VISUAL AND NOISE EFFECTS REPORTED BY RESIDENTS LIVING CLOSE TO MANAWATU WIND FARMS: PRELIMINARY SURVEY RESULTS

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ABSTRACT

Since 1996, when Tararua Wind Power Limited commenced the construction of 48 wind turbines, the number of existing wind turbines on the Ruahine and Tararua ranges has risen dramatically, to 158 in 2006, with more to come from unimplemented, approved resource consents. The companies behind the applications have won plaudits for the development of sustainable energy generation. However, the effects of wind energy can be controversial. In particular, it is reported in other countries that those who live near the wind turbines may suffer from undesirable visual and noise effects, and the national benefits and local costs may not be in balance. Assessing the precise impact of future wind farm development is important, since the number of proposed wind farms is likely to grow in the coming years. The objective of this study was to investigate the noise and visual effects on local residents from the existing wind turbines in the Manawatu and Tararua region. A total of 1100 urban and rural residents, the majority living within a 3km radius of the wind farms in the Tararua and Manawatu districts were administered a self-reporting survey. The survey asked residents to assess the visual and noise effects of the closest wind farm. This paper presents preliminary results from this study. It demonstrates that 45 percent of respondents living within 2km heard noise from the turbines, and 80 percent thought that the turbines were visually intrusive.

1 INTRODUCTION

New Zealand has a national goal of increasing the supply of renewable energy, such as wind farms, which is expressed in part by amendments to the Resource Management Act 1991 (RMA). The amendments elevate the importance of renewable energy as a consideration for decision makers to approve or decline a resource consent application. The recent Parliamentary Commissioner for the Environment's report on wind farms presents several scenarios for future wind farm development by 2016 with extremes ranging from 1,300 1.5MW turbines in 65 wind farms, to 67 3MW turbines in 7 windfarms (Parliamentary Commissioner for the Environment 2006). Wind farms tend to be located in prominent locations, such as open or coastal areas and ridgelines. Most are located close to existing infrastructure, such as a transmission line, and roads to reduce development costs. A wind farm consists of the turbines as well as substantial roads, buildings for substations etc., yards and high voltage transmission lines. The expansion of windfarms is likely to cause conflicts, particularly when this expansion occurs near existing housing. The benefits of wind farms are typically accrued nationally and include providing a renewable energy supply. The negative impacts are felt locally and include visual amenity and noise. Given the potential growth of windfarms, examining how these conflicts are addressed should be an important area of research.

Under section 104 of the RMA, planners are required to assess whether the effects of a wind farm can be avoided, remedied or mitigated. An applicant for a resource consent must include an assessment of environmental effects respecting the proposed project. This requirement has

already generated a number of landscape assessment reports to show the perceived visual effects, noise modeling and related predictive modeling. However since industrial-scale wind farms are relatively new in New Zealand, little research on existing wind farms exists on post-installation visual and noise effects.

The objective of this study was therefore to undertake a survey of the visual and noise effects experienced by residents' who live near wind farms on the Ruahine-Tararua ranges near Palmerston North. This area is ideally placed to inform understanding of wind generation in New Zealand, due to its concentration of existing wind farms. In this region, there are currently 158 turbines operational with a generation capacity of up to 300MW of wind energy. A further 128 turbines have been consented or are under construction; a development consisting of 129 turbines is in the resource consent and proposals are being developed for at least one other wind farm with more than 60 turbines. In other regions of New Zealand further large scale wind farms are also in the planning or consent stage.

It is generally agreed that a buffer zone between wind farms and housing is important to minimize visual and noise effects but the size of this zone has been subject to considerable debated. To date few turbines have been built within 1km of existing residences in New Zealand. However, with wind farms that are currently seeking consent, the distances between proposed turbines and existing homes is now under 600m.

We aim to investigate and inform planners about the potential effects of wind farms from a visual amenity and noise perspective. Specifically, this paper presents the preliminary analysis of this survey, in which we aimed to answer the following two questions:

- What are the most important visual amenity effects from the wind farms?
- What percentage of residents can hear the noise produced by the wind farms and does wind farm noise vary with distance?

2 RECENT LITERATURE ON THE EFFECT OF WIND FARMS

2.1 PUBLIC ATTITUDES TO WIND FARMS

Most New Zealanders support sustainable energy, and consider wind farms as a clean, green source of energy (Parliamentary Commissioner for the Environment 2006). A survey conducted on behalf of EECA on public opinions in New Zealand found that of the 750 people surveyed, 58.9 percent thought they were environmentally friendly, 0.1 percent thought they were attractive, 24.9 percent thought they were ugly, and 14.7 percent thought noise was a disadvantage (UMR Research Limited 2004).

