

Evidence of Dr Robyn Phipps,

In the Matter of Moturimu Wind Farm
Application

heard before the Joint Commissioners
8th – 26th March 2007
Palmerston North

1 MY EXPERTISE

In addition to being a person directly affected by this proposal, I have some qualifications and expertise which equips me to be able to comment on this proposal with knowledge.

1.1 MY CURRENT POSITION IS:

Senior Lecturer in Building Technology,
Massey University

1.2 MY QUALIFICATIONS ARE:

Bachelor of Building Science,
Bachelor of Architecture (Hons),
PhD the topic of which was healthy building environments
Certificate of mould remediation
Partial completion of Masters of Architectural Technology

1.3 HONORS, MEMBERSHIPS ETC RELEVANT TO THIS HEARING INCLUDE:

Director Health and Housing Research Programme. This is a world class and very active research unit that attracts Health Research Council and private sector funding. This research unit produces research that is regularly presented as keynotes at WHO scientific meetings, and is published in esteemed medical journals such as British Medical Journal and informs changes to the Building Code. Energy and cost benefit issues are central to the centre's research. My role in this established team is in the physical science and measurement of building environments, however physical science is intrinsically interwoven with health outcomes

Principle Researcher with the National Energy Research Institute (NERI) which is one of 6 research centers of excellence funded by the Tertiary Education Commission (TEC). I am a founding member of this centre for my recognized expertise in solar energy use.

Principle Investigator with Centre for Urban Health and Development (CUHAD). I am a principle investigator and theme leader with this centre of research excellence, which is recognition of my expertise in integrating the physical properties of the living environment and human health.

Associate Investigator with New Zealand Energy Research Centre (NZERC), I am a founding member and associate researcher with this centre for my recognized expertise in solar energy use. My role in this centre is passive solar technologies.

Past chair and currently Deputy Chair of the Clean air Society of Australia and New Zealand, special interest group for indoor air quality. This includes an advisory role to the Australian and New Zealand government and public bodies on indoor air quality in buildings, as well as training, conference organization and initiation of research projects.

Active member of International society for Indoor Air Quality and Climate and have been highly involved in several international tasks forces for healthy indoor environments

1.4 SENIOR LECTURER IN BUILDING TECHNOLOGY AT MASSEY UNIVERSITY.

- I have 12 years experience in research into indoor environmental quality and the effect this has on human health and wellbeing and energy efficiency of buildings.
- I am suitably qualified and experienced to interpret scientific data and literature on topics close to my expertise.
- I have developed and lead a postgraduate program at Massey University for in Indoor Air Quality and Healthy Environments. My own PhD thesis was in this subject and I have since supervised many other postgraduates in this area.
- I am leading the development of new taught papers on energy efficiency of buildings and research in this area.
- I have conducted research projects on many aspects of indoor environmental quality, energy efficiency and health outcomes, solar design of housing, energy efficient lighting in buildings, the effects of dampness and ventilation rates in buildings. I am a co-leader on a project investigating health, noise and other environmental parameters in primary schools.
- The transmission of noise through building elements is one of the topics that I teach at undergraduate level.

1.5 CODE OF CONDUCT FOR EXPERT WITNESS

I have read and understand the conditions of conduct for being an expert witness. I comply with all criteria for being an expert witness except that I am an affected party, in that I live at 408 Scotts Road. However, there is no one else in my field with my level of expertise in New Zealand to have as a substitute expert. This evidence has been peer reviewed by Bob Thorne.

2 EVIDENCE

2.1 My evidence consists of four areas of concern.

- The first is a presentation of a survey of Visual and Noise effects experienced by residents currently living close to the existing wind farms in the Tararua and Ruahine ranges.
- The second aspect is a review of literature on health effects, other than hearing loss, from exposure to noise and vibration as well as the transmission of noise and vibration into buildings.

- The third aspect is addressing the suggestion that adverse impacts of noise can be satisfactorily remedied by modifications to homes. Particularly it addresses an assessment of the effectiveness of sealing a home to stop noise intrusions.
- The fourth topic is solar energy and energy efficiency as alternative means of addressing energy supply issues.

3 SURVEY OF VISUAL AND NOISE EFFECTS EXPERIENCED BY RESIDENTS LIVING NEAR THE EXISTING WIND FARMS IN THE TARARUA AND RUAHINE RANGES.

3.1 I led a survey of the visual and noise effects experienced by residents living within a notional 3km ring of the existing wind farms in the Tararua and Ruahine ranges. A four-page, self-reporting/self-returning survey was developed to investigate the visual and acoustical effects experienced by residents who live within a notional 3km ring 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.

3.2 The methodology and preliminary results have been peer reviewed by two reviewers and are in press for the New Zealand Planners Institute Conference. The full NZPI paper is appended (Appendix 1) and a blank survey form in Appendix 2. Further to the NZPI publication, more detailed analysis has been conducted on the data, which is reported below. Some surveys that were returned after the preliminary data analysis had commenced have also been included in this latter analysis.

3.3 METHODOLOGY

3.4 Prior to administration, the survey was peer reviewed by two senior Massey University academics with considerable expertise in questionnaire design and it was trialed on a small sample of people not living in the subject region. One of the peer reviewers is Chairman 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 and confidentiality of the households.

3.5 The survey was divided into 5 sections; visual, noise, general, complaining about wind farm effects, future developments, and household details. 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.

3.6 Surveys were anonymous to protect the privacy of households, 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 (one per household) 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 households were interested in being contacted for further comment or would like to receive a copy of the survey results.

3.7 **Visual affects questions**

The 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.

3.8 Households 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.

3.9 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.

3.10 **Noise affects questions**

In the noise section, questions asked if households heard noise from the wind turbines (yes/no or not sure), the frequency they heard during the day and night. Data was sought on the qualitative aspects of the noise e.g. sounds like a train that never arrives, hum or swishing noise; respondents could select from 7 options or add their own description. Households were also asked if they had altered their house because of noise from the wind turbines.

3.11 **RESULTS AND DISCUSSION**

3.12 RESPONSE RATE:

Out of a total of 1100 survey forms delivered, 614 were returned, providing a response rate of 56%. This is considered to be very high for a self-reporting, self-returning survey, with no follow-up for late returned surveys and suggests a high level of interest in the subject matter. The surveys reported the affect experienced by the household, rather than just an individual

3.13 DISTANCE BETWEEN HOUSEHOLD AND CLOSEST WIND FARM

All distances from homes to closest turbines have been manually checked against delivery records. These distances are approximately accurate to 0.5km. All households responding to the survey were more than 2km from operational turbines. Only 16 percent lived between 2 and 2.5 km, 40% lived 2.5km away, and 29% lived 3km away. The frequency of distance from the respondent's home to the closest wind farm is shown in Figure 1 below.

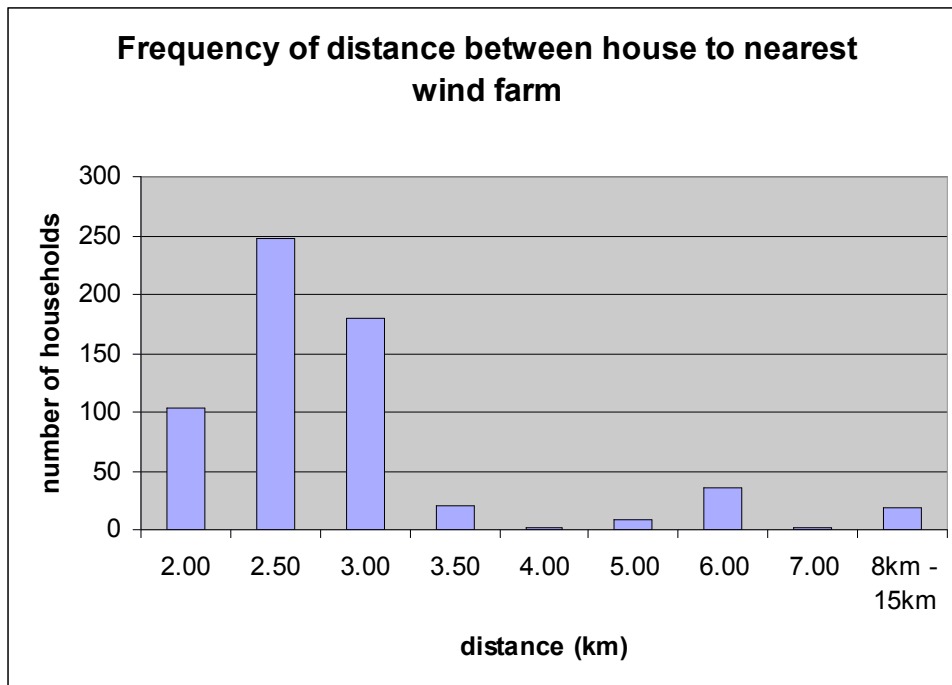


Figure 1 Frequency of households at distance bands to nearest wind farm

3.14 VISUAL

Of the 516 households that reported being able to see the wind farm, only 483 were used in the analysis, due to incomplete or insufficient answers.

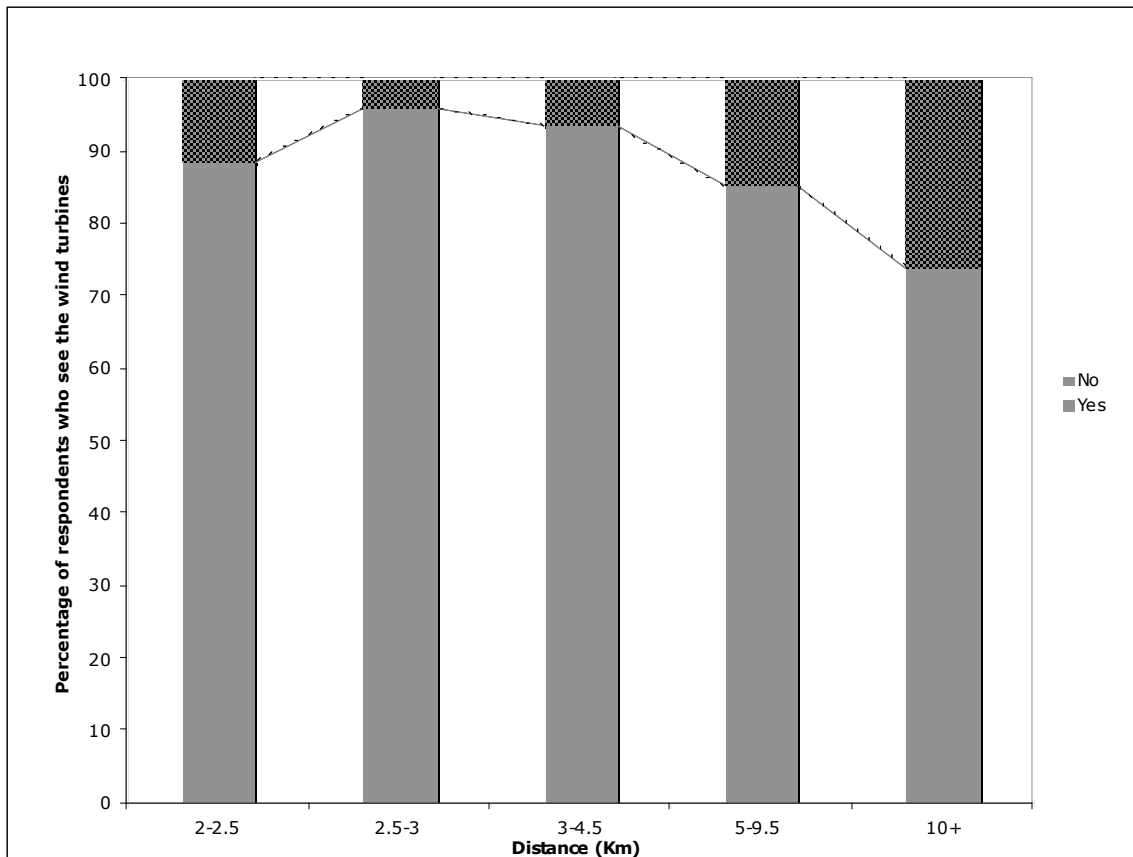


Figure 2 Percentage of households who see turbines with distance

3.15 Eighty percent of the households 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 of the general public thought wind turbines were ugly. This discrepancy between surveys could be due the EECA survey participants being drawn from all areas of New Zealand and represents the ideology of wind energy, rather than residents living close to wind farms who presented the reality.

