The Social and Economic Impact of Rural Wind Farms

Submission to the Senate Community Affairs Committee

By

Parkesbourne/Mummel Landscape Guardians Inc.

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Preface

To the Senate Community Affairs Committee

14 February 2011

My name is David Brooks. I am chairperson of the Parkesbourne/Mummel Landscape Guardians Inc. (PMLG).

I am not a physician, or an acoustician, or a noise engineer. I am a retired academic. I was formerly a Lecturer in the Department of English at the University of Sydney. Like many of my colleagues in PMLG and other community associations I have been compelled to spend my time researching the nature of wind farms and their impacts, because of the potential (and in some cases the actuality) of wind farm development in Australia to have adverse effects on local communities. I should much prefer to be spending my time in some other way. But the deficiencies of the planning and assessment process for wind farms in Australia, and specifically in NSW, have forced me to engage in the research which, it seems, the planning authorities are unwilling to undertake.

My own home is threatened by the Gullen Range Wind Farm project, now approved but not yet constructed. The house of myself and my wife lies to the east of the wind farm site, between 1.7 and 2 kilometres from five of the projected 73 turbines. Since the prevailing wind is from the west, we are downwind of the turbines, the worst place to be. There are 32 non-involved residences within 1.5 kilometres of the projected turbines, about 60 non-involved residences within 2 kilometres, and 118 non-involved residences within 3 kilometres. Most of these residences are to the east of the wind farm site, and so lie downwind from it. The investigations of noise experts Thorne (Thorne, 2010; Thorne et al, 2010) and Bakker et al (2009) [see Bibliography] suggest that in hilly terrain such as ours adverse noise impacts and adverse health impacts, particularly sleep disturbance, can be felt as far away as 3 kilometres from turbines. It is therefore reasonable to predict that some proportion of the 118 residences within 3 kilometres of the Gullen Range site will be adversely impacted by the wind farm. The Gullen Range Wind Farm, if it is ever built, will be a planning disaster for the local community.

This planning disaster will be repeated up and down the Great Dividing Range and on the South Coast in NSW, where the wind energy industry plans, with the encouragement of the current state government, to build 4204 turbines. (This figure comes from Russell Marsh, Policy Director of the Clean Energy Council, at an open day organized by the NSW Department of Environment, Climate Change and Water at the Yass Soldiers Club, December 6, 2010.)

Adverse impacts have already been felt, and are being felt by residents who live in the vicinity of the Crookwell One Wind Farm, the Cullerin Wind Farm and the Capital Wind Farm in NSW, and of the Waubra Wind Farm in Victoria (and no doubt of others). These people have names and addresses. They can be contacted.

Since you may have doubts about the reliability of evidence concerning specialist medical and acoustic matters presented to you by a layperson, I have quoted extensively from original sources. This fact makes this submission long and tedious to read. I apologize for the length and tedium, but in the circumstances they are unavoidable.

I have not had time to write an Executive Summary for the beginning of this submission, in the usual manner. I apologize for this. **A summary of the first section Adverse Health Impacts will be found on pp. 30-31. A summary of the second section Noise and Noise Guidelines will be found on pp. 55-57. The overall conclusions will be found on p. 58.**

This submission is already late. In the time available to me I have managed to deal only with adverse health impacts, and noise impacts and noise guidelines. I will write another, brief submission on property value impacts and the deficiencies of the planning process for wind farms in NSW, and send it to you within the next few days. You can decide whether you will accept it.

Wind farms make a negligible, but very expensive contribution to reducing greenhouse gas emissions, and tend to destabilize the power grid. I have not written on these topics. Others, professionally qualified, will no doubt make submissions to you concerning them. I refer you to:

> Andrew Miskelly and Tom Quirk, *Wind Farming in South East Australia* (2009), posted at www.docstoc.com
> Peter Lang, *Cost and Quantity of Greenhouse Gas Emissions Avoided by Wind Generation* (2009), posted at www.carbon-sense.com

Wind farms do have adverse health effects. This has been established in peer-reviewed studies, for which the references are given in this submission. There is of course an enormous peer-reviewed literature on wind turbine noise. Some of it is reviewed in this submission.

If you wish to question me on any aspects of this submission, I shall be happy to attend any session of the committee.

Finally, may I offer you some recommended reading?

> Nina Pierpont, *Wind Turbine Syndrome* (2009)
> Christopher Hanning, *Wind Turbine Noise, Sleep and Health* (2010), posted at www.windvigilance.com
> The Acoustic Ecology Institute, *AEI: Special Report: Wind Energy Noise Impacts* (2009), posted at www.acousticecology.org
> Punch, J., James, R., and Pabst, D., *Wind Turbine Noise: What Audiologists Should Know*, in *Audiology Today*, July/August, 2010, pp 20-31.
> Alec N. Salt, *Wind Turbines are Hazardous to Human Health*, posted at the website of the Cochlear Fluids Research Laboratory, Washington University, St Louis: www.oto2.wustl.edu/cochlea/wind.html
> Robert Thorne, *The Problems with 'Noise Numbers' for Wind Farm Assessment*, Paper submitted to the First International Symposium on Adverse Health Effects

From Wind Turbines, October 29-31, 2010

Pierpont’s study is a book, but the pieces by Hanning, the AEI, Punch et al, Salt, and Thorne are article-length, and would not take very long to read.

The fact sheets posted at the website of the *Society for Wind Vigilance* are indispensable: www.windvigilance.com .

Archives of important documents, including many of the peer-reviewed studies cited in this submission are available at www.wind-watch.org and at www.windaction.org .

You will no doubt be consulting:

NSW Legislative Council: General Purpose Standing Committee No 5, *Report 31 Rural Wind Farms* (December 2009)

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Contents

Adverse Health Impacts

Assertions and Counter-assertions

Recently reports by both the wind energy industry and government bodies have denied that wind turbines pose any health risk to human beings.

The report *Wind Turbine Sound and Health Effects: An Expert Panel Review* (December 2009), prepared for the American Wind Energy Association (AWEA) and the Canadian Wind Energy Association (CWEA) concludes:

1. Sound from wind turbines does not pose a risk of hearing loss or any other adverse health effect in humans.

2. Subaudible, low frequency sound and infrasound from wind turbines do not present a risk to human health.

3. Some people may be annoyed at the presence of sound from wind turbines. Annoyance is not a pathological entity.

4. A major cause of concern about wind turbine sound is its fluctuating nature. Some may find this sound annoying, a reaction that depends primarily on personal characteristics as opposed to the intensity of the sound level.[i]

Similarly, the report *Wind Farms Technical Paper: Environmental Noise* (November 2010), prepared by Sonus Pty Ltd for the (Australian) Clean Energy Council concludes:

> There is detailed and extensive research and evidence that indicates that the noise from wind farms developed and operated in accordance with the current Standards and Guidelines will not have any direct adverse health effects.[ii]

The report *Wind Turbines and Health: A Rapid Review of the Evidence* (July 2010), by the (Australian Government) National Health and Medical Research Council concludes:

> Based on current evidence, it can be concluded that wind turbines do not pose a threat to health if planning guidelines are followed.
>
> This review of the available evidence, including journal articles, surveys, literature reviews and government reports, supports the statement that: *There are no direct pathological effects from wind farms and that any potential impact on humans can be minimised by following existing planning guidelines.*[iii]

The report *The Potential Health Impact of Wind Turbines* (May 2010) by the Chief Medical Officer of Health of Ontario states:

> The review concludes that while some people living near wind turbines report symptoms such as dizziness, headaches, and sleep disturbance, the scientific evidence available to date does not demonstrate a direct causal link between wind turbine noise and adverse health effects. The sound level from wind turbines at common residential setbacks is not sufficient to cause hearing impairment or other direct health effects, although some people may find it annoying.[iv]

Three of the above four reports have been very severely criticised by the Society for Wind Vigilance, an international federation of physicians, acousticians, engineers, and other professionals, promoting the development of authoritative wind turbine guidelines to protect the health and safety of communities.