However, the development of industrial-scale wind farms near existing housing is contentious, and achieving a balance between national interests and local effects is precarious. Both in New Zealand and overseas, opinions among residents who live near wind farms vary greatly. Some are in favour of turbines and consider them as unobtrusive and visually attractive. Others are strongly opposed to wind farms, citing concerns that they ruin the visual quality of the environment, produce noise pollution and adversely affect wildlife (Devlin 2005). In Europe, community protests have had a significant impact on the introduction of wind power generation schemes (Parliamentary Commissioner for the Environment 2006) and it has been estimated that public opposition has prevented planning permission being granted for about 50 percent of European proposals. In the Netherlands 75 percent of proposals have been refused (Van der Loo 2001). A report prepared by the European Renewable Energy Council (Parliamentary Commissioner for the Environment 2006) stated that:

> *"For many years, wind energy was considered environmentally sound. But recently, major social objections and land use concerns related to operation and siting of turbines have been raised. Social acceptance is one of the greatest limiting factors of wind's potential growth."*

In New Zealand few submissions were received in opposition to earlier wind farm proposals, however more recent proposals have seen an increase in both number and sophistication of submitters in opposition. A review of resource consents heard between 1996 – 2005 revealed:

- *An increasing number of objectors*

- *Increasing sophistication of the objections*
- *Increasing uncertainty on the part of the applicant as to the likely success at hearing, in particular how many turbines may be allowed*
- *Increasing requirement for consultation by the applicants* (Fisher 2005)

2.2 VISUAL EFFECTS

Although visual assessment techniques can inform the public how a landscape will look after it has been developed as a windfarm, mitigating this visual effect remains elusive. This was evident at the Meridian West Wind, Makara, wind farm resource consent hearing and the joint Unison Networks Limited and Hawkes Bay Wind Farm Limited hearing, where there was little agreement between the experts (2005; 2006). In the latter hearing the Environment Court made the following comments;

> *"It is self-evident that landscape issues are matters about which reasonable and informed people may hold conflicting views. It is not possible to say that one is right and another is wrong….turbines need to be on or near ridgelines, and will often be on skylines, and there is no real prospect of remedying or mitigating their adverse visual effects. Either the activity proceeds, or the effects are avoided by refusing consent."*

Guidelines developed in Europe specific to the visual effects of wind turbines (Thomas 2002) have not been applied so far as a condition for resource consent in New Zealand. These guidelines provide a matrix showing an increasing visual effect with decreasing distance between the wind farm and the receiver and/or increasing height of turbines. They include assessment criteria that may be useful in New Zealand.

Turbines are visually unique elements in the landscape due to their:

- height (often taller than a 30 storey high rise building)
- the number of blades, 2 or 3
- spacing between turbines and placement, such as clustering, or arranged in rows
- colour
- movement, which contributes to their visibility, visual stimulation and attracts the eye (Parliamentary Commissioner for the Environment 2006)
- flickering shadows (Pederson 2005).

Due to their height and need for wind, turbines are not easy to screen or hide and the *"highly modern, technological and large scale nature of windfarms can dominate…"* (Parliamentary Commissioner for the Environment 2006). The scale and prominent location of wind farms means the visual impact can extend well beyond the site. In the hearing for Tararua wind farm (stage 3) James Baine, (2005) an expert presenting a social impact assessment for TrustPower stated:

> *"For the immediate community of interest and neighbours, separation distance between dwellings and turbines is a critical factor in assessing the significance of effects. This highlights the importance of buffer areas between dwellings and turbines. A separation distance of 2.0-2.5km appears to be the threshold below which acceptance is more likely to be replaced by negative sentiments from neighbours who experience no direct benefits."*

All existing New Zealand wind farms have been developed in rural settings. They therefore impact on rural amenity in several ways. For example, *"they introduce large potentially discordant structures that are not associated with normal types of rural activity. The associated works such as roading and earthworks can be at a scale that is unfamiliar in rural areas"* (Parliamentary Commissioner for the Environment 2006). This may influence public acceptance of subsequent proposals.