The flickering motion of the turbine blades also affected a significant number of households (9 percent). This result is in agreement with the Sinclair – Thomas matrix for visual assessment of wind farms (Thomas 2002).

3.17 An unsolicited comment was *“strobing shadows fill my kitchen when we cook my 2 year old boy hates them with a rage. Meridian told me to close the curtains but that can’t keep them out”*.

3.18 NOISE

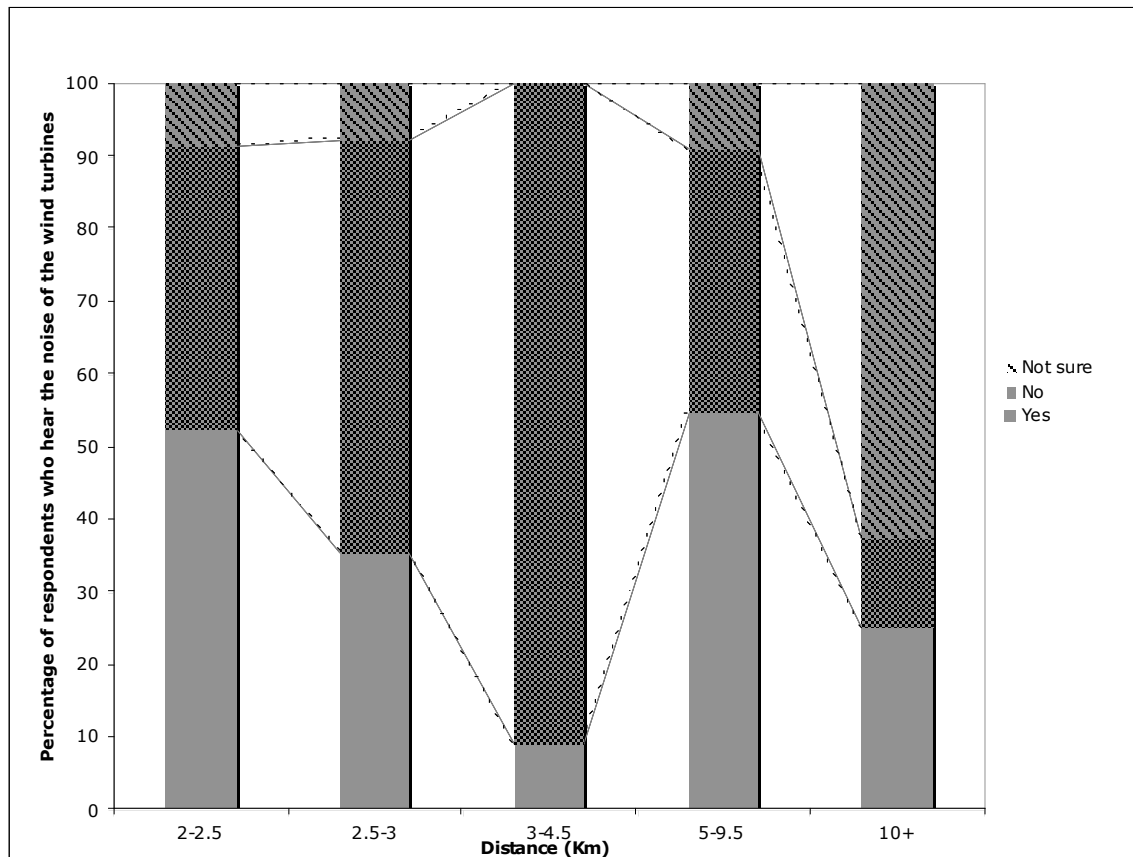


Figure 3. The proportion of households who hear the wind farms against distance

3.19 Figure 3 shows that proportion of households that could hear the wind farm noise plotted with distance. What is surprising is over 52 percent of households located between 2-2.5 kms and 5-9.5 reported they heard wind farm noise; 36% of households located 2.5-3 kms away believe they hear wind turbine noise; while as many as 25 percent of households' located 10 kms away and said they could still hear the wind farms. A chi-squared analysis showed these results were statistically significant.

3.20 Other literature has shown night time is often the period when people living near wind farms are most affected by noise. However, in this survey there was little difference between the frequency which turbine noise was heard during the day or night. Of the 284 households who answered the question on night time noise;

- 29% reported they never hear turbine noise at night
- 58% occasionally hear turbine noise at night
- 10% frequently hear turbine noise at night
- 3% hear turbine noise at night most of the time

3.21 Forty two households reported wind turbine noise disturbed their sleep occasionally; 21 had their sleep disturbed frequently and 5 most of the time.

Unsolicited comments included “we sleep with ear plugs to try and block out the noise but we still hear it”.

Table 1. Results of quality of life questions

Quality of life questions	Never	occasionally	frequently	most of the time
Noise from the turbines reduces quality of my life	195	51	36	5
Noise from the turbines means we don't spend as much time outside as we would like	212	47	23	2
Noise from the turbines means we close our windows more than we would like	244	45	41	2

3.22 Unsolicited comments included;

- “We want to double glaze but can't afford to (3 people made comments to this effect)”.
- “It makes no difference if the windows are open or closed, the noise just invades us”
- “The noise thumps the house we can't change it”
- “We've put in more insulation but it comes thumping up under the floor”

3.23 Several questions were asked on the qualitative characteristics of the wind farm noise. Households were asked what the noise sounded like and asked to tick boxes from the options in column one of Table 3 below. The second column shows the number of households identifying with each descriptor.

Table 2. Qualitative description of wind farm noise

The noise from the turbines sounds like:	Number of residents reporting this quality in the noise
A train that never arrives	128
Hum	90
Swishing noise	108
Rumbling noise	79
Low frequency sound	68
The noise makes my house vibrate	12
The noise gives me an unpleasant physical sensation in my body	13
Other	94

3.24 In designing the questionnaire we deliberately avoided any descriptors that could have an emotional bias, such as thumping. However most of the descriptors volunteered by the households are emotional. The number of households using this or a very similar descriptor is given in brackets. Their choice of descriptions includes, *thumping (12)*, *whooping (5)*, *booming (3)*, *storm coming (7)*, *river in flood (7)*, *storm in the ocean (13)*, *crashing waves (5)*, *washing machine*, *thump on top of rumble*, *clothes dryer*, *heavy machinery working at night*, *shuddering*, *boom box*, *metal on metal*, *screeching machinery metal*, *hovering helicopter*, *concrete mixer in the sky*, *street sweeper truck coming up my driveway*, *bulldozer on the horizon*, *never ending thunder*, *low throbbing*, *flapping*, *motorway*, and *geographical resonance*.

3.25 It is pertinent to note that most of the above description of the wind turbine noise, apart from screeching and metal on metal which are likely to be attributable to noise from mechanical failure, are sounds associated with lower frequency component of noise or the impulsive character of the wind turbine noise. This could be explained by four phenomena:

- When noise generated from outdoor sources strikes a building, the amount that penetrates the building envelope depends of the noise frequency. Low frequency noise penetrates a typical New Zealand domestic structure much more readily than higher frequency noise. Low frequency noise is difficult to stop without the use of heavy mass constructions like solid concrete walls, roof and floor.
- High frequency noise experiences a much greater degree of molecular absorption (and consequently noise level reduction) than low frequency noise as it moves away from the source . Consequently low frequency noise is more efficiently propagated and can be heard over greater distances.
- Goldstein (1994) showed that humans perceive low frequency noise as louder and more annoying than higher frequency noises with equal pressure levels. The effect of increased annoyance was observed regardless of the noise scheme weighting.
- The impulsive characteristic of wind turbine noise is more attention grabbing and annoying than a constant noise source (van den Berg 2006).

3.25.1 It is important to emphasis that the survey instructions asked households to report on the effects they experienced in their homes. In his evidence Mr Hunt referred to an effect where turbine noise could be heard by a receiver standing 500m directly in front of the turbine. As all homes in the survey were more than 2 km from the nearest turbine it doesn't appear this result can't be explained by the 500m effect described by Mr Hunt.

COMPLAINING ABOUT WIND FARMS

3.27 Ninety three (15%) of households reported they were sufficiently bothered by the visual and noise effects to feel like complaining, while sixty one (10%) of households reported that they had made complaints. Those who were sufficiently bothered but had not complained reported that they were either not a complaining type of person, didn't know who to complain to and

many doubted it would make a difference. Six people offered unsolicited comments along the lines of *“there was nothing that could be achieved by complaining once the turbines were in place.”*

3.28 The 61 households who had made complaints reported using a number of avenues or agencies including PNCC (25 people), Meridian (22 people), their local member of Parliament (2), their neighbours, friends and family (15) Aokautere or Ashhurst Guardians (4), letters to newspaper (2) local ward committee (2) television (1) or had made submissions opposing future wind farms (11). Several reported they had complained on a number of occasions. The number of people reporting to have complained to PNCC is difficult to reconcile with Mr Bakers evidence that PNCC have not received any complaints. This may suggest there are deficiency in the monitoring, administration and remediation of complaints.

3.29 Complaints are often used as an annoyance measure but these clearly under report community concerns given that only a small percentage of those affected complain. A community noise survey found only 44% of people seriously affected by noise complained (enhealth, 2004) .

3.30 Although the survey didn't asked about the response to their complaints, four people volunteered that nothing had happened. One expressed it was a David and Goliath situation and the locals would never be heard against big business and profitability of the wind farm. The tone of some of these unprompted responses to the lack of action from their complaints could be summarised as irate.

3.31 GENERAL QUESTIONS

A few general questions were asked in the survey. None of the households reported that a member of their household had gained employment or increased business from the local wind farms. One person reported they had lost business as a result of the wind farm development but didn't give details. Some considered the wind farm development had affected their television reception (41), radio reception (14) or phone reception (32). One resident who had lived in Ashhurst for 16 years commented that *“we had to buy a bigger TV antenna after the windmills started”*.