Of the AWEA/CWEA's *Expert Panel Review* the Society's critique states:

> It is apparent from this analysis that the A/CanWEA Panel Review is neither authoritative nor convincing. The work is characterized by commission of unsupportable statements and the confirmation bias in the use of references. Many important references have been omitted and not considered in the discussion. Furthermore the authors have taken the position that the World Health Organization standards regarding community noise are irrelevant to their deliberation – a remarkable presumption.
>
> There is no medical doubt that audible noise such as emitted by modern upwind industrial wind turbines sited close to human residences causes significant adverse health effects. These effects are mediated through sleep disturbance, physiological stress and psychological distress. This is settled medical science.
>
> There are many peer-reviewed studies showing that infra and low frequency sound can cause adverse health effects, especially when dynamically modulated. Modern upwind industrial scale turbines of the types now being located in rural areas of North America require study. The extent to which infra and low frequency noise from wind turbines inside or outside homes causes direct adverse effects upon the human body remains an open question – there is no settled medical science on this issue as of yet.[v]

Of the NHMRC *Rapid Review* the Society's critique states:

> The "Rapid Review" is an incomplete literature review with no original research. The report is biased from the outset as it seeks to support a restricted and preconceived conclusion. The end result is a deficient public health document.

> NHMRC asserts it "... only uses the best available evidence, in the form of peer-reviewed scientific literature, to formulate its recommendations." The contents of the "Rapid Review" reveal a different reality. The list of reference omissions is immense.
>
> The "Rapid Review" places an inappropriate level of credence in wind energy industry produced and or sponsored material to support its assertions. To compound this bias the "Rapid Review" selectively cites references which favour the wind energy industry while inexplicitly omitting relevant citations which do not.
>
> The "Rapid Review" is characterized by persistent allusions that people experience adverse health effects due to "attitude", "negative opinions" and "worry". These speculative theories are presented while ignoring authoritative knowledge on the subject of noise and health.[vi]

Of the report made by the Chief Medical Officer of Health of Ontario the Society's critique states:

> "The Potential Health Impacts of Wind Turbines May 2010" (CMOH Review) is a literature review and contains no original research. As a consequence the report has little relevance to addressing the issues of adverse health effects of an emerging technology. The report does acknowledge the relative paucity of existing medical evidence but paradoxically declines to offer any remedial action – to wit further research.
>
> In addition the conclusions of the CMOH Review are not supported by the content of the references cited and other relevant authoritative references.
>
> Studies of European wind turbine facilities have consistently concluded that wind turbine noise is more annoying than other commonly experienced noise sources such as traffic, aircraft and rail.
>
> Current research demonstrates that annoyance must not be trivialized. Annoyance is acknowledged to be an adverse health effect which contributes to stress, sleep disturbance and an increased risk of regulation diseases ...
>
> ... The CMOH Report appears to be a government-convened attempt to justify unsound practices of wind turbine development while denying the adverse health effects being reported by Ontario families.[vii]

Against the claims made by the wind energy industry and its government supporters that there are no adverse health effects from wind turbines we can set the assertions of health bodies or health professionals that there are, or can be.

Nine months before the Chief Medical Officer of Health, Ontario, published her report denying any connection between wind turbines and adverse health effects, the Regional Environmental

Assessment Coordinator of the Atlantic Region of Health Canada (the Canadian Department for Public Health) wrote to an Environmental Assessment Officer with the Nova Scotia Department of Environment, advising him that there are such connections. In her letter she is responding to a report concerning the Digby Wind Power Project. In part she writes:

> Appendix B (Addressing Concerns with wind Turbines and Human Health) – The final sentence in Appendix B states that "*there is no peer-reviewed scientific evidence indicating that wind turbines have an adverse impact on human health*". In fact, there are peer-reviewed scientific articles indicating that wind turbines may have an adverse impact on human health. For example, Keith et al. (2008), identified annoyance as an adverse impact on human health that can be related to high levels of wind turbine noise. In addition, there are several articles by Pedersen (and others) related to wind turbine annoyance (as referenced below). The relationship between noise annoyance and adverse effects on human health is also further investigated in the manuscript by Michaud et al. (2008).
>
> Health Canada advises that this statement be revised to indicate that there are peer-reviewed scientific articles indicating that wind turbines may have an adverse impact on human health.[viii]

She then gives him the references to Keith et al. 2008, Michaud et al. 2008, Pedersen and Halmstad 2003, Pedersen and Persson Waye 2008, Pedersen and Persson Waye 2007, Pedersen and Persson Waye 2004, WHO 1999, and van den Berg et al. 2008 (see Bibliography to this submission).[ix]

Dr Christopher Hanning BSc, MB, BS, MRCS, LRCP, FRCA, MD was formerly Consultant in Sleep Disorders Medicine, and founder/director of the Leicester Sleep Disorders Service. Now retired, he is Honorary Consultant in Sleep Disorders Medicine to the University Hospitals of the Leicester NHS Trust based at Leicester General Hospital (UK). Dr Hanning writes in his paper *Wind Turbine Noise, Sleep and Health*:

> There can be no reasonable doubt that industrial wind turbines whether singly or in groups ("wind farms") generate sufficient noise to disturb the sleep and impair the health of those living nearby and this is now widely accepted.[x]

Carl V. Phillips, MPP PhD is a specialist in epidemiology. In 2010 he submitted *An Analysis of the Epidemiology and Related Evidence on the Health Effects of Wind Turbines on Local Residents* to the Public Service Commission of Wisconsin. In this submission he states:

> There is ample scientific evidence to conclude that wind turbines cause serious health problems for some people living nearby. Some of the most compelling evidence in support of this has been somewhat overlooked in previous analyses, including that the existing evidence fits what is known as the case-crossover study design, one of the most

> useful studies in epidemiology, and the revealed preference (observed behaviour) data of people leaving their homes, etc., which provides objective measures of what would otherwise be subjective phenomena. In general, this is an exposure-disease combination where causation can be inferred from a smaller number of less formal observations than is possible for cases such as chemical exposure and cancer risk.
>
> The reported health effects, including insomnia, loss of concentration, anxiety, and general psychological distress are as real as physical ailments, and are part of accepted modern definitions of individual and public health. While such ailments are sometimes more difficult to study, they probably account for more of the total burden of morbidity in Western countries than do strictly physical diseases. It is true that there is no bright line between these diseases and less intense similar problems that would not usually be called a disease, this is a case for taking the less intense versions of the problems more seriously in making policy decisions, not to ignore the serious diseases.