2.3 CUMULATIVE VISUAL EFFECTS

Several wind farms located in close proximity can create cumulative effects. This is particularly pertinent to their visual impact. The cumulative visual effects have not so far been comprehensively addressed in New Zealand, possibly because it is a relatively new phenomena in this country, but have been researched elsewhere, notably in a report by the Scottish Natural Heritage (Williams 2005). This report lists the effects on the visual amenity and landscape from wind farms as a function of:

- the number of and distance between individual wind farms
- how wind farms relate to each other visually

- the overall characteristics of the landscape and its sensitivity to wind farms
- and the siting and design of the wind farm.

While the cumulative effect on the whole of New Zealand may not be significant, the cumulative effects at a regional or localized level can be significant (Parliamentary Commissioner for the Environment 2006). The Tararua ranges, near Palmerston North is a New Zealand example where several wind farms of different height turbines, tower types and number of blades have been located together. The Parliamentary Commissioner's report on wind farms states that this raises concerns for cumulative effect in this region. Wind farms are not unique in this regard. Other reports prepared by the Parliamentary Commission for the Environment state that the RMA has not adequately addressed the cumulative effects of other land uses such as subdivisions and urban development (Parliamentary Commissioner for the Environment 2001) This suggests that cumulative visual effects of wind farms should receive closer attention in the consent process and should be a specific section of a visual assessment.

2.4 NOISE

Noise is one of the most frequently raised concerns, both in New Zealand and overseas about wind farms (Parliamentary Commissioner for the Environment 2006). Wind turbines generate noise from a number of sound production mechanisms related to the interactions between the turbine blades and air, and as the blade passes the tower. Gear box and generator noise in modern turbines is not significant when turbines are new but increases significantly as turbines wear (Stewart 2006).

New Zealand planners have recourse to a non-mandatory standard that is specific to the noise from wind turbine generators (*NZS 6808: 1998 Acoustics - The Assessment and Measurement of Sound from Wind Turbine Generators*). This standard is designed to provide a level of investigation and reporting that may be specified by land use planning procedures under any relevant legislation' (New Zealand Standards 1998)). This Standard also allows for Councils to apply their own noise criteria to be used, such as noise criteria given in their District Plan.

NZS6808 uses a simple propagation model that does not account for wind, ground or topographical effects, such as contours, and uses a simplified approach to account for atmospheric effects (New Zealand Standards 1998; EPA 2003). This can underestimate both the noise produced and transmission of this noise. A four day caucus of acoustic consultants for the West Wind wind farm hearing heard before the Environment Court, found that NZS6808 is workable but has some significant technical deficiencies that need addressing, such as atmospheric effects (Thorne 2007). A member of the West Wind acoustic caucus concluded that there is a temptation to only fulfill the requirements of the standard without considering the complex nature of wind farm noise, such as third octave data, topographical effects and atmospheric stability (van den Berg 2005). In practice, the application of NZS6808 may too simplistic an approach to something that is as complex as noise from a wind farm (EPA 2003).

The approach of Standard NZS6808 is unusual in that it allows wind turbines to produce noise up to the greater of 40dbA or ambient noise levels plus 5dbA. The premise of this approach is the wind that makes turbines turn will also produce masking noise. However, van den Berg (2006) has found that with modern turbines, which can be 80 – 110m tall, there are frequent periods with sufficient wind at hub height to turn the turbines and generate noise, with corresponding stillness and lack of masking noise at ground level. He found that this effect is most pronounced at night time. Van den Berg, has concluded that the number and severity of noise complaints near wind farms are partially explained by three findings;

- that actual sound levels are considerably higher than predicted noise
- wind turbines can produce noise with an impulsive character which has been described as a "wump, wump sound" each time the turbine blade passes the tower (van den Berg 2004; van den Berg 2006)
- noise measurements, which are expressed as averages of sound energy, substantially under represent the loud/quiet nature of the pulsing sound produced by turbines.

This study found residents up to 1900m away from wind farms expressed annoyance with noise, which is contrary to conventional wind industry calculations, which assumes minimal noise beyond 500m. Significant variations occurred between day and night time noise due to higher wind speeds at hub height turning the turbines during the night hence producing night time noise

compared to lower wind speeds and a consequent lack of masking noise at ground level close to residences (van den Berg 2006).

This research highlights some of the technical shortcomings that could be addressed in NZS 6808:1998. The standard was due for review in 2006, however the revised version has yet to be released. It is of interest that a household that was only 400m from the Te Apiti wind farm was deemed uninhabitable and the occupants were relocated by the wind farm owner after irresolvable noise issues (Campbell 2006).