3.32 SUMMARY OF RESULTS

516 households reported they could see turbines from their homes. Of these, 80 percent considered the turbines to be visually intrusive, and 73 percent thought that they were unattractive. These local expressions of concern are at odds with the national support for wind energy expressed in other published studies and could reflect the reality of living near wind turbines as opposed to the ideology of renewable energy.

3.33 Turbine noise was heard by 52 percent of households living within 2-2.5 km of the wind farm, 36% living within 2.5-3 km away and 25 percent of households living over 10 km 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.

- 3.34 This survey shows that wind farms have significant visual and noise effects upon a larger population than is envisaged under current visual assessment techniques and the New Zealand noise standards, and at a much greater distance.
- 3.35 It is a reasonable assumption that the numbers of people affected by visual intrusion and noise would be considerably higher if the terrain was more open and not obstructed by a river valley compared to the Linton area where there is less obstruction from topography.

PHONE CALLS FROM PUBLIC

- 3.36 In research questionnaires it is standard procedure to provide the contact details of the project leader and invite people with questions or concerns to make contact. In the 3 weeks following the distribution of the survey I had 54 phone calls from people within the survey area who wished to make more comments than allowed for in the survey and a few people in the Pohangina Valley who wished to discuss their experiences with wind turbine noise or vibration. All calls were handled by listening, opened questions to gain more understanding of their issues and in some cases offering advice on energy efficiency measures that may address their concerns. I didn't seek names or addresses from callers and if these were offered I didn't record them to protect caller privacy.
- 3.37 The callers could roughly be divided into;
- Group A wind farm supporters (13 callers) and
 - Group B people who were distressed by living near a wind farm and wished to voice their concerns (41). There were no neutral callers. All callers expressed strong to very strong emotions.
- 3.38 Nine of the Group A objected to people who complained of wind farms. Eleven of the Group A callers expressed fear either of the alternative to wind farms being nuclear electricity generation or of a power crisis leading to wholesale black outs or massive energy price rises. None of these callers were aware that they could make energy efficiency improvements to their home to reduce their consumption and all but one were interested to learn about energy efficiency. None of these callers were aware of EECA or that they may be eligible for subsidies for insulation or solar hot water. Four of these callers were concerned that labeling homes in the vicinity of the wind farms as having noise problems would affect their property prices; two used the word "blight" and said they experienced noise but didn't discuss this widely as they were fearful of ramifications of their house price and they queried the confidentiality of the survey.
- 3.39 All of the group B callers reported they either experienced noise issues (27) vibration issues (19) or both (5). Disturbance of sleep was reported by all but 2 callers in group B. All callers were very emotional; two were audibly crying. All but one described the noise as having an impulsive character eg thumping or whooping. Some thought the noise was worst inside their home whilst some said it was worse outside. Many (19) described frustration with the complaints going nowhere. One caller was having their

house investigated by Meridian but expressed no confidence that the measurements would achieve anything. 21 of group B callers were very concerned about the windfarms under construction and described the ranges as saturated, or overcrowded. Sentiments such as “Enough is enough” and “why are we generating electricity for Auckland” were mentioned by 12 callers. One caller in this group was irate that the survey hadn’t asked about financial loss. He operated a corporate style farmstay and long standing clients had complained of the noise and stopped returning. Two callers said they often stayed with friends in town to have a restful sleep away from turbine noise.

- 3.40 Three of the group B callers reported they lived on the western side of Pohangina valley, which is about 15km north of Ashhurst. These three callers all reported that they experienced parts of their house rattling and they attributed this to the wind turbines.

3.41 INTREPRETATION OF SURVEY RESULTS IN RELATION TO MOTURIMU

These results clearly demonstrate that wind farm noise has a significant effect on people that may well extend more than 5 km from the site of turbines. There were no people responding to this survey who lived within 2 km of operational turbines; there a large number of people living within 2km of the proposed Moturimu wind farm.

- 3.42 There are both differences and similarities between the wind turbines in the survey region and Moturimu. Some of these features will increase the noise at the households, some will reduce it.

- The turbines close to the survey population are of different power outputs to those proposed at Moturimu (most are smaller, some are larger).
- the distance from the turbines to the receivers in this survey was greater than 2km for all households which gives an additional 1.3 km buffer zone compared to the closest homes near Moturimu.
- In geographical area of the survey there is a river and topographic effects that would most probably reduce the noise transmission from the turbines to the majority of receivers. This does not exist for Moturimu.
- The predominant wind direction is also blowing away from Ashhurst, which is away from the location of the largest population cluster, however with Moturimu there are a large number of homes in Kahuterawa Valley down wind of the predominate wind direction.
- The existing turbines in the survey and the proposed Moturimu are all modern tall upwind wind turbines generators.
- The existing and the proposed Moturimu are both located in rolling to steep terrain with strong shifting winds.

- 3.43 There is no reason to suggest that the population surveyed deviated from a population of average people with average noise sensitivities. If there is any potential effect it could be that people with noise sensitivities have already self selected out of the population by shifting out of the area. There is evidence of this in the Tailor Baine survey where a person affected by

noise was in the process of selling and shifting away. Further in the Phipps survey the ????

- 3.44 The housing in the survey area is representative of typical New Zealand housing stock, albeit with a skew towards newer more tightly constructed housing. It is typical of mixed age and condition and would contain housing with both thermal insulation and no insulation.
- 3.45 A “habituation effect” has been reported where people get used to road noise soon after a new road is constructed. Wind farms have been operational in the survey area for many years. It is unlikely any further habituation will occur.
- 3.46 The evidence from my research and the evidence of Dr Mosley at Ashhurst clearly indicates severe and significant adverse noise and vibration effects on residents that is not anticipated by either the approving authorities or the owner of the windfarm. Such effects are not anticipated in NZS 6808 and this standard is not adequate to protect the health and amenity of residents. The potential for the noise effects to occur are highlighted in Mr Thorne's evidence as having high probability of occurrence within our community.
- 3.47 Based on the research and evidence produced to this hearing it is clear that the turbines will create significant adverse health and amenity effects on residents in the locality. It is my submission that the wind farm should not be approved.
- 3.48 Further, and based on the evidence presented to this Hearing, it is my submission that the shortcomings evident in 6808, clause 4.4.2 of NZS 6808 must be amended to reduce the indicative allowable level of noise in clause -
 4.4.2 As a guide to the limits of acceptability the sound level from the wind farm should not exceed, at any residential site, and at any of the nominated wind speeds, the background sound level (L95) by more than 5 dBA, or a level of 30 dBA L95, whichever is less.
- 3.49 As a comparison, other international bodies have recommended much lower community noise limits to protect health and well being and in particular a quiet sleep time. The limits recommended by the International Standards Organisation are setout below and it is important to note that health based noise limits set much lower levels of noise for rural environments in recognition of the lower ambient noise levels. In particular this standard seeks to protect the night time quiet period. This noise level should be enforced under section 4.4.4 of NZS6808.

Table 3 ISO 1996-1971 Recommendations for Community Noise Limits – limits to protect health and wellbeing

District type	Daytime upper limit	Evening time upper limit (7-11pm)	Night time upper limit (11pm-7am)
Rural	35 dBA	30 dBA	25 dBA
Suburban	40 dBA	35 dBA	30 dBA
Urban residential	45 dBA	40 dBA	35 dBA
Urban mixed	50 dBA	45 dBA	40 dBA

- 3.50 This noise criteria is very relevant to Moturimu. I have conducted many night time and early morning noise measurements at the top end of Scotts Road and ambient noise levels are typically between 17 to 22 dBA. In still conditions all 10 minute nighttime noise measurements were under 20dBA L95. It is important to note that a volume change of 3-5 dB is clearly noticeable and a volume change of 10dB is perceived as twice as loud (Alberts, 2006). While NZS 6808 allows for 40dBA to be produced from the wind farm on quiet still nights this will produce a volume increase of over 20dBA over background noise.
- 3.51 With regard to Moturimu, it is essential that noise levels are met at residences for construction noise including traffic movements as well as operation of the turbines. To enable this strict hours of operation of the construction activities, including site traffic, is vital to protect amenity values and avoid sleep disturbance and ensuing health problems. ISO 1996-1971 provide relevant guidance for appropriate noise levels for different times of day to protect health and wellbeing.

A REVIEW OF LITERATURE ON HEALTH EFFECTS, OTHER THAN HEARING LOSS, FROM EXPOSURE TO NOISE AND THE TRANSMISSION OF NOISE INTO BUILDINGS

4.0 INTERPRETATION OF LITERATURE

There are several generalised rules which scholars use to assess the quality of research and reports. Some confusion of these quality assessments was apparent in the Applicants evidence and I would like to take the liberty to give a brief clarification to quality assessments of research literature.

- 4.1 Papers presented in journals are of higher quality than papers presented at conferences. The peer review process is more rigorous for a journal than a conference and researchers get more credit for journals so place their most important findings for journals. Conferences are a quicker way of publishing material than journals and are often used for preliminary results or smaller studies that aren't suitable for journals.
- 4.2 Not all journals are equal. The rating of journals is called the impact factor. A journal with a high impact factor will attract the best quality research papers and the best quality reviewers. They publish only the cream of papers and may reject over 80% of good quality papers that go on to be published in other journals with a lower impact factor.
- 4.3 Reports can be peer reviewed or not peer reviewed and there are degrees of robustness of the review process of reports. For example reports released by organisation such as the World Health Organisation (WHO) have a higher level of peer scrutiny by international experts, and generally carries more weight than a report prepared for a smaller organisation.
- 4.4 Research sponsored by private organisations or industry groups can be subject to commercial bias. This bias can occur through several

mechanisms. Sponsors can withhold research if the results don't fit their commercial cause. Alternatively, authors can produce results that will favour the sponsor to gain economic advantage. Commercial bias of papers can often be identified in the acknowledgements and for report commercial bias can be found by a scrutiny of the list of organisation or affiliations of authors. Work of this nature would generally be given lesser weight than research funded by impartial providers such as a government health research funding agency or WHO.

4.5 A PhD thesis in the European or New Zealand education system is usually the equivalent of a substantial 3 year full time study. The examinations process is very robust with the thesis examined by 3 experts, one being an international expert in the respective topic, the other two are national experts and all of whom had no previous involvement in the project. European PhD often involve a public defense in that the candidate faces an auditorium full of experts probing the research, which gives a very high level of scrutiny.

4.6 A masters thesis is typically only a 1 year body of work and scholarly level is significantly lower than a PhD. The review process varies between universities for example Canterbury University only requires 1 external national expert reviewer other universities require 2 external reviewers.

5.0 NOISE IS A SIGNIFICANT EFFECT FROM WIND TURBINES

5.1 The Parliamentary Commissioner for the Environment (PCE) has also identified noise as 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) and this effect was noticed by respondents in the above survey. Wind turbine noise has been reported in many publications and there has even been an International conference solely on this topic.