Dr Phillips also writes:

> The reports that claim that there is no evidence of health effects are based on a very simplistic understanding of epidemiology and self-serving definitions of what does not count as evidence. Though those reports probably seem convincing prima facie, they do not represent proper scientific reasoning, and in some cases the conclusions of those reports do not even match their own analysis.[xi]

In May 2009 the Minnesota Department of Health: Environmental Health Division published *Public Health Impacts of Wind Turbines*. It states:

> The most common complaint in various studies of wind turbine effects on people is annoyance or an impact on quality of life. Sleeplessness and headache are the most common health complaints and are highly correlated (but not perfectly correlated) with annoyance complaints. Complaints are more likely when turbines are visible or when shadow flicker occurs. Most available evidence suggests that reported health effects are related to audible low frequency noise.[xii]

Surveys

Within the last few years several self-reporting surveys have been conducted of the health complaints of local residents who are the neighbours of wind farms. The results are fairly uniform.

Harry

In the UK Dr Amanda Harry, MB, ChB, PG, DipENT surveyed forty-two people living between 300 metres and 1.6 kilometres of wind turbines. She published the results of the survey in February 2007. 81% reported that their health had been affected since the erection of the turbines. 76% reported that, as a result, they had visited their doctor. 73% asserted that their quality of life had been altered since living near to the turbines.[xiii] Dr Harry summarises:

> The range of symptoms mentioned by complainants includes headaches, sleep disturbance, anxiety, depression, stress, vertigo and tinnitus. People complain of the noise, vibration and shadow flicker (caused by rotation of the blades and the reflection of the sun). [xiv]

Pierpont

In 2009 Dr Nina Pierpont, MD, PhD published the results of a similar but more elaborate survey of 37 wind farm neighbours, from a range of countries, comprising Canada, UK, Ireland, Italy and USA. The survey participants lived between 305 metres and 1.5 kilometres from the turbines. Dr Pierpont reports that the core symptoms complained of by participants were sleep disturbance, headache, tinnitus, other ear and hearing sensations, disturbances to balance and equilibrium, nausea, anxiety, irritability, energy loss, motivation loss, and disturbances to memory and concentration.

32 subjects had disturbed sleep. 19 subjects experienced headaches that were increased in frequency, intensity, and/or duration compared to the baseline for that person. 14 subjects experienced tinnitus. 11 subjects experienced ear popping, ear or mastoid area pressure, ear pain without infection, or a sensation that the ear drum was moving but not producing a sensation of sound.16 subjects experienced disturbance to their balance or sense of equilibrium. 11 adult subjects described the unfamiliar symptoms of internal quivering, vibration, or pulsation. These symptoms were associated with agitation, anxiety, alarm, irritability, nausea, tachycardia, and sleep disturbance. 20 subjects had problems with concentration or memory. 28 subjects perceived themselves or were perceived by parents to be more angry, irritable, more easily frustrated, impatient, rude, defiant, or prone to outbursts or tantrums than at baseline. 21 subjects felt or acted tired. 24 had problems with motivation.

Dr Pierpont's 37 subjects were divided into 10 families. At the time of writing of the report 8 of the 10 families had moved away from their homes because of turbine-associated symptoms. A ninth family could not afford to move, but carried out renovations to try to keep the noise out. The tenth family is reported to be still struggling to stay in their home.

Dr Pierpont's study was published in a peer-reviewed book, *Wind Turbine Syndrome*. The peer reviews are contained in the book (pp. 287-292).[xv]

Phipps

In 2007 Dr Robyn Phipps, Senior Lecturer in Building Technology at Massey University, submitted testimony *In the Matter of Moturimu Wind Farm Application*, before the Joint Commissioners, Palmerston North, New Zealand. Part of her testimony was a report on a peer-reviewed survey that she had carried out into the visual and noise impacts experienced by residents living close to existing wind farms in New Zealand.

The survey form was delivered to about 1100 households. 614 forms were returned, giving a response rate of 56% (considered very high for this sort of self-reporting, self-returning survey).

All the households that responded were more than 2 km from turbines. 16% lived between 2 and 2.5 km; 40% lived 2.5 km away; 29% lived 3 km away.

80% of households considered that the turbines were intrusive. 73% considered the turbines to be unattractive. 52% of households between 2 and 2.5 km, and between 5 and 9.5 km said that they heard wind farm noise. 36% of households located 2 to 5.3 km away believed they heard wind farm noise. 25% of households located as far away as 10 km still heard the wind farm noise.

42 households reported that the wind turbine noise disturbed their sleep occasionally. 21 households reported that their sleep was disturbed frequently. 5 households had their sleep disturbed most of the time. (So, 68 households or 11.1% of respondents suffered sleep disturbance.)[xvi]

Dr Phipps writes:

> The evidence from my research and the evidence of Dr Mosely 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 wind farm. Such effects are not anticipated in NZS 6808 [the New Zealand standard for wind farm noise] and this standard is not adequate to protect the health and amenity of residents....
>
> Based on the research and evidence produced to this hearing it is clear that the turbines [of the proposed Moturimu wind farm] will create significant adverse health and amenity effects on residents in the locality.[xvii]

Nissenbaum

In May 2010 Dr Michael A. Nissenbaum, MD reported the preliminary results of his survey of about 30 adults who live within 3500 feet (1061 metres) of 28 x 1.5 MW turbines at Mars Hill, Maine, USA. These subjects were compared with a control group of 27 people living 3 miles (4.8 km) away, and not exposed to the turbines.

Dr Nissenbaum reports:

> 82% (18/22) of exposed subjects reported new or worsened chronic sleep deprivation, versus 4% (1 person) in the non-exposed group. 41% of exposed people reported new chronic headaches vs 4% in the control group. 59% (13/22) of the exposed reported ‘stress’ versus none in the control group, and 77% (17/22) persistent anger versus none in the people living 3 miles away. More than a third of the study subjects had new or worsened depression, with none in the control group. 95% (21/22) of the exposed subjects perceived reduced quality of life, versus 0% in the control group. Underlining these findings, there were 26 new prescription medications offered to the exposed subjects, of which 15 were accepted, compared to 4 new or increased prescriptions in the control group. The prescriptions ranged from anti-hypertensives and antidepressants to anti-migraine medications among the exposed. The new medications for the non exposed group were anti-hypertensives and anti-arthritics.

Dr Nissenbaum comments:

> There is absolutely no doubt that people living within 3500 feet of a ridgeline arrangement of turbines 1.5 MW or larger turbines [sic] in a rural environment will suffer negative effects.

Dr Nissenbaum’s Mars Hill study is soon to be completed, and is being prepared for publication. Preliminary results have been presented to the Chief Medical Officer for Ontario, and also, by invitation, to Health Canada.[xviii]

It may be noticed that the turbines in the Mars Hill study are only 1.5 MW capacity. This is smaller than the capacity of turbines usually proposed for wind farms now. For example, Cullerin in NSW has 15 x 2 MW turbines, while Capital in NSW has 67 x 2.1 MW turbines. The Gullen Range project plans to use turbines that may be as big as 3.3 MW. Larger capacity tends to be associated with greater height. The 1.5 MW turbines of Crookwell One are only half the height of those proposed for Gullen Range. Capacity and height are both factors contributing to the magnitude of noise produced, and therefore, the distance at which the noise is found to be disturbing. If 1.5 MW turbines are disturbing at 1000 metres, it is reasonable to suppose that 2, 2.5, and 3 MW turbines will disturb at considerably greater distances.