2.5 CUMULATIVE NOISE

Some acoustical consultants consider the approach of NZ6808 in focusing on ambient sound plus 5dbA as erroneous, especially in areas with staged wind farm developments, or where there are a number of wind farms close together. In these situations, each subsequent development or stage of a development is permitted to build on the noise produced by existing turbines, with a net effect of ramping up ambient noise (Stewart 2006).

2.6 LOW FREQUENCY NOISE

Noise, especially low frequency noise, is a particularly contentious component of a planning consent assessment. Some acoustic consultants argue that low frequency noise is below the threshold of hearing, and is therefore undetectable (Leventhall 2005). It is not well addressed in NZS6808:1998 which uses only the dBA scale, which excludes low frequency noise (New Zealand Standards 1998).

However, low frequency noise disturbance has been well documented as an effect from wind turbines (Casella 2001; van den Berg 2004; Jakobsen 2005; van den Berg 2005). The Report of the Noise Review Working Party 1990 published by the Department of the Environment (Batho 1990) commented on low frequency noise as follows: …."*Low frequency noise can have serious effect on the quality of life of those affected by it".* The Batho report and others (Guest 2003) cited low frequency noise as a significant issue for regulators and planners, due to the difficulties with measuring it and mitigating it. The Casella report has cited low frequency noise as having several pertinent features different to other frequencies of community noise:

- low frequency noise is not attenuated with distance from the source, making low frequency noise more prominent at greater distances
- low frequency noise is not attenuated by typical building envelope designs to the same extent as other frequencies making low frequency more prominent inside a building
- inside buildings resonance can be set up inside a room with nodes (quiet points) and antinodes (loud points), which can elevate low frequency noise inside a room
- older peoples' hearing is proportionally more acute at low frequencies than other mid or high frequencies and
- low frequency noise can cause light weight elements of a building structure to vibrate.

2.7 HEALTH EFFECTS OF NOISE AND LOW FREQUENCY NOISE

Adverse health effects have been reported from wind farm neighbours. The World Health Organisation (WHO) has defined health as *"a state of complete physical, mental and social wellbeing, and not merely the absence of infirmity."* The WHO guidelines for community noise list specific effects to be considered when setting community noise guidelines. These include interference with communication; noise induced hearing loss; sleep disturbance effects; cardiovascular and psycho-physiological effects; performance reduction effects; annoyance responses; effects on social behaviour (Berglund 2000).

Symptoms akin to vibroacoustic disease (Branco 2004) and increased frequency of hypertension and cardiovascular illness have been reported by people living close to wind farms. Although complex and controversial, it is thought that these symptoms arise from a combination of persistent audible noise, flicker and low frequency noise destabilising the human body (Stewart 2006). Hearing has evolved from our survival instincts to respond to danger as well as to alert, warn and communicate; our hearing is operational even when people are asleep. As a result, both

wanted and unwanted sound directly evokes reflexes, emotions and actions which are both stimulants and stressors. The auditory system has the fastest response rate in the human brain and processes information hundreds of times faster than other senses (Hudspeth 2000). The extent to which noise is a stimulant or stressor is a factor of noise source, onset of the noise, duration and characteristics of the noise and whether the exposure is voluntary or involuntary (EnHealth 2004).

Worldwide there have been calls to have a mandatory buffer zone of 1.6km around wind farms, and in many situations an even greater distance between wind farms and residences, so as to avoid noise and visual impacts (Gueniot 2006), Stewart 2006). However, until recently there has been little research conducted in New Zealand on the effects from current wind farms to inform the political or planning process. Consequently, we conducted a survey of visual and noise effects to inform the consent process.

3 METHOD

A four-page, self-reporting survey was developed to investigate the visual and acoustical effects experienced by residents who live within 3km of existing wind farms in the Manawatu and Tararua region. Some surveys were delivered to residence outside the 3km notional ring, in order to survey a complete street. Questions were asked about the distance from respondent's house to the nearest turbine, whether they could see turbines from their home, visual impacts, noise impacts, financial gain from the wind farms, effects on television, radio and phone reception, whether they had complained or considered complaining about the wind farm effects. Other questions canvassed their views on future developments and descriptor data, including the number of persons living in the household and length of time living at the address.

Prior to administration, the survey was peer reviewed by two senior academics with considerable expertise in questionnaire design and trialed on a small sample of people not living in the subject region. One of the peer reviewers was a Chair of a Massey University Ethics committee and advised that ethics approval was not required due to the low sensitivity of the questions and appropriate provisions for anonymity of respondents.