6.0 NZS6808

6.1 New Zealand Standard NZS 6808:1998 Acoustics - The Assessment and Measurement of Sound from Wind Turbine Generators is a non mandatory Standard. It allows for Councils to apply their own noise criteria to be used, such as noise levels established in ISO1996-1971. The inadequacies of NZS 6808 have been addressed in several key documents (EPA, Bellhouse, West Wind caucus of noise consultants). These inadequacies include lack of consideration of:

- low frequency noise and infrasound
- atmospheric effects,
- cumulative noise,
- the impulsive nature of wind turbine noise.

- 6.2 This standard was due for review in 2006, however the revision has yet to occur.

LOW FREQUENCY NOISE

- 6.4 Some acoustic consultants have claimed that wind farms don't produce low frequency as they haven't measured it. The literature suggests this is more due to a problem with the assessment method, in that the use of the dBA weighting attenuates (filters out) the low frequency noise.

- 6.5 In a review of low frequency noise and infrasound from wind turbines Bellhouse (2004) concludes that International Standard IEC 61400-11 Wind Turbine Generator Systems – Part 11 Acoustic noise measurement techniques deals with the concerns around infrasound and low-frequency sound that are not covered in NZS6808, and that these two standards should be used in conjunction to cover all noise pressure levels. NZS6808 also references IEC61400-11. The purposes of IEC61400-11 include *“that it will would be applied by the:*

- *Wind turbine manufacturer striving to meet well defined acoustic emission performance requirements;*
- *The wind turbine purchaser in specifying such performance requirements;*
- *The wind turbine operator who may be required to verify that the stated or required acoustic performance specifications are met for new and refurbished units;*
- *The wind turbine planner or regulator who must be able to accurately and fairly define acoustic emission characteristics of a wind turbine in response to environmental regulations or permit requirements for new or modified installations.”*

- 6.6 This International Standard states *“that optimum measurements will include directivity, infrasound, low-frequency noise, low frequency modulation of the broad band noise, impulses, and unusual noises such as hisses, whine, hiss or hum, and distinct impulses in the noise such as bangs clatters, clicks, or thumps, or noise that is irregular in character to attract attention.”*

- 6.7 Annex A to Standard IEC61400-11 provides useful information on infrasound and low frequency sound from wind turbines. It concludes that *“although infrasound can be barely audible to the human ear, it can still cause annoyance”* and that *“The annoyance caused by noise dominated by a low-frequency component is often not adequately described by the A-weighted sound pressure level, with the result that the nuisance from such noise may be underestimated if assessed only using an LAeq value”* and goes on to recommend the use of the of the G –weighted sound pressure level rather than A-weighted.

- 6.8 Low frequency noise is not well addressed in NZS6808:1998 which uses only the dBA scale, which excludes low frequency noise (New Zealand Standards 1998). A- weighted sound measures have been particularly criticised as not being accurate indicators of the disturbing effects of noise with strong low frequency components (Kjellberg, 1984, Persson & Bjorkman, 1988; Broner & Leventhall 1993; Goldstein, 1994) A highly peer

critiqued review of community noise written by two of the world's most eminent environmental health experts Birgitta Berglund and Thomas Lindvall WHO, 1995) found significant failings with exclusive use of the A weighted noise level. They have stated;

“In the past sound pressure levels has been measured by A-weighting. At the same time, both in the laboratory and field, evidence has accumulated that an A-weighting predicts loudness and annoyance of community noise rather poorly. Not only does A-weighting sound pressure level under estimate the impact of the low frequency components of noise (Goldstein 1994) but it is strongly dependent on the exposure pattern at the time.

The A-weighting filter is unrepresentative of the loudness of sounds containing a mixture of noises and tonal components. In such cases, A-weighted sound pressure level is less suitable for the prediction of loudness or annoyance. That is also true for noise containing most of its energy in the low frequency range of 15Hz – 400Hz. It may then under- predict perceived loudness by 7 to 8 dBA relative to a 1,000Hz target noise (Kjellberg 1984). The reason is that loudness increases due to the bandwidth increase and that spectrum shape is not accounted for to a satisfactory degree by the A-weighting filter. A decrease in A-weighted sound pressure level can result in a corresponding increase in loudness or annoyance. This clearly reveals the shortcoming of using overall SPL either unweighted or A-weighted, as an indicator of loudness or annoyance.

6.9 Mr Hunt, in his evidence presented during the first week of the hearing, showed two different shaped graphs of the noise output from the V52 turbine and explained that “believe it or not they presented the same data”. I noticed general confusion from those present at the hearing on how the two graphs could be the same data and consider it worth while to pick up on an explanation as Mr Hunt was under tight time constraints and didn't have a chance to explain how the two different shaped graphs do show the same data in slightly different formats. I have reinterpreted the data as best as possible from the limited data provided by the applicant. The data in Figure 4 is unweighted, that is it shows all noise frequencies. Clearly the highest noise levels are produced at the lower frequencies. The third octave data shown overlaid in figure 5 is the A-weighted data. The lower frequency noise has removed from the analysis by the use of the A weighted filter; it is important to note that in reality the turbine will still produce this noise. The lower frequency noise hasn't been eliminated by clever engineering; however it has been removed from analysis. Also the third octave data is based on an average and this can mask some tonal characteristics. These are the characteristics that need to be considered in section 4.4.3 of NZS6808 and the evidence produced by Mr Hunt is inadequate allow full and essential consideration of these special tonal effects. Figure 6 shows the amount of noise lost from the analysis.

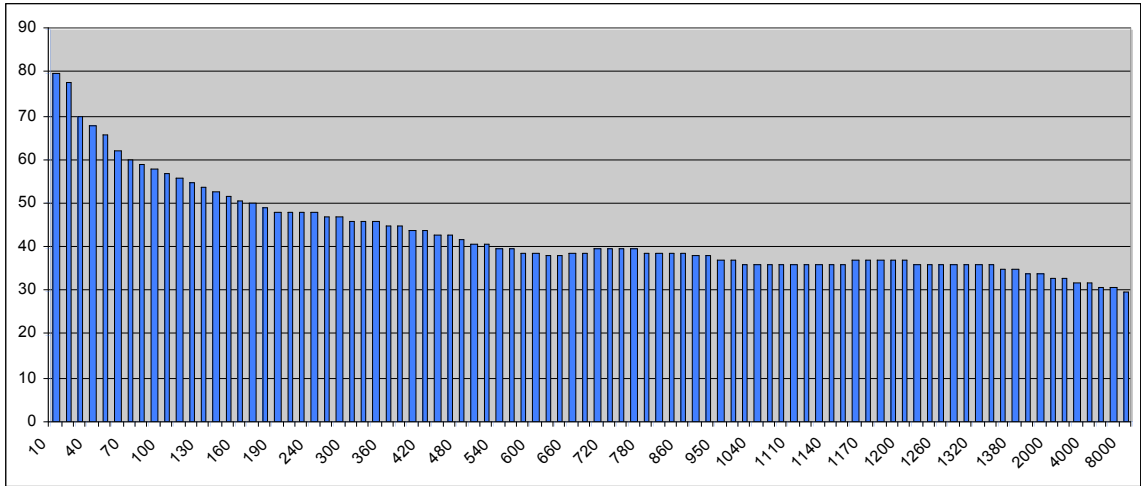


Figure 4 V52 unweighted data

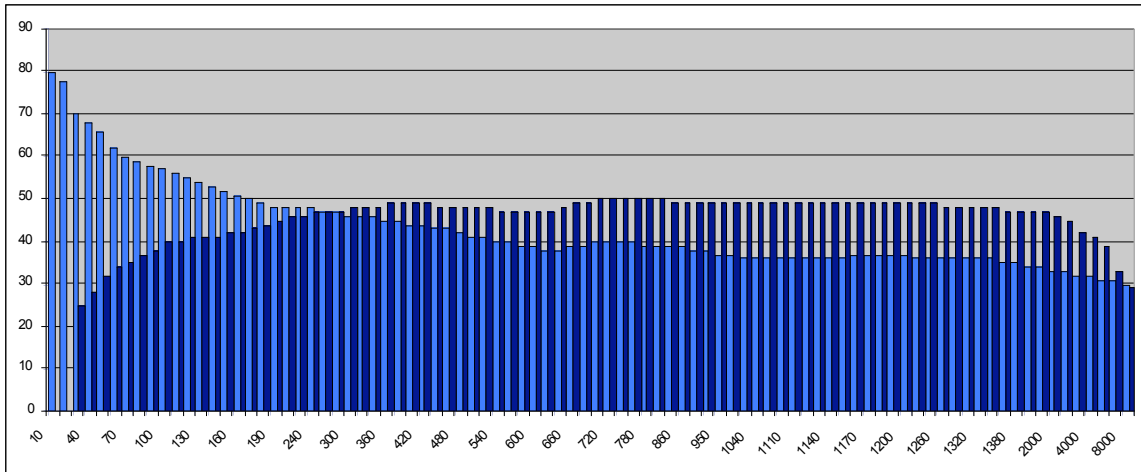


Figure 5 V52 unweighted and A-weighted data overlaid

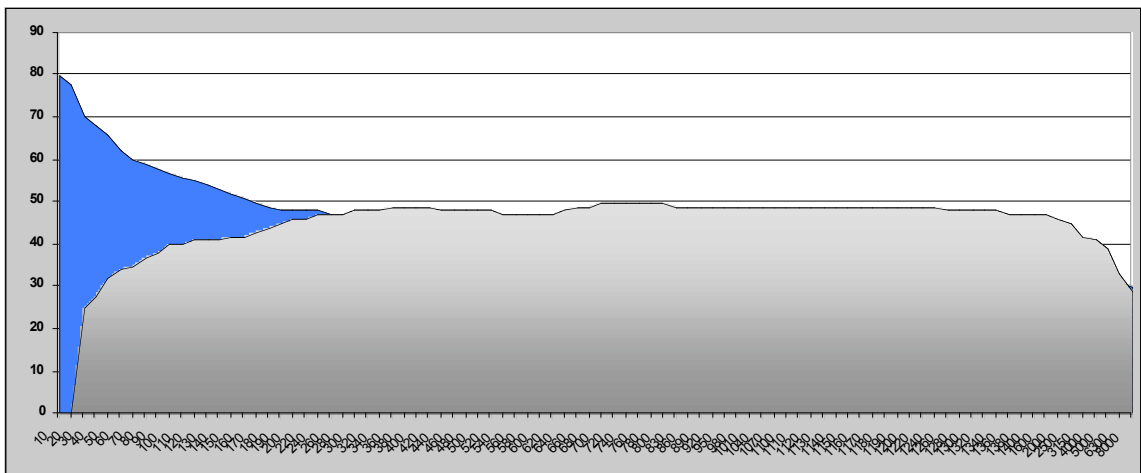


Figure 6 V52 Noise lost the analysis

6.10 The Batho report and others (Guest 2003) cited low frequency noise as a significant issue for regulators due to the difficulties with measuring it and mitigating it. The Casella report (Casella 2001) 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 for example the low frequency or bass noise from a neighbour's loud music will carry to households many streets even though the high frequency noise or melody has been attenuated with distance.
- 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 lightweight elements of a building structure to vibrate, such as a vibrating or rattling window.

6.11 These points have been reiterated by many other authors. Adverse effects from noise may be greater than for low frequency noise other noises for equal sound pressure levels regardless of which weighting scheme is used.