Nonetheless, the work of Dr Robert Thorne on the Waubra Wind Farm shows that even 1.5 MW turbines can have a disturbing effect at much greater distances than 1000 metres.

Thorne

Dr Robert Thorne, PhD is an Australian noise expert. His PhD is in health science, and he holds specialist qualifications in acoustics. He is principal of the Queensland-based company Noise Measurement Services Pty Ltd. Dr Thorne was commissioned by a Mr and Mrs N. Dean to make a noise impact assessment of the Waubra Wind Farm in Victoria. The wind farm consists of 128 x 1.5 MW turbines. The Deans live close to the wind farm, and report adverse health effects. Dr Thorne’s report is peer-reviewed. The latest version (revision 1) is dated July 2010.[xix]

The Waubra Wind Farm began to operate in March 2009 in the Ballarat section, and in May 2009 in the northern Waubra section. Dr Thorne interviewed five families who live between 1000 and 2000 metres of the Waubra turbines. He reports:

> Family A reports headaches (scalp and around the head pressure), memory problems and nausea when the turbines are operating. Symptoms include an inability to get to sleep and sleep disturbance, anxiety and stress, pressure at top and around head, memory problems, sore eyes and blurred vision, chest pressure. When the turbines are stopped the symptoms do not occur. A difference in severity is recorded with different wind directions.
>
> Family B reports tinnitus, dizziness and headaches since the turbines have started operating. Sleep disturbance at night with the sound of the turbines interrupting sleep pattern. Vibration in chest at times. Tiredness and trouble concentrating during the day. Does not have problems sleeping when not at Waubra overnight.
>
> Family C reports the noise coming from the turbines at night disturbs sleep. During the day there is noise which causes bad headaches, sore eyes causing impaired vision, earache and irritability.
>
> Family D reports suffering from sleep disturbance, headaches, nausea and tachycardia (rapid heart rate) since the turbines started operating.
>
> Family E reports that when the turbines are operating, symptoms include feeling unwell, dull pains in the head (acute to almost migraine), nausea and feeling of motion sickness. At night when the turbines are in motion sleep disturbance from noise and vibration (unable to get any meaningful deep sleep), sleep deprivation leading to coping problems.[xx]

In addition, Dr Thorne presents a table that correlates complaints made about the wind farm with distance from the turbines of the complainants. It is noteworthy that adverse health effects are reported by residents who live at much greater distances from the turbines than even 2 kilometres. Thus:

> [Complainants] 9. 3500-4300 metres. Frequently suffer from headaches, tinnitus, irritability, sleepless nights, lack of concentration, heart palpitations.
> [Complainants] 10. 3400-3800 metres. Headaches ringing in ears when turbines are operating. Pressure in ears, heart palpitations and anxiety attacks. Awaken at night, sleep disturbance.
> [Complainants] 11. 3000-4600 metres. Elevated blood pressure, heart palpitations, ear pressure and earache, disrupted sleep, increasing frequent headaches, head pressure, vibration in body, mood swings, problems with concentration and memory. Awaken at night, sleep disturbance.[xxi]

Dr Thorne comments:

> A common observation is that the adverse health effects noted did not exist before the wind farm commenced operation, or [they] diminish/disappear when not in the district affected by turbines.[xxii]

Dr Thorne also provides a table of complaints and distances from turbines relating to the Westwind Wind Farm at Makara, New Zealand, which commenced operation in May 2009. In this case the complainants live between 750 metres and 2200 metres from the turbines. The turbines are 2.3 MW. 9 of the 10 groups of complainants complain of sleep disturbance, even at distances further than 1500 metres, out as far as 2200 metres.[xxiii]

From the work of Harry, Pierpont, Phipps, Nissenbaum, and Thorne, as well as from other surveys and registers of complaints we know that there are complaints of the adverse health effects of wind turbines from the UK, the USA, Canada, Ireland, Europe, Australia and New Zealand, and Japan. The phenomenon is global, which is hardly surprising, since the human body is the same everywhere, and people everywhere need sleep.

The Victims Speak

Before we turn to the specific issues of annoyance and sleep deprivation, and the hypotheses that have been put forward to explain the cluster of symptoms associated with wind turbine noise, I will quote some of the statements made by those who are suffering from the impact of wind farms. Their voices surely deserve to be heard, especially considering the callous indifference of the wind energy industry and of its supporters in government. According to the wind energy industry, victims are responsible for their own suffering. They bring it on themselves by having a “bad attitude” to wind farms. Please remember that the people whose angst you are about to listen to are regarded by industry and government as self-tormentors.

1. I get little sleep when the noise from the turbines is constant in its low frequency noise. I feel so depressed I want to get away and stay away until I know the wind direction has changed.

2. I get headaches and thumping in the ears. I also find its continual noise very distressing.

3. Constant worry about noise. I feel sick when the turbines are running fast and towards the property. I came here to a rural area for peace after a busy city life. I feel this has been ruined by the turbines.

4. My plan was to stay here – in my newly converted barn (7 years old) (we farmed here) until I died. We have our own private water supply, a good supply of fire wood, my own painting studio – VERY IMPORTANT TO ME! And a good workshop for my husband; friends nearby, brother and sister nearby. I was born 2 miles away – Now WE HAVE TO MOVE. This move has been forced upon us. We planted 7000 trees here. Etc. Etc. Etc....

5. I dare not sleep at home.

6. Tired, disturbed by noise. Feel it as much as hear it. Developers deny there are any problems unless we can prove, but how can we do that?

7. Our quality of life we had before the wind farm has gone. We no longer control the way we live our lives e.g. if we can work or sit in the garden, or at times even where we can sit in our own home or get a full night's sleep.

8. Not being able to choose when I work or sit in my own garden. Not getting full night's sleep. Waking with headaches when the noise is bad and feeling sick. Ears feel like I experience when travelling by plane – feel as if they are swollen inside. I cannot work more than 2-3 hours in the garden when the wind direction is from the east. We cannot see the wind farm from our property but at times the noise is horrendous.

9. As soon as the wind farm was operating I experienced horrendous continuous noise when the wind was from the east. This was both inside and outside my home. There were many times I had to leave the garden because of the noise. It was like a Chinese water torture, it was a constant pulsating noise. It was almost a feeling of compression as much as noise. I had to move bedrooms at times in order to escape the noise. It imprints on you, if you have had it all day in the garden, it stays with you, once it's in your head it's hard to get rid of. It's weird. It's a feeling as much as a noise. It's torture.

10. Even if you shut the window, the noise is still there, but not as much. The problem is, once you get the noise in your head, it's always there, it does annoy you and it is difficult to disregard.

11. Once the noise gets into your head, it also seems to beat at the same frequency as my heart and I find it annoying and am unable to get any sleep – this can go on for nights on end. It's not always the level of the noise, it's the intermittent nature. You think "Oh it's stopped" then it starts up again.