The survey was divided into 5 sections; visual, noise, general, complaining about wind farm effects, future developments, and household details. However, as only the visual and noise effects is the subject of this paper, other data will be reported in a subsequent paper. Most questions in the survey only required a tick the box response, with responses mostly on a five point lichter scale or yes/no as appropriate.

Surveys were anonymous to protect the privacy of respondents, however the street address was recorded at time of delivery, so a cross check could be made on approximate distance from turbines to residence. The surveys were delivered to about 1100 urban and rural letterboxes in September 2006. Surveys included a reply paid envelope and a separate detachable postcard that could be completed if respondents were interested in being contacted for further comment or would like to receive a copy of the survey results.

Our first objective was to assess which of the various visual effects of wind farms were considered most significant. Wind farms could be considered visually significant from an aesthetic point of view or because they contain moving parts. Equally their impact could be seen to be important because they involve a change to a significant landscape feature that many residents identify with. The challenge is to understand which of these factors best explains attitude. Respondents were asked to rate on a five point scale (from disagree strongly to agree strongly), to what extent they agreed or disagreed with each of the following statements about visual amenity:

- I think the turbines spoil the view
- I think turbines are quite attractive
- I find the movement of the turbines irritating
- The turbines are intrusive in my view
- The view of the turbines doesn't bother me
- I am aware of shadows or flicker from the turbines
- Watching the turbines can create an unpleasant physical sensation in my body

- The view of turbines reduces my enjoyment of my property
- I enjoy watching the turbines.

Visual questions were asked in both the positive and negative sense e.g. *"I think turbines spoil the view?"* and *"I think turbines are quite attractive?",* to balance opinions.

In the noise section, questions referred to heard noise from wind turbines, the frequency heard during the day and night, as well as qualitative aspects of the noise e.g. sounds like a train that never arrives or swishing noise. Respondents were also asked if they had altered their house because of noise from the wind turbines.

4 RESULTS AND DISCUSSION

4.1 RESPONSE RATE

Out of a total of 1100 survey forms delivered, 604 where returned, providing a response rate of 55%. This is considered to be high for a self-reporting, self-returning survey and suggests a high level of interest in the subject matter of the survey. Some surveys were returned after the analysis had commenced and will be included in subsequent reports.

It is assumed that many respondents guessed the distance from their home to the closest turbine, as a reported distance greater than 3km was relatively common. These distances will be manually corrected against delivery records in subsequent analysis. Only one respondent gave the distance between their home and closest wind farm as less than 1km, and only forty eight (8 percent) respondents reported they lived closer than 2km.

4.2 VISUAL

Of the 516 respondents that reported being able to see the wind farm, only 483 were used in the analysis, due to incomplete or insufficient answers. We employed a principal component analysis (PCA) to examine which of the above statements accounted for the largest amount of variation in the dataset and which of the above statements was the most important for the residents.

Table 1 shows the PCA results, with the numbers in the diagonal being a calculation of the contribution that each of the components made to the overall variability of the dataset.

Table 1: Principle components of visual amenity

	spoil view	attract-ive	move-ment	Intrusive	doesn't bother me	flicker	physical sensation	reduce enjoy-ment	like watching
spoil view	0.24	0	0	0	0	0	0	0	0
attractive	0	0.36	0	0	0	0	0	0	0
movement	0	0	0.31	0	0	0	0	0	0
Intrusive	0	0	0	8.09	0	0	0	0	0
doesn't bother me	0	0	0	0	0.38	0	0	0	0
flicker	0	0	0	0	0	1.08	0	0	0
Physical sensation	0	0	0	0	0	0	0.20	0	0
Reduce enjoyment	0	0	0	0	0	0	0	0.53	0
Like watching	0	0	0	0	0	0	0	0	0.49
	2%	3%	3%	69%	3%	9%	2%	5%	4%