NZS6808 DOESN'T ACCOUNT FOR ATMOSPHERIC EFFECTS

6.12 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 be too simplistic an approach to something that is as complex as noise from a wind farm (EPA 2003).

6.13 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 tall (80 – 110m) modern turbines there are frequent periods with sufficient wind at hub height to turn the turbines and generate noise, with corresponding relative 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.

6.14 Van den Berg found residents 2km 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).

6.15 The Applicant has suggested that the effects found in this study would not occur in New Zealand due to the difference in topography. However the impulsive characteristic of noise produced as the blade passes the tower is a universal phenomena, irrespective of topography or nationality. The same applies to the under-representation of peaks and lows when data is averaged. Inversions, and higher air speeds at higher altitudes relative to stiller air at ground level and a consequent lack of masking noise are also universal phenomena. Mr Hunt in his evidence made some criticism of Mr van den Berg’s research and queried his impartiality in that he has appeared for communities opposing wind farm developments. I have sufficient confidence in the research peer review process to reassure Mr Hunt that Dr van den Berg’s work would have been scrutinized by leading acoustic experts for both method and analysis. Acceptance of his PhD thesis and publication of his research in acoustics journals ranked at 9 & 10 worldwide is sufficient testament.

CUMULATIVE NOISE

6.16 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).

7.0 HEALTH EFFECTS OF NOISE AND LOW FREQUENCY NOISE

7.1 WHAT IS HEALTH?

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.”*

This definition has been established for nearly 50 years and has been extensively peer reviewed and accepted. Every international environmental health conference that I have attended has had at least one presenter

display this definition which is met with nods of agreement from an informed audience. The definition clearly includes emotional states such as annoyance and sleep disturbance as health effects, in addition to diseases such as diabetes or depression and cardiovascular disease.

7.2 THE RMA AND HEALTH

The RMA is intrinsically about protection of health. While the overriding purpose of the Act is to promote the sustainable management of natural and physical resources, this is defined in Section 5(2) as meaning:

*“managing the use, development and protection of natural and physical resources in a way, or at a rate, which enables people and communities to provide for their social, economic and cultural wellbeing and for their **health** and safety.”*

Health effects are also covered in numerous other sections of the Act.

7.3 HEALTH AND NOISE

The Applicant stated there is no evidence of health effects from noise. This is difficult to reconcile as substantial body of compelling evidence in the literature on adverse health affect from noise including a high ranked international journal called Noise and Health, dedicated to this topic as evidence in biomedical, medical, and environmental health literature, published both in peer reviewed reputable journal papers and peer reviewed reports.

7.4 Research shows that the effect of noise is much more than auditory. Noise stimulates the brains reticular activating system. Neural impulses spread from the reticular system to the higher cortex and through out the nervous system. Noise can therefore influence perceptual, motor and cognitive behaviors and also triggers glandular, cardiovascular and gastrointestinal changes by the means of the autonomic nervous system (Suter, 1991 in Enhealth, 2004).

7.5 It is recognised that 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).

7.6 While acousticians working with the wind energy industry conclude audible and low frequency noise from wind farms is unlikely to cause health effects, it is important to note that experts who approach this issue from a medical perspective have arrived at the opposite conclusion.

7.7 Forty years ago the World Health Organisation (WHO) (WHO,1966) concluded noise was an occupational hazard and public nuisance and identified that the level of annoyance involved more the characteristic of the

noise than the intensity. Further it disturbed sleep and was a danger to physical and mental health.

- 7.8 More recently, WHO, the European Community members and numerous other high level health organisations have determined that there is a large body of evidence linking exposure to noise with many health effects and social consequences other than hearing loss. The WHO guidelines for community noise health effects as

...”hearing impairment, startle and defense reactions; aural pain; ear discomfort; speech interference; sleep disturbance; cardiovascular effects; performance reduction; and annoyance responses. These health effects in turn can lead to social handicap; reduced productivity; decreased performance in learning; absenteeism in the workplace and school; increased drug use; and accidents.”

- 7.9 These effects were reiterated by Berglund who lists health effects from community noise as

“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).

- 7.10 Disruption to the ability to learn, sleep disturbance, ischaemic heart disease and hypertension have been proven effects. Further adverse health effects ensue from sleep deprivation and sleep disturbance and this is discussed in more detail later in this evidence.

- 7.11 The link between noise and annoyance has been well established. Noise can't be blamed for initiating serious mental health problems but it is well established that people who are stressed or depressed are more affected by noise. Noise acting as a stressor and sleep disruptor has an impact on the cardiovascular system. Both stress reactions and sleep deprivation will evoke mechanism such as increased release of stress hormones, including adrenaline, noradrenalin and cortisol. These have a cascade of physiological effects and will increase blood pressure and vasoconstriction. Cortisol will increase blood pressure, suppress the immune system. A cross sectional study found an association between environmental noise annoyance and cardiovascular disease (Belojevic 2002). Pederson and Wayne found an association between wind turbine noise and annoyance and lower sleep quality and negative emotions and found this adverse effect was stronger on rural than suburban environments and in hilly terrain (Pederson 2005; Pederson 2007)

7.12 **NOISE AND CHILDREN**

The health effects of noise on children has been given special attention by the environmental health, biomedical and education research community. On one hand children have the ability to hear extremely quiet noise, yet they haven't developed the mental ability to tune out distractions. Impaired cognitive function, reading, motivation, headache, annoyance, and hypertension are most pronounced in children exposed to environmental noise and can result in life-long academic under achievement and sub optimum health (Enhealth, 2004).

7.13 Evidence is very strong for the effects on child health from exposure to noise (Evans 1993). Tasks involving central processing, and language comprehension, reading, attention, problem solving and memory are most affected by exposure to noise.

7.13 Children exposed to environmental noise will have;

- Deficits in sustained attention and visual attention,
- Difficulties in concentrating in comparison with children in quieter environments
- Poorer auditory discrimination and speech perception
- Poorer memory
- Poorer reading ability and school performance on national standardized tests
- Habituation to auditory distraction,
- less motivation, more annoyance,
- poorer quality of life
- raised catecholamine secretion and altered blood pressure (Evans 1993; Heines 2001)

7.14 The effects on vulnerable sub-groups within the child population (learning disability, autism, hearing impaired) has been highlighted in the research as being especially susceptible to environmental noise. This will be discussed in more detail by another submitter. The effects of noise on children is pertinent to this resource application as large number of families with young children live near the proposed wind farm, many potentially within the 50dBA contour, and two primary schools are located within the 40dBA contour, as shown in the noise contour maps produced by Mr Thorne.

7.14 HEALTH AND LOW FREQUENCY NOISE

“Low frequency noise (levels below 200 Hz) are perceived through both touch and hearing, which accounts for the greater level of annoyance from people exposed to low frequency noise. Recently greater attention has been given to the effects of low frequency noise because it is pervasive and many structural attempts at remedy are inadequate” (Enhealth, 2004)

7.15 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”.

7.16 Professor Des Gorman, Head of the School of Medicine at Auckland University and Professor of Occupational Medicine, has given his permission for me to repeat a quote from him. Prof Gorman is both a

neurologist and environmental health practitioner and so is conversant on the effects on the brain as well as noise. He has stated:

“low frequency noise is very distressing for people exposed it. It torments people and compromises sleep”.

7.17 While not suggesting that the following comment has the standing of a journal report for completeness I refer to a recent report on Campbell Live stated most people can't hear low frequency noise but those who can are driven crazy with the sensation. It disturbs sleep and can be a physical sensation in the human body as much as it is an auditory response.

7.18 The WHO are clearly concerned about low frequency noise and health effects and have concluded

“The evidence on low frequency noise is sufficiently strong to warrant immediate concern....Health effects due to low frequency noise components in noise are estimated to be more severe than for community noises in general (WHO, 1996).

7.19 Leventhall, who is an acoustic consultant to the wind energy industry, and who is often cited as a key opponent of the relationship between low frequency noise and health has presented conflicting conclusions. His conclusions have oscillated between “low frequency noise is below the threshold of hearing, and is therefore undetectable” (Leventhall 2005) to “Low-frequency noise causes extreme distress to a number of people who are sensitive to its effects”. It is worth noting that the introduction to the Dti report on low frequency noise quoted by the Applicant, the report has a disclaimer that it is not a Government report and should not in anyway be considered as such. The authors of this report are largely acoustic consultants to the wind energy industry this could possibly introduce some bias.

7.20 Exposure to low frequency noise has been found to elicit stress reactions and in some instances resonance reactions in vocal chords and internal organs. Stress reactions in response to low frequency noise include bizarre auditory sensations such as pulsations or flutter in the ear. It increases the release of stress hormones like adrenaline, noradrenalin and cortisol. Cortisol extraction has a wide range of effects on the metabolism of proteins, carbohydrates and fats and will temporarily suppress the immune system and sharpen attention (Enhealth, 2004). As with other noise, low frequency noise has been found to affect annoyance, stress, irritation, unease, fatigue, headache, nausea and disturbed sleep. (Casella 2001)

7.21 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). A number of physiological (blood pressure and heart rate) and psychological effects were found in laboratory studies (Chen 2004).

7.22 NOISE AND SLEEP

It is not known why mammals need to sleep, however it is well established that it is a fundamental for restoring biological function, body chemistry as well as mental outlook, behaviors and emotion. It is essential to our

wellbeing and health and we are programmed to spend more than a third of our life in a semi conscious and unproductive state. Sleep quality and its effects on health is not only about duration but the ability to cycle undisturbed through the various sleep phases (Dutch Health Council, 2004; (Netherlands 1994).

- 7.23 Noise interferes with sleep in a number of ways;
- awakening – it causes the sleeper to awaken repeatedly resulting in poor sleep as well as other health impacts,
 - alter sleep pattern- noises may make the sleeper change from heavier to lighter sleep,
 - reduce the percentage and total time in REM sleep
 - increase body movement
 - change cardiovascular responses
 - cause effects on slow wave sleep
- 7.24 These changes can affect mood and performance the next day (Enhealth, 2004).
- 7.25 Sleep loss reduces cognitive function and can affect physiology, behaviour and subjective outcomes. Statistically significant variations occur in vigilance, memory, learning, hormone levels and sexual function. All stages of sleep are equally vulnerable to disturbance by noise and cardiovascular irregularities and increases in blood pressure can occur without the sleeper awakening (Carter 1994).
- 7.26 Professor Philippa Gander, from Massey University, Public Health Research Centre, is a world expert of sleep. She has found that disturbed sleep, either due to disruptions of the REM cycles or duration lead to significant physiological changes including the release of two appetite hormones (which leads to over eating), headaches, blood pressure, impaired cognitive function and reactions, tinnitus, and type-2 diabetes.
- 7.27 The medical consequences and social cost of over-eating, obesity and cardiovascular disease and type-2 diabetes are documented extensively in other literature. These include fatalities, days off work or school, hospital cost, and medications.
- 7.28 Professor Gander's research centre has also demonstrated a sleep deprived driver will have their reaction time impaired similar to a driver under the influence of alcohol. Both sleep deprived drivers and drunk drivers place the driver, their passengers and other road users at high risk of accidents (Gander 2005). The NZ Police have determined from accident reports that fatigue can impact on a drivers reaction times, their concentration and general understanding of the road and traffic around them. In 2005 fatigue was a significant factor in 40 fatal traffic crashes, 162 serious injury crashes and 449 minor injury crashes. For every 100 drivers or motorcyclists killed in road crashes where fatigue was a factor, 45 passengers and another 27 road users were also killed. Driver fatigue is difficult to identify or recognise as contributing to a crash. This means it's likely that fatigue is under-recorded (Landtransport 2005). The medical and

social costs of road accident injuries and fatalities and damage to property is well established in other literature.