12. Our lives are hell, they have been ruined and it's all due to those turbines.[xxiv]

13. It makes no difference if the windows are open or closed, the noise just invades us.

14. The noise thumps the house we can't change it.

15. We've put in more insulation but it comes thumping up under the floor.[xxv]

16. I am having problems living and working indoors and outdoors on our property ... Problems include headaches, nausea, pain in and around the eyes, sleep disturbance, pain in back of head; we feel this is coming from generation of wind as it is OK when turbines are stopped.

17. The sound of the turbines when functioning is on most days so intrusive that it affects my concentration and thought processes when performing complex tasks. I suffer from sleep interruption as a direct result of the noise which then affects my ability to function at 100% the following day. One is aware of a throbbing in the head and palpitations that are in synchrony with the beat of the turbines and to a degree the flashing of the red lights. Because of this impact on my everyday life it causes me great stress and in turn great irritability.

18. We have had a persistent level of disturbance noise now for several hours throughout the evening that is now preventing us sleeping since 11.15 pm. The predominant noise is a continuous loud booming rumble that is even more noticeable after a gust at ground level. When the wind noise drops, the background noise from the turbine continues and is also felt as a vibration being transmitted through the ground. Even with wind noise the vibrations in the house continue. The varying wind speed also causes a beating noise from the blades that occurs in cycles creating yet another form of noise disturbance.[xxvi]

19. Our finances are not as good because of living in two places. All family events including Christmas has not been in our family home. No one should have this happen to them. We were fine before the wind farms came.

20. I am unable to come home to visit my parents as often as I would like. Due to my parents ongoing adverse health effects I feel discouraged.... My childhood home no longer feels like a place to relax....in a peaceful environment. I am sick over what the turbines have done to my family and community.

21. My house is worth nothing now. I could never sell it. Angry, sad, disillusioned, exhausted.

22. I now live on drugs that don’t seem to help.

23. Because of this I do not want to stay in our home or for that matter come home. The biggest change has been the effect on my Mom, sister and Dad’s health, especially Mom. To see her suffering from health problems, getting sicker and sicker just pisses me off. It really bothers me a lot.

24. My family has been ripped apart with Mom not able to live at home. Not having Mom around to talk to about school or friend and personal stuff has been and is hard. Very hard.

25. The rear of our house is all windows, at night all you see is the warning lights. It is driving me crazy. We had no say in the mills because we weren’t getting one. The persons that got them get paid and don’t live near them.

26. Now all I see is flickering blades and blinding red lights. The sunsets have disappeared into the money hungry pockets of our government....I now am a prisoner in my own home of 23 years.

27. Our anguish is great. We feel betrayed. There is no help. This is our home, our refuge, but we can hardly stand to be here.[xxvii]

The above are just a selection of the victim-statements that I have retrieved from books, articles and the Internet. And what I have retrieved is just a selection from what is available. One could fill a book with reports such as these. Are all these people lying? Are they all deluded? Are they all the victims of their own imagination? Are they all unconsciously punishing themselves for failing to stop a wind farm? The wind energy industry would say yes. Members of the committee will have to decide whom they believe.

Annoyance

From one point of view the word ‘annoyance’ is inadequate to express the misery and anguish felt by many of the residents who are neighbours of wind farms. From another point of view the term also fails to suggest the conditions of physical ill health that can accompany or be produced by the mental state of annoyance.

In its *Guidelines for Community Noise* (1999) the World Health Organization (WHO) clearly lists annoyance as one of the potential adverse health effects of noise. It states:

> The health significance of noise pollution is given in this chapter [ch. 3] under separate headings, according to the specific effects: noise-induced hearing impairment; interference with speech communication; disturbance of rest and sleep; psychophysiological, mental-health and performance effects; effects on residential behaviour and *annoyance*; as well as interference with intended activities. [emphasis added][xxviii]

WHO uses the term ‘annoyance’ to cover a variety of mental states and behaviours:

> However, apart from “annoyance”, people may feel a variety of negative emotions when exposed to community noise, and may report anger, disappointment, dissatisfaction, withdrawal, helplessness, depression, anxiety, distraction, agitation, or exhaustion (Job 1993; Fields et al. 1997, 1998). Thus, although the term annoyance does not cover all the negative reactions, it is used for convenience in this document.[xxix]

WHO’s list of negative emotions obviously fits the effects reported by the victims of wind farm noise, such as we have illustrated above.

WHO also comments on changes in social behaviour that can be induced by noise:

> Noise can produce a number of social and behavioural effects in residents, besides annoyance (for review see Berglund & Lindvall 1995). The social and behavioural effects are often complex, subtle and indirect. Many of the effects are assumed to be the result of interactions with a number of non-auditory variables. Social and behavioural effects

> include changes in overt everyday behaviour patterns (e.g. closing windows, not using balconies, turning TV and radio to louder levels, writing petitions, complaining to authorities); adverse changes in social behaviour (e.g. aggression, unfriendliness, disengagement, non-participation); adverse changes in social indicators (e.g. residential mobility, hospital admissions, drug consumption, accident rates); and changes in mood (e.g. less happy, more depressed).

This description also fits the circumstances of the victims of wind farm noise. Of special concern is the potential effect on children:

> ..... Particularly, there is concern that high-level continuous noise exposures may contribute to the susceptibility of schoolchildren to feelings of helplessness (Evans & Lepore 1993).[xxx]

The US Environmental Protection Agency connects noise, annoyance and adverse health effects. It states:

> The traditional definition of noise is “unwanted or disturbing sound”. Sound becomes unwanted when it either interferes with normal activities such as sleeping, conversation, or disrupts or diminishes one’s quality of life. ... for some, the persistent and escalating sources of sound can often be considered an annoyance. This “annoyance” can have major consequences, primarily to one’s overall health.

It also states:

> Studies have shown that there are direct links between noise and health. Problems related to noise include stress related illnesses, high blood pressure, speech interference, hearing loss, sleep disruption, and lost productivity .... research has shown that exposure to constant or high levels of noise can cause countless adverse affects [sic].[xxxi]

No one is claiming that wind farm noise results in hearing loss, but the other conditions do apply to the situation of wind farm neighbours.

WHO has recently conducted a survey known as LARES (Large Analysis and Review of European Housing Status). This survey included the collection of data concerning noise annoyance in the housing environment, and the evaluation of the data in relation to medically diagnosed illnesses. The researchers report that the “subjective experience of noise stress can, through central nervous processes, lead to an inadequate neuro-endocrine reaction, and finally lead to regulatory diseases”. They also state:

> Adults who indicated chronically severe annoyance by neighbourhood noise were found to have an increased health risk for the cardiovascular system and the movement apparatus, as well as an increased risk of depression and migraine....With children the effects of noise-induced annoyance from traffic, as well as neighbourhood noise, are evident in the respiratory system. The increased risk of illness in the respiratory system in

> children does not seem to be caused primarily by air pollutants, but rather, as the results for neighbourhood noise demonstrate, by emotional stress.[xxxii]