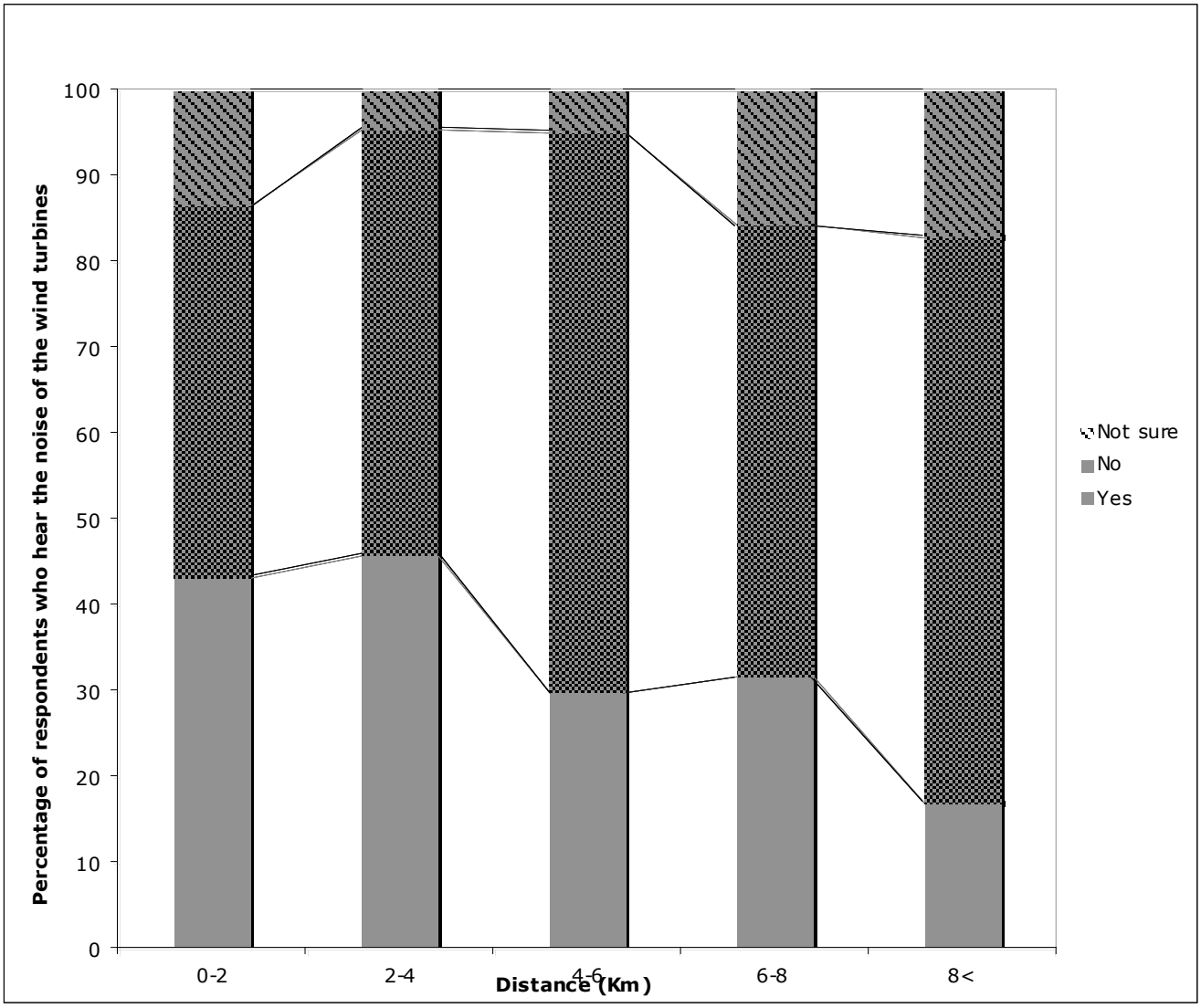
The results demonstrate that the most important visual effect of wind farms was whether respondents considered that they are visually intrusive. This factor accounted for 69 percent of the variability in the data. The flickering motion of the turbine blades was the only other factor

that appeared to affect the views of a significant number of respondents (9 percent) as an area of concern. This result is in agreement with the Sinclair –Thomas matrix (Thomas 2002)

Eighty percent of the respondents considered that the turbines were intrusive, and 73 percent thought that they were unattractive. This latter result is in contrast to the UMR national survey conducted for EECA which found that only 24.9 percent thought wind turbines were ugly. This discrepancy between surveys could be due the EECA survey participants being drawn from all areas of New Zealand, rather than residents living close to wind farms.

4.3 NOISE

Figure 1: The proportion of respondents who hear the wind farms against distance



In the second part of the analysis, respondents were asked for the distance (that is, their subjective estimate of distance) between their home and the wind farm, and to provide data about the kind of noise that they heard. A substantial amount of data on noise was collected in the survey, which will be used in a subsequent publication to highlight, among other points, the qualitative impacts of the noise. For this preliminary paper we were interested in the relationship between the distance of the wind farm and participants' perceptions of possible adverse effects of noise from the wind farm.