7.29 Measurable sleep disturbance has been observed as noise levels exceed 35dBA and the effects increase with increasing noise levels. These and other health effects have given sufficient evidence for WHO to recommend that the equivalent sound pressure level should not exceed 30dBA indoors, if the negative effects on sleep disturbance are to be avoided (Berglund 1999).

7.30 The guideline categorically state that

“to avoid sleep disturbance, indoor guideline values for bedrooms are 30 dB LAeq for continues noise and 45dB LA max for single loud events.... Lower noise levels maybe annoying depending on the nature of the noise source. If the noise includes a large proportion of low frequency components, values even lower than the guidelines values will be needed, because low frequency components in noise may increase the adverse effects considerably....

and it goes on to recommend the use of dBC weighting rather than dBA

... More regular variations with time have been found to increase the annoying aspects of the noise. For example, noises that vary periodically to produce a thumping or pulsing sensations can be more disturbing than continuous noise.

This document also recognises the need to sleep with a window open for ventilation and for cooling in warm weather.

7.31 The Institute of Environmental Medicine at Stockholm University has undertaken extensive research on the impact of community noise and sleep. They found noise affects sleep in several ways including;

- Increasing the time needed to fall asleep,
- Altering the cycle of sleep stages and
- Deceasing the quality of REM sleep,

7.32 Any one of these problems over an extended period can lead to more serious health problems. Sleep disturbances have been linked to three characteristics of noise exposure, including:

- The total noise exposure (including daytime exposure)
- The peak noise volume,
- For intermittent noise, the number of volume peaks

7.33 Sleep quality has been found to be eroded much more by a number of noise events that were roughly 5dBA above the threshold of the noisy event.

7.34 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. 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; Pederson 2007).

VIBRATION AND HEALTH

- 7.35 The Phipps survey, Morsley survey and Bennett survey all independently observed that people living close to wind turbines in New Zealand experience vibrations from wind turbines. The effects of vibration in buildings and health effects from vibrations have been well researched and documented for over four decades.
- 7.36 The American National Standard Guide to the Evaluation of Human Exposure to Whole Body Vibration ANSA S3.18-1979 and the International Standard ISO 2361 Human Response to Whole Body Vibration are both widely referenced in public health and occupational health text books. Whilst the adverse health effects from vibration were first observed in occupational medicine, it is well established and noted in ANSA S3 18 – 1979 that vibrations will also cause adverse health in non occupational settings. This standard states that “avoiding vibration in the home environment is of high importance” due to prolonged exposure. This standard goes on to state that “high standards should be applied to the home, and perceptible vibration should be minimal or absent, particularly at night.” This standard states that primary adverse health effects can occur from the direct physiological effects, and secondary reactions occur in response to noise from vibrating or rattling building components. “In addition startle reactions, fear of damage to the structure or fear of being hit by falling objects, and interference with sleep, conversation or other activities will occur when parts of the home are rattled by vibrations (American National Standard Institute 1979).
- 7.37 When the building structure vibrates these vibrations are transferred to the human body as a whole through the supporting surfaces; through feet when standing, the buttocks when sitting, or the supporting area of the body when reclining. Vibration in buildings can interfere with activities and affect occupants in many ways. The quality of life can be reduced as can work efficiency (American National Standard Institute 1979)
- 7.38 Whole-body vibration has many widespread and varied effects and these effects are not always easy to diagnose, as the body does not have one receptor for this energy as for example the ear does for sound energy or noise resulting in hearing loss, but vibration effects are manifested far and wide in the body and may be mistaken for a number of other common ailments (Joubert, 2001).
- 7.39 The most pronounced and common effect is lower back pain which is caused by various mechanisms of vibration on the musculo-skeletal system of the body, namely the degeneration of the intervertebral discs, which leads to an impairment of the mechanics of the vertebral column allowing tissues and nerves to be strained and pinched leading to various back problems. The nutrition of the discs is also affected by long periods of sitting aggravated by vibration exposure, which causes tissue nutrients needed for growth and repair of the discs to flow outwards by diffusion instead of inwards where they are required and this leads to increased wear and reduced repair of the discs. The vertebral bodies are also damaged by the vibration energy that leads to an accumulation of micro fractures at the end plates of the vertebral bodies and associated pain. Muscle fatigue also occurs as the muscles try to react to the vibrational energy to maintain balance and protect and support the spinal column, but these are often too slow as the muscular and nervous

system cannot react fast enough to the shocks and loads being applied to the body. Other health effects that have been associated with whole-body vibration are haemorrhoids, high blood pressure, kidney disorders and even impotence and other adverse reproductive effects in both men and women (Seidel 1986; Joubert 2001).

7.40 There is also the effect of resonance, or natural frequency, wherein the human body as well as other physical structures, respond by acting as a sort of a vibration "tuner" rejecting certain impinging vibration frequencies and responding or "tuning" to other vibration frequencies by actually amplifying and exacerbating these impinging vibration frequencies. For example, human whole body vibration resonance occurs in the vertical (up-down) direction from 4-8 Hertz. This means that if a person is exposed to vibration in this range these vibrations will reach the spine, then the spine will most likely involuntarily respond by actually amplifying and exacerbating the effects of the whole body vibration exposure. In other words, our body has the ability to select, accept, and amplify certain vibration frequencies over others in doing so it can worsen the effects of the vibration (Wasserman 2005).

7.41 Professor Alan Hedge from Cornell University is a co-author of a leading text book on health effects from vibration, and has concluded that whole body vibrations may create chronic stresses and sometimes even permanent damage to affected organs or body parts. Professor Hedge also stresses the adverse health effects stem from the amplification of the vibration and the effect of resonance where the original vibration is amplified in the body or structure. Individual body members and organs have their own resonant frequencies and do not vibrate as a single mass. This causes either amplification or attenuation of the original vibration by certain body parts due to their own natural resonant frequencies. Vibration in the range of 0.5 to 80 Hz have significant effects on the human body. Vibrations between 2.5 and 5 Hz generate strong resonance in the vertebrae of the neck and lumbar region with amplification of up to 240%. Vibrations between 4 and 6 Hz set up resonance in the human trunk with amplification up to 200%. Vibrations in the order of 20 and 30 Hz set up strongest resonance between the head and shoulders with amplification of up to 350% (Stanton 2004).

7.42 Professor Hedge found health effects from vibration include;

- Blurred vision
- Motion sickness
- Decrease in manual coordination
- Drowsiness (even with proper rest)
- Low back pain or injury
- Insomnia
- Headache
- Upset digestion

7.43 Impaired health from vibration can take 4 years or more of exposure for conditions to be medically observable.

NOISE MITIGATION MEASURES

7.44 At a public consultation held in the Plaza shopping centre, I asked Mr Voll what mitigation measures would be provided if turbine noise was a nuisance

to residents. Mr Voll replied they would install double glazing to affected homes.

7.45 While it is helpful that Mr Voll has both recognised the adverse impacts and suggested a method of mitigation, this is a solution that is marginally effective as noise especially for noise in the lower frequency range which has a long wave length and will readily be transmitted through the typical New Zealand house construction. In the vicinity of the proposed wind farm there are many dwellings constructed prior to the 1978 change to the building code that would have no thermal insulation in the walls or floor and at best would have thermal insulation added to the ceiling cavity. Homes constructed after 1978 will have a degree of thermal insulation to walls and the ceiling. However, thermal insulation is not effective at reducing noise transmission and even acoustic insulation is not effective in reducing low frequency noise. Installing double glazing without also installing acoustic insulation in the walls, ceiling and underfloor cavity (if the house has one) is not effective, as external noise will pass through any building element with the least resistance. All affected homes would require a mitigation package that would address all elements of the building envelope.

7.46 This requires a whole house approach and would include heavy mass materials for roof, walls and floor, such as concrete, concrete tile, or concrete block, acoustic insulation to all external walls and the ceiling, as well as double glazing and sealing of all penetrations. Recladding the exterior with thick heavy mass walls will require alterations to window and door joinery. Careful design or services, including power points, waste pipes, water pipes, vent pipes etc. is required to avoid transmission pathways. This will affect internal layout as it will preclude the placement of plumbing fittings on external walls unless there is sufficient room to construct a services duct for pipes so as not to inadvertently create a transmission pathway. As the house is now a sealed box it is essential to add and operate a mechanical ventilation system with acoustically dampened air intakes. Tight sealing of the homes envelope will have significant impacts on the indoor air quality, which in turn can impact on the occupants' health. All of this is a significant undertaking and will involve significant loss of amenity to the household.

7.47 The reality is there is no mitigation measures that can address noise in the outdoor living areas, other than very tall trees which will take longer to grow than the predicted life of the turbines or separation distance between the turbine and the households of 5 km.

DETRIMENTAL EFFECT ON INDOOR AIR QUALITY FROM TIGHTENING THE HOME'S ENVELOPE TO MITIGATE NOISE INGRESS

7.48 The consequences on the indoor air quality and human health of tightening up housing are significant. Air inside a home can be up to 1000 times more polluted than outdoor air. Any measure that impedes ventilation will concentrate indoor pollutants. Over 40% of New Zealand houses have fungi contamination that may include species which are respiratory irritants, toxic or carcinogenic. New Zealand has one of the highest rates of asthma in the world and the link between housing and asthma has been well established (Howden-Chapman).

IS THE DOOM OVER NEW ZEALAND'S ENERGY SUPPLY ALL A PACK OF LIES?

- 8.0 Madame Chair asked the question if all the doom over New Zealand's energy supply has been a pack of lies? The answer is not so much a pack of lies, but since these predictions new energy generation has increased beyond original predictions and the ability to conserve energy without the loss of amenity has increased. The next section of my evidence will address this question. I will endeavor to address the complexities of this succinctly as possible by using analogies with every day life.
- 8.1 New Zealand used to have an abundance of very cheap hydro electricity and this allowed the country to have inefficient energy use standards such as building performance and inefficient habits. A decade ago predictions for New Zealand's energy supply were that demand for energy was growing faster than growth in generation and transmission capacity. This triggered alarm bells and set in place many excellent initiatives to address energy consumption and increase generation. Current energy forecasting shows New Zealand is well on the way to achieving the required electricity supply except at peak locations, such as Auckland and at peak times. The largest current challenge is managing the distribution of the supply load with the peak demand required in Auckland. As mentioned by Dr Bennet there are conditions when there is too much energy generation south of the Waikato and hydro is spilled; this needs to be avoided to prevent waste.