Wind turbine noise is more annoying than other kinds of industrial/transportation noise, at comparable sound levels. This has been demonstrated several times by the Swedish acoustician Eja Pedersen and her colleagues. In *Perception and annoyance due to wind turbine noise: a dose-response relationship* (2004) Pedersen and Persson Waye present a graph which shows that wind turbine noise "highly annoyed" 15% of people at only 38 dBA (i.e 38 decibels, measured on the A-weighting scale). By contrast, for 15% of people to be "highly annoyed" by aircraft noise, the aircraft noise has to reach 57 dBA. For 15% to be "highly annoyed" by road traffic, the road traffic noise has to reach 63 dBA. For 15% to be "highly annoyed" by railway trains, the train noise has to reach 70 dBA. The graph also shows that when wind turbine noise reaches 41 dBA 35% of people are "highly annoyed". These figures suggest that annoyance at wind turbine noise is not only due to the *level* of sound, but also, and more particularly, to the *character* of the sound. We shall consider this below in the section on noise.[xxxiii]

In *Project WINDFARMperception: visual and acoustic impact of wind turbine farms on residents* (2008) Pedersen, van den Berg, Bouma and Bakker report that, according to their investigation, "annoyance from wind turbine sound was related to difficulties with falling asleep and to higher stress scores."[xxxiv]

In their most recent study *Response to noise from modern wind farms in The Netherlands*(2009) the same four researchers state:

> Previously, the relatively high annoyance with shunting yard noise has partly been explained by the impulsive nature of some yard activities (Miedema and Vos, 2004). Wind turbine sound also varies unpredictably in level within a relatively short time span, i.e., minutes to hours. It can be postulated that it could be even more important that neither type of noise ceases at night. In contrast, in areas with traffic noise and/or industrial noise, background levels usually return to lower levels at night, allowing residents to restore themselves psycho-physiologically. A large proportion of respondents in the present study reported hearing wind turbine sound more clearly at night ...[xxxv]

At the beginning of this submission I quoted from the AWEA/CWEA *Expert Panel Review*, and from a report by the Chief Medical Officer of Health of Ontario. Both concede that wind turbine noise causes annoyance, but both dismiss this fact on the false assumption that annoyance is not an adverse health effect. As we have now seen, annoyance is regarded by the medical profession as an adverse health effect, and there is no doubt that wind turbine noise is annoying, and even especially annoying. It follows that there is evidence to think that wind turbine noise can have adverse health effects. And, as we saw, it has been admitted by an official of Health Canada that "there are peer-reviewed scientific articles indicating that wind turbines may have an adverse impact on human health." This can no longer be denied.

Sleep Disturbance

As we have already seen, the World Health Organization in its *Guidelines for Community Noise* (1999) lists sleep disturbance as one of the potential adverse health effects of noise:

> The health significance of noise pollution is given in this chapter [ch. 3] under separate headings, according to the specific effects: noise-induced hearing impairment; interference with speech communication; *disturbance of rest and sleep*; psychophysiological, mental-health and performance effects; effects on residential behaviour and annoyance; as well as interference with intended activities. [emphasis added][xxxvi]

In its section on sleep disturbance [3.3] WHO writes:

> Uninterrupted sleep is known to be a prerequisite for good physiological and mental functioning of healthy persons (Hobson 1989); sleep disturbance, on the other hand, is considered to be a major environmental noise effect.[xxxvii]

It also states:

> The primary sleep disturbance effects are: difficulty in falling asleep (increased sleep latency time); awakenings; and alterations of sleep stages or depth, especially a reduction in the proportion of REM-sleep (REM = rapid eye movement) (Hobson 1989). Other primary physiological effects can also be induced by noise during sleep, including increased blood pressure; increased heart rate; increased finger pulse amplitude; vasoconstriction; changes in respiration; cardiac arrhythmia; and an increase in body movements (cf. Berglund & Lindvall 1995). For each of these physiological effects, both the noise threshold and the noise-response relationships may be different. Different noises may also have different information content and this also could affect physiological threshold and noise-response relationships (Edworthy 1998).
>
> Exposure to night-time noise also induces secondary effects, or so-called after effects. These are effects that can be measured the day following the night-time exposure, while the individual is awake. The secondary effects include reduced perceived sleep quality; increased fatigue; depressed mood or well-being; and decreased performance (Ohrstrom 1993a; Passchier-Vermeer 1993; Carter 1996; Pearsons et al. 1995; Pearsons 1998).
>
> Long-term effects on psychosocial well-being have also been related to noise exposure during the night (Ohrstrom 1991). Noise annoyance during the night-time increased the total noise annoyance expressed by people in the following 24 h. Various studies have also shown that people living in areas exposed to night-time noise have an increased use of sedatives or sleeping pills. Other frequently reported behavioural effects of night-time noise include closed bedroom windows and use of personal hearing protection. Sensitive

> groups include the elderly, shift workers, persons especially vulnerable to physical or mental disorders and other individuals with sleeping difficulties.[xxxviii]

A review of the surveys by Harry (2007), Pierpont (2009), Phipps (2007), Nissenbaum (2010) and Thorne (2010), as well as the recorded statements of the victims of wind turbine noise will show that some of the neighbours of wind farms are suffering from sleep disturbance, sleep deprivation, daytime fatigue, depressed mood, and decreased performance, as well as other symptoms such as stress, anxiety, awakenings accompanied by panic attacks, etc. The surveys also testify to an increased use of medications, and altered behaviour such as changing bedrooms or, in extreme cases, sleeping in the basement, or even outside the house in a tent![xxxix]

Sleep disturbance as a result of wind turbine noise is also confirmed by the study *Project WINDFARMperception* (2008) mentioned earlier.[xl]

Sleep disturbance does not only occur at relatively short distances from turbines, i.e. less than 1000 metres. As we have seen from Thorne's investigations, sleep disturbance is reported by residents living as far as 2200 metres, 3400-3800 metres, 3500-4300 metres, and 3000-4600 metres from turbines. Bakker and colleagues offer some confirmation of this. In their 2009 presentation to the 3rd International Meeting on Wind Turbine Noise they report that that the noise from the Tararua Wind Farm in New Zealand causes sleep disturbance for residents living as far away as 3 kilometres from the turbines.[xli] As we shall see in the section on Noise below, the noise impact of a wind farm does not only depend on sound level and distance, but on the siting of multiple turbines relative to one another, on atmospheric conditions, and on topography. We must therefore conclude that there is already evidence that in some circumstances a wind farm can disturb the sleep of neighbours living at least as far away as 3 kilometres, or even 4 kilometres, and possibly 5 kilometres.

I referred earlier to Dr Christopher Hanning. Dr Hanning is an internationally renowned specialist in sleep disorders medicine. He has posted a comprehensive review *Wind Turbine Noise, Sleep and Health* on the website of the Society for Wind Vigilance. He updates the study from time to time to take account of new research. The latest version is dated November 2010. Dr Hanning writes:

> There can be no reasonable doubt that industrial wind turbines whether singly or in groups ("wind farms") generate sufficient noise to disturb the sleep and impair the health of those living nearby and this is now widely accepted.[xlii]

He gives the following account of the effects of inadequate sleep:

> Inadequate sleep has been associated not just with fatigue, sleepiness and cognitive impairment but also with an increased risk of obesity, impaired glucose tolerance (risk of diabetes), high blood pressure, heart disease, cancer, depression and impaired immunity as shown by susceptibility to the common cold virus. Sleepy people have an increased risk of road traffic accidents. Sleepiness, as a symptom, has as much impact on health as epilepsy and arthritis. It is not insignificant.[xliii]

Dr Hanning has some pertinent and crucially important observations to make on the different kinds of sleep disturbance. He distinguishes between insomnia, remembered awakenings, non-remembered awakenings, and arousals:

> Noise interferes with sleep in several ways. Firstly, it may be sufficiently audible and annoying to prevent the onset of sleep or the return to sleep following an awakening....
>
> Secondly, noise experienced during sleep may arouse or awaken the sleeper. A sufficiently loud or prolonged noise will result in full awakening which may be long enough to recall. Short awakenings are not recalled as, during the transition from sleep to wakefulness, one of the last functions to recover is memory (strictly, the transfer of information from short term to long term memory). The reverse is true for the transition from wakefulness to sleep. Thus only awakenings of longer than 20-30 seconds are subsequently recalled. Research that relies on recalled awakenings alone will therefore underestimate the effect.
>
> Noise insufficient to cause awakening may cause an arousal. An arousal is brief, often only a few seconds long, with the sleeper moving from a deep level of sleep to a lighter level and back to a deeper level. Because full wakefulness is not reached, the sleeper has no memory of the event but the sleep has been disrupted just as effectively as if wakefulness had occurred. It is possible for several hundred arousals to occur each night without the sufferer being able to recall any of them. The sleep because it is broken, is unrefreshing resulting in sleepiness, fatigue, headaches and poor memory and concentration (Martin 1997), many of the symptoms of “wind turbine syndrome”. Recent research (Dang-Vu, 2010) has shown that some subjects are more easily aroused than others.[xliv]

The importance of these distinctions is that research into the sleep disturbance caused by wind turbine noise has got no further than recording remembered awakenings. As Dr Hanning writes:

> Unfortunately **all** government and industry sponsored research in this area has used **reported awakenings** from sleep as an index of the effects of turbine noise and tend to dismiss the subjective symptoms. Because most of the sleep disturbance is not recalled, this approach seriously underestimates the effects of wind turbine noise on sleep. [bold in original][xlv]

Therefore, while it is certain that wind turbine noise is disturbing the sleep of some neighbours of wind farms, the extent and depth of that disturbance has not been studied. Clearly, it ought to be studied.

The wind energy industry and its supporters in government have acknowledged that the neighbours of wind farms report sleep disturbance, but they tend to dismiss these complaints – wrongly, since sleep disturbance is undoubtedly an adverse health effect.

We can conclude that sleep disturbance is an adverse health effect recognised by the medical profession, that wind turbine noise causes sleep disturbance for some neighbours of wind farms, and that this is acknowledged in peer-reviewed literature.

A final note: the wind energy industry and the British government seem to be currently staking everything on the notion that the symptoms of ill health, including sleep disturbance, are the secondary effects of *stress*, in the hope that if the stress can be treated, all the other symptoms will disappear. The notion that the real cause of all the complaints is stress was put forward by Dr Geoff Leventhall, who acts as a consultant to the wind energy industry, and who was one of the authors of the *Expert Panel Review*. In his evidence to the Public Service Commission of Wisconsin in 2009 Dr Leventhall said, "The symptoms of .. Wind Turbine Syndrome ... sleep disturbance, headache, tinnitus, ear pressure, dizziness, vertigo, nausea, visual blurring, tachycardia, irritability, problems with concentration and memory, and panic attack episodes associated with sensations of internal pulsation or quivering when awake or asleep ... I am happy to accept these symptoms, as they have been known to me for many years as the symptoms of extreme psychological stress from environmental noise, particularly low frequency noise." [xlvi]The same line was taken by David Colby, another of the authors of the *Expert Panel Review*. Dr Colby stated on radio: " We're not denying that there are people annoyed and that maybe some of them are getting stressed out enough about being annoyed that they're getting sick."[xlvii] According to this view, the problem is not with the turbines, but with the human tendency to get stressed. If the stress can be treated, this relieves the industry of the obligation to move the turbines. And it seems that the British Government is cooperating with this futile manoeuvre. On 28 January 2010 the magazine *Countryside News* reported an interview with Dr Leventhall. "Dr Geoff Leventhall said there was no doubt people living near the turbines suffered a range of symptoms, including abnormal heart beats, sleep disturbance, headaches, tinnitus, nausea, visual blurring, panic attacks and general irritability." "'I have lots of people phoning me up and telling me that it's ruining their lives – and it's genuine,' he said." "But Dr Leventhall said he is taking part in a Defra [UK Department for Environment, Food and Rural Affairs] project that aims to use psychotherapy to enable sufferers to live with the noise." [xlviii]

It can be safely predicted that psychotherapy will not prevent sleep disturbance, high blood pressure, tinnitus, or any of the other involuntary conditions to which people are subjected by wind turbine noise. The victims are likely to become even more 'annoyed' by the idea that it might.

What all this amounts to is that the wind energy industry recognizes that its turbines are causing adverse health effects in people, and it is trying to evade the responsibility of taking the only effective action to put an end to these effects, namely, to shut down turbines or to move them. The British government, it seems, is complicit in this evasion.

Medical Research I : Pierpont

In 2004 Dr Geoff Leventhall was already suggesting that the adverse health effects suffered by neighbours of wind farms are ultimately due to the negative attitude towards wind farms of the sufferers:

> Their patients [neighbours of wind farms commented on by Dr Harry and Dr Osborne] may well have been experiencing adverse symptoms, but we have to keep in mind that people who have failed, for whatever reason, in strong objections to a development, build up in themselves a level of unfulfilled expectations and consequent stress, which peaks after the failure and can overload their coping capabilities. This leads them to lay the blame on whatever straw they can clutch. This is especially so in group activities, where mutual support may turn to a mutual, interacting misery, which worsens the situation.... The very low levels of low frequency noise and infrasound which occur from wind turbines will not normally cause problems. If problems have occurred, it is possibly for some other stress-related reason.[xlix]

Dr Nina Pierpont, MD, PhD rejects this account of the symptoms suffered by the neighbours of wind farms. She states:

> There is nothing “psychosomatic” about it. The physiologic pathway flows from physical forces (air pressure changes, noise, vibration) to physical sensations (chest pulsations, internal vibration, tinnitus, headache, ear fullness) to brain integration of sensory signals to distortions of brain functioning (sleeplessness, concentration and memory deficits, physical symptoms of anxiety) – not the reverse. Research clearly shows there are precise and definable neurologic connections that explain how distorted sensory signals can derail normal psychological and cognitive function and, in fact, trigger physical symptoms.[l]

It may be noted that Dr Leventhall is an acoustician, and neither a psychologist nor a physician. Moreover, as we shall see in the section on Noise below, he is wrong about the levels of low frequency noise and infrasound from wind turbines being low. The levels are not low, but relatively high. It is only recently that they have been measured accurately.

Dr Pierpont has called the cluster of symptoms experienced by neighbours of wind turbine noise ‘Wind Turbine Syndrome’, and she has published her book *Wind Turbine Syndrome: A Report on a Natural Experiment* (2009) to present her own account of the syndrome. It should be emphasised again that this *is* a peer-reviewed work (see pp. 287-292 of the book). In the book she presents the findings twice: once as a technical report for fellow clinicians; and again in simpler language for laypeople.[li] This ought not to undermine the professional status of this publication, which has been highly commended by her peer-reviewers.