Figure 1 is a graph of the data that were analysed. Not surprisingly, the proportion of respondents that could hear the wind farm reduced progressively with distance. What is surprising is that as much as 72 percent of respondents reported hearing turbine noise. In particular, 45 percent of

respondents "located" between 0-2 kms heard wind farm noise; while as many as 20 percent of respondents' "located" 8 kms away could apparently still hear the wind farms. A chi-squared analysis showed these results were statistically significant. There was no apparent difference between the numbers of participants who reported hearing them more during the day or night.

These preliminary results suggest strongly that there is an important effect of wind farm noise upon people that may well extend several kilometers from the site of turbines. Further research is recommended, including physical noise measurements that could include third octave data as well as modulation and tonal characteristics, under a range of atmospheric conditions. As noted in the literature review, topography is an important factor in noise propagation. In this geographical area there is also a river and topographic effects that would most probably reduce the noise transmission from the turbines to the majority of receivers. The predominant wind direction is also blowing away from Ashhurst, which was the location of the largest population cluster. Both of these factors may reduce the number of people hearing the wind farm compared to other locations. It is also recommended that this survey be repeated in one – two years to assess if the noise issues are decreasing as people become accustomed to the noise or increase as more turbines are constructed. The first wind farm in this area has been operational for ten years.

The results suggest that the wind farms have significant noise influences upon a large number of people in the area. One immediate suggestion is that by only concentrating on NZS6808:1998, planners could underestimate the noise effects on a large number of people. This could give grounds for the precautionary principle to be used until more research has been conducted on the noise from wind farms. The noise issues may be addressed in the next revision of NZS6808. In this survey only one respondent gave the distance between their home and the closest wind farm as less than 1km. However, wind farms currently in the consent process are proposing distances down to 400m from existing homes, which could exacerbate the noise and visual effects from those reported in this survey.

5 CONCLUSIONS

The wind farm consent process under the RMA is attracting increasing levels of public opposition, with visual and noise effects being two primary concerns. The high response of 55 percent from this survey is higher than expected for a self-reporting – self-returning survey and suggests strong, local public interest in this topic. The results of this paper are preliminary but they do highlight the complexity of assessing the effects of windfarms.

In this survey, 516 respondents reported they could see turbines from their homes. Of these, 80 percent considered the turbines were visually intrusive, and 73 percent thought that they were unattractive. Analysis showed visual intrusiveness was the strongest concern. These concerns of the visual intrusiveness expressed by locals living near wind farms are at odds with the national support for wind energy reported in other studies.

The Parliamentary Commissioner for the Environment has acknowledge that visual effects from wind farms are difficult if not impossible to mitigate, therefore careful selection of the location may help to reducing the visual effect and public opposition.

The results also show that wind farms have significant noise effects on a larger population and at a greater distance than would be expected by applying NZS6808:1998. Noise from Manawatu wind turbines was heard by 75 percent of all respondents. Of these, 45 percent of households living within 2km of the wind farm and 20 percent of households living up to 8km away reported hearing turbine noise. This strongly suggests that NZS6808:1998 is underestimating the number of people affected by noise, possibly exacerbated by atmospheric conditions and special noise characteristics.

Under the RMA, planners in New Zealand are expected to reach an understanding of the likely effects of a potential development before they grant a resource consent. Refining the modeling tools and techniques that planners, landscape architects and acoustic consultants use is a constantly evolving. Research conducted in countries where wind farms have been in existence

longer than New Zealand could be relevant to the New Zealand context. Along with these techniques however, planners may employ the precautionary principle where uncertainty or ignorance exists concerning the nature or scope of environmental harm. The results would suggest that unless a review is undertaken of the noise standards for windfarms, resource consent applications for windfarms may be refused in the future on precautionary grounds.

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7 REFERENCES

(2005). Report and Decision of the Joint Hearings panel in the matter of the application for resource consent by TrustPower Limited for the construction and operation of 40 wind turbines and associated services being an extension to the existing Tararua Wind farm on the slopes of the Tararua ranges. Palmerston North.

(2005). Report and Decision of the Joint Hearings panel in the matter of the application to construct, use and maintain a wind farm on 55.8 square kilometre site to the west of Wellington City. Joint Hearings Commissioners. Wellington, Wellington City Council**:** 1-50.

