor plane, changing the thickness of the trailing edge boundary layer, which is directly related to the sound level emitted. Perhaps humans may not be able to "switch-off" from the modulation noise because of its nature and characteristics. He suggests it may be possible to control modulation through pitch variation over a revolution.

Wind noise is commented on by those exposed, as always being present, if there is a good resource, and even though it varies slightly, it is also noticeable. Modulation sound level could also increase in large wind farms if the turbines operate in synchronisation.

ACCEPTABLE SOUND LEVELS AND DISTANCES

There are guidelines in Australia and New Zealand for acceptable sound levels from wind farms. Those following the NZ standard approach (NZ, Vic, Tas) have an acceptable contribution sound level of 40 dB(A) or LA95 + 5 dB(A), whichever is greater, as shown in Figure 4. Those following the SA Guideline (SA and NSW) have an acceptable level of 35 dB(A) or LA90 + 5 dB(A). In each case, the LA95 or LA90 is the average from a regression analysis of sound levels against turbine location 10m elevation wind speed, for at least 2000 intervals of 10 or 15-minute sample periods, typically obtained over two to three weeks of measurements. If the noise contains special audible characteristics, a penalty of 5 dB is added.

Fowler suggested that the regression analysis should be split into daytime and night-time, as lower sound levels typically occur at night (Fowler 2005). This would extend the background data collection period if it were required to obtain 2000 data points at night-time. However it would provide a greater accuracy for night-time exposures, when annoyance has been found to be highest, as noted in the previous section.

van den Berg suggested a contribution sound level of 35 dB(A) to prevent sleep disturbance and severe annoyance, and a 5 dB lower value for amenity hours (between work and sleep).

For low background locations where the sound levels can be 25 dB or lower (as shown for example in Figure 4), this paper considers that an acceptable night-time contribution sound level of 35 dB(A) is a significant increase, and annoyance could be expected. However it is likely to be acceptable if there is no modulation. If modulation occurs, a penalty of 10 dB may be more appropriate than 5 dB, given the nature of the frequency range of the modulation sound.

A limit for acceptability of +5 dB on the regression analysis of night-time only LA90 sound levels is likely to result in lower rates of annoyance.

Changes to current guidelines for acceptability are policy decisions that regulators need to consider in depth. Improvement of the guidelines to make future wind farms less likely to be annoying may be desirable, but may impose too great a restriction on wind farm development, or leave currently approved wind farms above the acceptable range.

The evidence of a dose response to sound levels from wind farms can be related to distance from them. The greater the distance from a turbine or group of turbines, the lower the sound level, an obvious statement. But how far away should they be? And is there a distance beyond which a different, lower, level of acoustical analysis could be allowed.

For a site with one to three modern 2 to 3 MW turbines, van den Berg suggests indicative distances are:

- At 1km: 30–35 dB(A), if penalty applies 35–40 dB(A).
- At 3km: 20–25 dB(A), if penalty applies 25–30 dB(A).
- At 6km: approximately 20 dB(A) (van den Berg, 2006)

Recent work by the author on predicting sound levels from a 36-turbine wind farm of 2MW units of 105 dB PWL, found that for propagation conditions downwind with a neutral atmosphere and cold moist atmosphere, the SA guideline level was achieved at a distance of 1,200m. This did not include any penalty for tonality.

If a modern wind farm (for example several 100 to 105 dB(A) PWL turbines) is proposed to be at a minimum distance of 2km from the nearest residential receivers, then it is unlikely that significant noise annoyance will occur. A noise assessment could be based on predicted sound levels at the residences only, without the need for detailed background measurements and regression analysis. Acceptable sound levels could be 30 dB(A) at 10m elevation wind speeds of 6m/s or less and 35 dB(A) at 8m/s. Acceptable sound levels for this type of lower level analysis would need to be determined by regulators and the industry.

If the distance is less than 2km, then a detailed analysis should be required. Acceptable sound levels are unlikely to be achieved at distances of less than 1000 metres.

The NSW DEC approach to acceptability of proposed wind farms, is that if the predicted sound level is less than the SA guideline level for acceptability, then the noise is considered acceptable. If the prediction is above the guideline level, then it is not approved. This compares with their approach to industrial noise with the Industrial Noise Policy guidelines, of 1 to 2 dB above Project Specific Noise Levels (PSNL's) being acceptable, 3 to 5 dB above PSNL's requiring a management plan, and greater than 5 dB above the PSNL is not approved.

The lower leeway for wind farms is on the basis of the community not yet being adapted to wind turbine noise whereas they are to industrial noise, and there is not enough data available as yet in the Australian context to allow for any exceedance (DEC, 2006).

MODEL VALIDATION

Predictions of wind farm noise are yet to be validated in Australian conditions. If model validation in Australian conditions was undertaken, it would remove another source of contention from opponents of wind farm proposals. There is a range of computer noise models available for this and they achieve a range of results. These have been discussed elsewhere (Tickell, 2006). Once the order of accuracy with specific models is known, published and verified, the uncertainty in predictions would be known.

Validation could be achieved using available sound level data, if wind farms are required to conduct suitable commissioning tests and make the data publicly available. This requires measurements at distances of 100m to 1000m from a wind turbine. Currently, most projects are only required to measure sound levels at the nearest residences, such as that reported for Toora by Fowler. In many cases the wind turbine noise may not be above the ambient sound levels to determine a suitable accuracy of the wind farm sound level contribution. This approach does nothing to assess the accuracy of the prediction models used in the environmental impact assessment.

CONCLUSIONS

Wind farms in Australia are often subject to opposition from communities when they are first announced. Often, expectations or perceptions of noise are major sources of objection and submissions.

Once wind farms are built, the rates of complaints are very low in Australia and New Zealand. This is mostly because of the distance between wind farms and residential receivers.

In cases where the distances are relatively small, less than 500m, there can be expected to be complaints of noise annoyance that can be shown to be justified by measurement.

Annoyance is related to sound level, which can be related to distance between the sources and the residential receivers. There are other factors involved in annoyance, and modulation of sound from the turbines is a recently described significant source of annoyance. An individual's response to wind farms appears to be a major factor in the response to noise annoyance.

To allow further development of wind farms without noise becoming an issue, it is likely that a lower acceptable level for contribution sound and less modulation noise will be required. There will also need to be publicly available information about complaint history and monitoring results for operating wind farms.

A reduced potential for annoyance may be achieved if the noise limit is based on the night-time regression analysis of LA90 vs turbine wind speed, plus 5 dB. If modulation occurs, a 10 dB penalty at night-time could be applied. However, this will leave many currently approved wind farms with predicted or operating sound levels exceeding these objectives.

If a proposed wind farm has more than 2km distance to the nearest residence, then a detailed background noise analysis should not be required and only predictions be required to show acceptable sound levels can be achieved. Such sound levels might be 30 dB(A) for wind speeds up to 6m/s at 10m elevation, but an acceptable sound level would need to be developed by regulators.

Models used in prediction of wind turbine noise need to be validated in Australian conditions to reduce their uncertainty.

The long-term aim for the wind turbine industry and its acoustical consultant advisors should be to remove noise as an issue for new developments.

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