ENERGY EFFICIENCY

- 8.2 The New Zealand Energy Strategy states the important principle, "to invest in energy efficiency whenever possible as this is cheaper in the long run than the cost including externalities, of new generation." This principle is repeated in different forms in the New Zealand energy strategy.
- 8.3 Energy efficiency is considered as the most promising source of freeing up energy capacity, and is capable of delivering substantial savings in overall energy consumption. In the past New Zealand has had the luxury to use its energy very wastefully. Two thirds of all electricity is consumed in some way in buildings and consequently energy efficiency programmes are focusing and achieving good results within the building sector.
- 8.4 Very substantial savings in energy consumption could be achieved for modest little change to the building and no lose of amenity. Often energy efficiency measures lead to a vast improvement warmth and dryness of the home and health of the occupants (Howden Chapman, 2007).
- 8.5 The Home Energy Rating Scheme (HERS); incentives for industry and commercial facilities operators to optimise efficient use of energy; financial incentives for the installation of solar water heating; changes to the building code to mandate a level of solar utilisation and the BEACON sustainability programme are but a few such projects. These initiatives are either in their infancy or will come into operation in the next 12 months.
- 8.6 As discussed in the evidence by EECA, home insulation subsidies are available to all low income home owners. In addition to the subsidies,

Contact energy, Trustbank, and many other insightful businesses are offering co-payments to top up the home insulation subsidies. As home heating accounts for 34% of the energy used in a home increases in insulation can have a dramatic reduction in the need for energy.

- 8.7 A further very simple measures that would cause no reduction in amenity for households but would save NZ a huge amount of energy. In the HEEP study Nigel Isaacs identified that households waste 112 + or – 4 W or 10% of the total average residential power demand in standby load. Standby load is the energy used by appliances such as TVs, DVDs, and computers while they are in standby mode and waiting to be used. Isaacs calculated this as costing NZ 160MW. This could easily be saved by turning appliances off at the appliance rather than via the remote (Isaacs, 2006).
- 8.8 Compact energy efficient fluorescent light bulbs use one fifth of the electricity of a conventional incandescent light bulb. The government has recently invested \$3 million to extend a campaign that was successful in getting energy efficient compact fluorescents into 80% of homes. If 70% of New Zealand homes replace only four old bulbs with four energy efficient bulbs, the country's energy savings will exceed the capacity of New Plymouth's power stations and provide sufficient energy for either all of Hamilton or Dunedin. These four light bulbs retail for under \$16, a very modest sum and much more cost effective way of increasing supply than simply building more generation (Parliamentary Commissioner for the Environment, 2006).
- 8.9 The Tertiary Education Commission has recently granted nearly \$1M dollars to the National Energy Research Institute (NERI) which is a collaborative centre of excellence that stretches across 4 universities, to promote education at all levels (schools to tertiary institutes as well as general public) in smart energy technologies. Dr Peter Read and I are both members of NERI. Before investing in NERI the Tertiary Education Commission undertook a very rigorous peer review, including scrutiny that the project team could achieve the energy efficiency goals. Their investment is testament to their confidence that significant reductions in energy are achievable and this will translate into economic growth as well as brighter prospects for New Zealand's ability to meet its electricity needs.
- 8.10 The above initiatives are giving energy forecaster's confidence of a brighter future and there are more efficiency measures being proposed.

INCREASED GENERATION

- 8.11 Further, the generation market has responded and new generation has increased at a rate higher and faster than previously predicted.
- 8.12 The above factors are giving energy forecasters greater confidence in the surety of supply capacity. Evidence suggests that the energy supply threat has reduced and that the generation market is correcting to avoid a possible oversupply.
- 8.13 Mighty River has just cancelled plans to construct a new gas fired electricity generator at Marsden on the grounds that the new energy forecasts show it

would produce more energy than New Zealand requires in the foreseeable future, and an oversupply would lead to price instability. Contact Energy has also deferred construction of Otahuhu C for the same reason.

- 8.14 Current predictions for the energy future have changed from “we need every possible GW” to “we need to address certain pinch points”. The pressure to generate the total energy needs is relaxing, however there is still concern over the placement of the supply in relation to the large load centres and supply to meet peak periods.
- 8.15 These constraints or pinch points were explained in the presentations by Dr David Bennett and Dr Peter Read. It is worth noting that both Dr Bennett and Dr Read` are highly respected in their field and have no vested interest in energy generation.
- 8.16 The two biggest energy supply issues are;
- getting the load through the Waikato bottleneck in the transmission network to Auckland load centre and
 - being able to meet the peak load.
- 8.17 Auckland is both the largest and the fastest growing load centre in New Zealand and concerns about energy supply for Auckland are still valid. All energy generated south of Waikato will face large losses during transmission. An analogy for this is pouring 100L of water into a leaking hose may only realise 90L by the time it arrives in Auckland. The longer the length of pipe, or electricity transmission line; the larger the transmission loss. The transmission network is very constrained by the capacity of the transmission lines in the Waikato. This has been documented by the Parliamentary Commissioner and the need for generation north of Waikato to avoid both transmission losses and the bottleneck are being advocated.
- 8.18 Construction of more wind farms in the Manawatu will not contribute greatly to the Auckland load.

PEAK SUPPLY LOADS

- 8.19 The commercial and industrial sectors typically demand electricity from 7:00am to 7:00pm 5 days per week. Nighttime and weekends loads are lighter than during the day, and lighter in summer than winter. The residential sector tends to have two distinct peaks, one around 6-8:00am for morning coffees and showers; with a larger peak that builds from late afternoon, peaking around 7pm and tailing into the evening. The winter load is substantially higher than the summer load. This is graphically represented in figure 7.

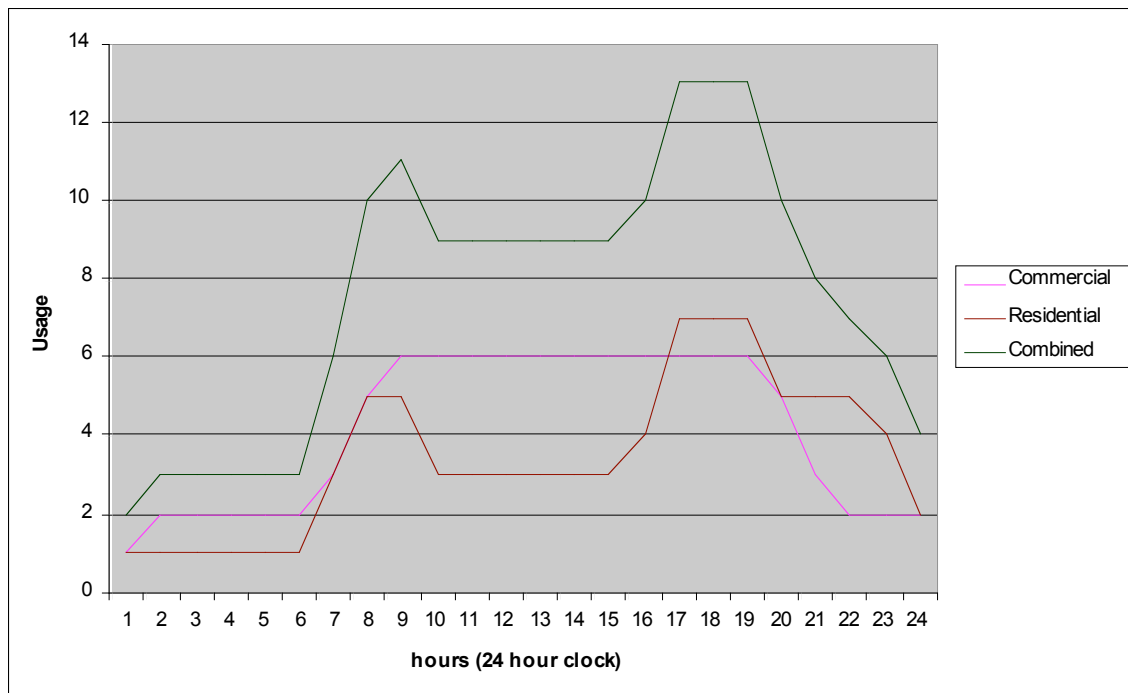


Figure 7 Peak load energy use

- 8.20 The peak supply loads occur when these sectors are demanding electricity simultaneously. Both electricity generation and transmission need to have sufficient capacity to meet the peak load but may have substantial excess capacity at non-peak period. New generation is most valuable if it can be guaranteed to be available to contribute to the peak load, with ideally any excess able to be stored for peak periods.
- 8.21 Assessment of any energy source without understanding its contribution to management of the peak demand period can be likened to running a catering business without being able to control the time the meals arrive. For example, the peak loads for a commercial kitchen will occur around 7:00am, midday and 6-7:00 with lull periods in between. To be efficient the kitchen needs to be able to produce sufficient meals and produce these meals at the times required by the diners. Meals produced during periods of low demand will be wasted unless they can be stored.
- 8.22 Managing the peak daily load is easy with hydro and gas as these can both be stored in periods of low demand and utilised in periods of high demand. Gas is accessible all year and storable until required. Energy supply from gas can not be turned on and off quickly and unless it is running in idle mode which still consumes energy. This “idling” wastage occurs if gas is used as a reserve for when wind energy generation drops during periods of light wind. For this reason the Electricity commission has cited hydro as the reserve for lulls in wind energy, not gas. This effectively changes the calculation of green house gas savings wind is offsetting a renewable energy not a fossil fuel. It can also lead to wasteful spilling of hydro as shown by Dr Bennet.
- 8.23 Wind energy does little to address the peak loads it is neither guaranteed to be available for peak electricity demand periods and can’t be stored in light

electricity demand periods. Therefore it can not be relied on to offset peak electricity load generation capacity.

- 8.24 Further Nigel Isaacs, Principal Scientist with BRANZ and a leading researcher in energy supply, has conducted various scenarios models using energy from different sources to determine ways to address the peak load. He has shown that moving to alternative fuels such as solar, gas or wood in a low emission wood burner for space heating, water heating and cooking will make a very significant contribution to reduction of the peak energy load. Reliance on electricity generation and transmission fails to address the peak load and will result in increasing demand for peak generation and transmission capacity (Isaacs, 2007)

SOLAR ENERGY AND ENERGY EFFICIENCY AS ALTERNATIVE SOLUTIONS

- 8.25 Much of the evidence presented at the hearing has assumed that wind energy is the renewal energy of choice. To present balance to the debate we need to introduce the discussion of other renewable energy sources. Hydro and wave power have been mentioned in passing. Surprising very little discussion has occurred on the role of solar energy in New Zealand.
- 8.26 New Zealand has an abundance of solar resource. Solar radiation in New Zealand delivers about 1kW per square meter, which is a virtually limitless free operational resource for much of New Zealand. Even the south of the south island has sufficient solar energy to provide the energy for about 70% of typical houses hot water requirements and about 90% of home space heating. As an example, Associate Professor Bob Lloyd has constructed a passive solar designed house near Dunedin at an additional \$3000 above standard construction costs. He maintains his house at over 18 deg C and only needs to supplement the solar heat if there are 3 or more days with no sun, even in mid Dunedin winter.
- 8.27 New Zealand has a much higher solar resource than either Japan or Germany. Yet both these countries have a much higher uptake of solar energy utilization.
- 8.29 Solar energy can be used in three ways, solar water heating, photovoltaic panels and passive or active solar space heating. Although photovoltaic are used to generate electricity for many New Zealand homes, they are outside my expertise and I will not discuss them in this hearing. However solar water and passive solar are two renewable energies which, as EECA mentioned, have huge potential in New Zealand. The New Zealand update of solar technologies has in the past been ridiculously low in part due to the low performance criteria set in building standards, cheap hydro electricity and poor leadership. The main reason for lack of solar is that the energy is harvested and used directly by the household without passing through an electricity meter. As only the household profits from solar energy this is an unattractive option for generation companies.
- 8.30 The mandatory need to incorporate a significant amount of solar design for all new homes will commence in New Zealand from 2008 when the next

revision of the Building Code comes into force. The code revision will address a massive waste of energy for space heating and water heating which accounts for 34% and 29% respectively of energy consumed in houses.