(2006). Unison Networks Limited and Hawkes Bay Wind Farm Limited v Hastings District Council. Judge Thompson. Wellington.

Batho, W. J. S. C. (1990). Report of the Noise Review Working Party, Department of the Environment.

Berglund, B. L., Thomas.; Schwela, D.H. (2000). Guidelines for Community Noise. Geneva, World Health Organisation.

Branco, M. A.-P., M. (2004). "Vibroacoustic disease." Noise and Health **6**(23): 3-20.

Campbell, J. (2006). Campbell Live TV3. New Zealand.

Casella, S. (2001). Low Frequency Noise Update. DEFRA Noise Programme, Department of the Environment, Northern Ireland Scottish Executive
National Assembly for Wales**:** 1-11.

Devlin, E. (2005). "Factors Affecting Public Acceptance of Wind Turbines in Sweden." Wind Engineering **29**(6): 503-511.

EnHealth (2004). The Health Effects of Environmental Noise - Other than Hearing Loss. Canberra, Australia, EnHealth Council, Department of health and Aging, Commonwealth of Australia**:** 1-71.

EPA (2003). Wind Farms: Environmental Noise Guidelines. Adelaide, Australia, Environmental Protection Authority**:** 1-22.

Fisher, R. (2005). "Wind Energy in New Zealand: Regulatory and Policy Lessons to Date." New Zealand Journal of Environmental Law **9**: 307-335.

Gueniot, C. (2006). Panorama du Médecin. Paris, France, National Academy of Medicine.

Guest, H. (2003). "Inadequate standards currently applied by local authorities to determine statutory nuisance from LF and infrasound." Journal of Low Frequency Noise, Vibration and Active Control **22**(1): 1-7.

Hudspeth, A. K., M (2000). "Auditory Neuroscience: Development , Transduction and Integration." National Academy of Sciences **97**(22): 11690-11691.

Jakobsen, J. (2005). "Infrasound Emission from Wind Turbines." Journal of Low Frequency Noise, Vibration and Active Control **24**(3): 145-155.

New Zealand Standards (1998). "New Zealand Standard NZS6808:1998 Acoustic - The Assessment and Measurement of Sound from Wind Turbines Generators."

Parliamentary Commissioner for the Environment (2001). Managing change in paradise: Sustainable development in peri-urban areas. Wellington, Parliamentary Commissioner for the Environment.

Parliamentary Commissioner for the Environment (2006). Wind power, people and place. Wellington, Parliamentary Commissioner for the Environment**:** 144.

Pederson, E. W., Kerstin Persson (2005). Human Response to Wind Turbine Noise - Annoyance and Moderating Factors. Wind Turbine Noise: Perspectives for Control, Berlin, INCE/European Conference.

Stewart, J. (2006). Location, Location, Location - An Investigation into the Windfarms and Noise. London, UK, The Noise Association**:** 1-32.

Thomas, S. (2002). Visual assessment of Windfarms: Best Practice, Scottish Natural Heritage.

Thorne, B. (2007). Noise Assessment Report Proposed Motorimu Windfarm Palmerston North. Brisbane, Australia, Noise Measurement Services**:** 1-57.

UMR Research Limited (2004). Ominbus results; Research for EECA into public attitudes to wind power. Auckland, UMR Research Limited.

van den Berg, G. P. (2004). Do wind turbines produce significant low frequency sound levels? 11th International Meeting on Low Frequency Noise and Vibration and its Control, Maastricht, the Netherlands, http://www.viewsofscotland.org/library/docs/LF_turbine_sound_Van_Den_Berg_Sep04.pdf.

van den Berg, G. P. (2004). "Effects of the Wind Profile at Night on Wind Turbine Sound." Journal of Sound and Vibration **277**: 955-970.

van den Berg, G. P. (2005). "The Beat is Getting Stronger: the Effect of Atmospheric Stability on Low Frequency Modulated Sound of Wind Turbines." Journal of Low Frequency Noise, Vibration and Active Control **24**(1): 1-24.

van den Berg, G. P. (2006). The Sounds of High Winds: the effects of atmospheric stability on wind turbine sound and microphone noise. Rotterdam, University of Groningen**:** 1- 200.

Van der Loo, F. A. (2001). Mediating Windpower in the Netherlands: the Task Force Windpower Implementation. Novem: Ultretch, Dutch Wind Energy Association**:** 1-4.

Williams, K. (2005). Guidance; Cumulative effect of Windfarms, Scottish Natural Heritage**:** 1-32.