8.31 The HEEP study, conducted by BRANZ, (Isaacs 2006) which was a very detailed 10 year study on the energy use in New Zealand homes has found the energy use patterns shown in figure 8. Hot water and space heating account for 63% of energy used and it is possible to use solar harvested on site instead of electricity generated at a remote site for the vast majority of both space heating and water heating. This is important as residential energy use is currently the fastest growing electricity sector and the latest changes to the Building Code will arrest this growth.

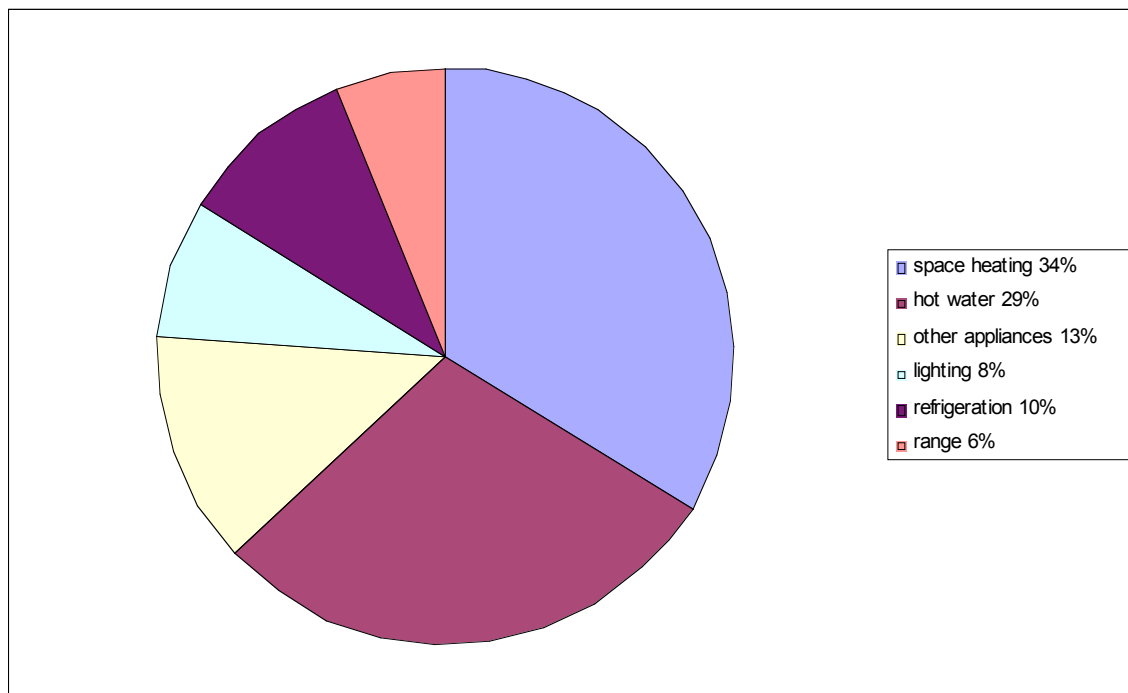


Figure 8 Household energy uses (Isaacs, 2006)

8.32 With support from EECA, solar water heating is coming of age in New Zealand. To harvest the sun's free energy for hot water heating all that is required is a sloped surface facing north, a roof is ideal and the only additional requirement is a solar collector and some plumbing.

8.33 There is a long list of features that solar water heating doesn't have. These include:

- No emissions of noise
- No visual pollution
- No transmission losses or distribution network required
- No traffic problems associated with either erection or operation
- No earthworks

- No green house gas emissions
- No footprint
- No price shocks
- No imported fuels
- No purchases of expensive overseas components and impact on foreign exchange
- No dividends to foreign investors.

It does provide free hot water for about 80% of a household's requirements. It does provide security of supply, as well as work for tradespeople. Once installed there is very little maintenance required.

8.34 Solar water heating removes load from the peak electricity demands. Recent energy modeling by Nigel Isaacs Principle Scientist with BRANZ (Isaacs, 2007) has shown that the peak load is the driver for both generation and transmission and they are commending energy sources which shift the load away from electricity which will reduce the need for both peak generation and network capacity.

8.35 Solar hot water also puts extra disposable income in the pockets of average New Zealanders. This has an economic multiplier effect so will feed economic development.

8.36 The cost of one wind turbine is approximately the same cost of solar hot water for 1600 homes with consideration of the financial assistance available from EECA.

8.37 New Zealand's low land use density and rolling land means most homes are blessed with the ability to have glazed wall facing north of sufficient area for solar space heating. In a simplistic sense this, plus some exposed thermal mass eg polished concrete, or tiles or slate over concrete to store the heat and plenty of insulation to retain the solar heat, are all that is required for a passive solar home.

8.38 Most new homes constructed have these and code changes will bring code required insulation closer to a solar home standard bridging the financial difference between these constructions. In addition a higher level of thermal insulation is required. Solar space heating features includes:

- No emissions of noise
- No visual pollution
- No transmission losses or distribution network required
- No traffic problems associated with either erection or operation
- No earthworks
- No green house gas emissions
- No footprint
- No price shocks
- No imported fuels

- No purchases of expensive overseas components and impact on foreign exchange
 - No dividends to foreign or corporate investors.
- 8.39 It does provide house warming for about 80% of a household's heating requirements (Phipps 1996; Phipps 2000). It provides a home that is warmer and dryer, with less mould, dustmites. This has been shown to reduce health costs, hospitalization, days off school and work and provide a drier, warmer home. The economic and social benefits of this are huge. It does provide security of supply. It provides some work for house designers with expertise in passive solar design. Once installed there is no maintenance required and it will be effective for the life of the home. A New Zealand home lasts for 100 or more years, it has a pay back of around 5 years meaning the house will receive 95 years heating for free. If health benefits are included it could have a payback of 1 year. It removes peak load from generation and transmission.
- 8.40 Passive solar space heating removes load from the peak electricity demands. As above, recent energy modeling by BRANZ has shown that the peak load is the driver for both generation and transmission and they are commending energy sources which shift the load away from electricity which will reduce the need for both peak generation and network capacity.
- 8.41 It puts extra disposable income in the pockets of average New Zealanders. This has a significant economic multiplier effect so will feed economic development. The cost of one wind turbine is approximately the same cost of solar passive heating for 670 homes.
- 8.42 Mandating that all new homes move towards solar design will make a massive reduction in the growth in electricity demand. It has been calculated that alone, this change to the building code will save nearly 2000MW per new home which equates to 70GW per year. This is an efficient totally renewable resource with no adverse amenity or health effects, and does not have the prejudice of wind power.

9.0 REFERENCES

American National Standard Institute (1979). The American National Standard Guide to the Evaluation of Human Exposure to Whole Body Vibration ANSA S3.18-1979.

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

Belojevic, G. S.-T., M. (2002). "Prevalence of arterial hypertension and myocardial infraction in relation to traffic noise exposure." Noise and Health 4: 33-37.

Berglund, B. L., Thomas.; Schwela, D.H. (1999). Guidelines for Community Noise. World Health Organisation. Geneva.

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.

Carter, N. L., Ingham, P., Tran, K., (1994). "Environmental noise and sleep - A study of arousals, cardiac arrhythmia and urinary catecholamines." Sleep **17**: 49-55.

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

Chen, Y. H., S. (2004). "An investigation on the physiological and psychological effects on infrasound on persons." Journal of Low Frequency Noise, Vibration and Active Control **23**(1): 71-76.

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.

Evans, G. W., Lepore, S.J. (1993). "Non-auditory effects of noise on children." Journal of Children's Environment **10**: 31-55.

Gander, P. H. M., N. S.; Harris, R. B.; Reid, P. (2005). "Sleep, sleepiness and motor vehicle accidents: a national survey." Australian and New Zealand Journal of Public Health **29**(1): 16-21.

Goldstein, M. (1994). "Low -frequency components in complex noise and their perceived loudness and annoyance." Work and Health **2**.

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.

Heines, M. S., SA.; Job, RFS.; Berglund, B. (2001). "A follow up study of the effects of aircraft noise exposure on child stress responses and cognition." International Journal of Epidemiology **30**: 839-45.

Howden-Chapman, P. M., A.; Crane, J.;Viggers, H.; Cunningham, M.; Blakely, M.; Cunningham, C.; Woodward, A.;Saville-Smith, K.;O'Dea, D.;Kennedy,M.; Baker M.; Waipara, N.;Chapman, C.;Davie G "Effect of insulating existing houses on health inequality: cluster randomised study in the community." British Medical Journal **bmj.39070.573032.80v1**.

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

Isaacs, N. C. M. F., L. ; Pollard, A.; Saville-Smith K.; Fraser. R.; Rossouw P.; Jowett, J. (2006). Energy use in New Zealand households - HEEP year 10 report. Wellington, BRANZ.

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

Joubert, D. (2001). Whole body vibration and health. Queensland, Australia, Central Queensland University.

Kjellberg, A., Goldstein, M., Gamberale, F. (1984). "An assessment of dBA for predicting loudness and annoyance of noise containing low frequency components." Journal of Low Frequency Noise and Vibration **3**: 10-16.

Landtransport (2005). Factsheet 24 - Fatigue: Staying alert while you're driving, Landtransport.

Netherlands, H. C. o. (1994). Noise and Health. Hauge.

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 (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.

Pederson, E. W., KP (2007). "Wind turbine noise, annoyance and self reported health and wellbeing in different living environments." Journal of Occupational and Environmental Medicine.

Phipps, R. A. (1996). Passive Solar in Buildings: New and Emerging Renewable Energy Technologies in New Zealand., Jointly published by the Energy Efficiency and Conservation Authority and the Centre for Advanced Engineering.

Phipps, R. A. (2000). Passive Solar Design in New Zealand Homes. Report prepared for EECA. Energy -Wise Renewable - 11., EECA.

Seidel, H. H., R. (1986). "Long-term effects of whole-body vibration: a critical survey of the literature." International Archives of Occupational and Environmental Health. **58**(1): 1-26.

Stanton, N., ; Hedge, A.; Brookhuis, K.;Salas, E.;Hendrick, H.W. (2004). Handbook of Human Factors and Ergonomics Methods, CRC Press.

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

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

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.

Wasserman, D. E. W., J.F. (2005). Occupational vibration: a brief overview.