Dr Pierpont summarises her conclusions as follows:

> Wind Turbine Syndrome, I propose, is mediated by the vestibular system – by disturbed sensory input to eyes, inner ears, and stretch and pressure receptors in a variety of body locations. These feed back neurologically onto a person’s sense of position and motion in space, which is in turn connected in multiple ways to brain functions as disparate as spatial memory and anxiety. Several lines of evidence suggest that the amplitude (power or intensity) of low frequency noise and vibration needed to create these effects may be even lower than the auditory threshold at the same low frequencies. Re-stating this, it appears that even low frequency noise or vibration too weak to be heard can still

> stimulate the human vestibular system, opening the door for the symptoms I call Wind Turbine Syndrome. I am happy to report there is now direct experimental evidence of such vestibular sensitivity in normal humans.[lii]

The cluster of symptoms designated Wind Turbine Syndrome consists in the following: "sleep disturbance, headache, tinnitus, ear pressure, dizziness, vertigo, nausea, visual blurring, tachycardia, irritability, problems with concentration and memory, and panic episodes associated with sensations of internal pulsation or quivering that arise while awake or asleep."[liii]

The existence of the syndrome is postulated on the basis of Dr Pierpont's own survey of the neighbours of wind farms who report adverse health effects, in the light of the surveys and reports of others (principally Harry, Phipps, and Pedersen and her colleagues). Having established the syndrome as a phenomenon to be explained, Dr Pierpont's task is to review the medical literature to find physiological mechanisms that explain the symptoms.

Dr Pierpont's hypothetical explanation for Wind Turbine Syndrome turns on the functioning of the balance system of the human body. The balance system involves the reception of signals concerning motion and position through four channels: (i) the eyes, (ii) the vestibular system of the inner ear, (iii) stretch receptors from muscles and joints all over the body (the somato-sensory system), (iv) stretch and pressure receptors associated with organs in the chest and abdomen. "The balance system requires that at least two of the first three channels (visual, vestibular, and somato-sensory) be working and providing harmonious data at every moment if we are to maintain balance."[liv] Dr Pierpont suggests that wind turbine noise and/or vibration (and indeed the visible motion of the blades) can disturb any of the four channels of signals, in definite and specifiable ways. If this happens with people who, for various reasons, already have a deficient functioning of one or more of the four channels, then the result can be that their total balance system is disturbed, and they experience the symptoms of Wind Farm Syndrome.[lv] Dr Pierpont notes the especially vulnerable groups are: small children (whose balance system has not yet fully developed), the elderly (whose balance system is deteriorating), the motion sensitive (including migraine sufferers), and those with pre-existing inner-ear disorders (e.g., Meniere's disease).[lvi]

(Of course, Dr Pierpont's hypothesis does not preclude the possibility that some wind farm neighbours with no pre-existing vulnerability may also suffer sleep disturbance merely because of the level of wind turbine noise above the quiet background noise of a rural area.)

Dr Pierpont recognises the limitations of her study: the smallness of the sample of subjects studied, the restrictions of the method of self-reporting survey, and the limited availability of medical records for the subjects. She also recognises the need for further research, especially epidemiological studies on a large enough scale; neurotological research on subjects, using objective examination and testing, as well as clinical history; clinical/laboratory research into the effects of low frequency noise and vibration on the human vestibular system; and collaborative research between physicians and noise engineers to determine the specific frequencies and intensities of sound that correlate with subjects' symptoms in real time.[lvii] Nonetheless, Dr Pierpont puts forward her findings as a valid 'case series'[lviii], with a hypothesis that, as she recognises, needs to be tested and demonstrated by further research. Her case series is sufficient, she implies, to justify the further research.

Medical Research II: Salt

Dr Alec Salt, PhD, MSc., BSc. is a medical researcher at the Cochlear Fluids Research Laboratory in the Department of Otolaryngology [ears, nose, and throat] at the Washington University School of Medicine, St Louis, Missouri. He has recently published a paper on the potential effects of infrasound on the inner ear, in the context of wind turbine noise, in the peer-reviewed journal *Hearing Research*. The paper is called *Responses of the ear to low frequency sounds, infrasound and wind turbines.*[lix]

Dr Salt has presented the findings of his research in a paper read to the First International Symposium on the Global Wind Industry and Adverse Health Effects, held at Picton, Ontario, October 29-31, 2010. The paper is called: *Infrasound: your ears 'hear' it but they don't tell your brain*.[lx] Dr Salt has also presented his research in a more informal way in a posting on the website of the Society for Wind Vigilance, for which he acts as a Scientific Advisor. This informal presentation is uncompromisingly called *Wind Turbines are Hazardous to Human Health*.[lxi]

Noting that wind turbines generate high levels of infrasound (inaudible sound below 20 Hz, i.e. less than 20 cycles per second), Dr Salt comments:

> Even though you cannot hear the sound, it is easily detected by the ear at the levels that are produced and can have effects on the body that profoundly disturb some individuals.[lxii]

Dr Salt compares the effect of inaudible infrasound with the effect of invisible ultra-violet light. No one believes that ultra-violet light is harmless merely because it is invisible. It is known to be very harmful.[lxiii] And yet the wind energy industry insists that infrasound must be harmless because it is inaudible. Dr Leventhall has asserted: "Infrasound ... is below the audible threshold and of no consequence."[lxiv] Against this view Dr Salt is emphatic. He counters, "For years, people have been told that infrasound you cannot hear cannot affect you. This is completely wrong." [lxv]

Dr Salt refers to the Outer Hair Cells of the inner ear. The Outer Hair Cells are stimulated by infrasound. "[A] Physiologic pathway exists for infrasound at levels that are not heard to affect the brain." He traces out this pathway as: Infrasound – Outer Hair Cells – (via type II nerve fibers) subconscious brain: ear fullness, ear pressure, discomfort, alerting/sleep disturbance.[lxvi] Infrasound thus can produce some of the symptoms of Wind Turbine Syndrome.

He notes that the Outer Hair Cells can become "overworked, tired, irritated."[lxvii]

But he also notes that, although the general character of infrasound stimulation is known, the effects remain to be quantified. This is true of ear pressure or fullness, discomfort, and arousal from sleep; ear fullness, tinnitus, and unsteadiness; unsteadiness; and stress and anxiety.[lxviii]

He sums up: “Sounds you cannot hear can affect you, can disturb you, can harm you, can cause disease, [including] auditory and balance disorders, and the effects of sleep deprivation [which] are serious (hypertension, diabetes, mortality).”[lxix]

He concludes:

> Because the inner ear does respond to infrasound at levels that are not heard, people living near wind turbines are being put at risk by infrasound effects on the body that no one presently understands.
>
> Until a scientific understanding of this issue is established we should not be dismissing these effects, but need to be erring on the side of caution.[lxx]

This is the strongest and most explicit warning concerning wind turbine noise to come from the medical profession at the level of peer-reviewed research.

Medical Research III: Laurie

The most recent piece of medical research bearing on the issue of wind turbines and potential adverse health effects is the preliminary work carried out by Dr Sarah Laurie, a GP living in South Australia, who is also Medical Director of the Waubra Foundation. Dr Laurie released the preliminary results of her study in a media release posted on Dr Nina Pierpont’s website on 28 December 2010. Dr Laurie writes of her examination of subjects living around wind farms in Australia:

> Preliminary results of investigations (24-hour blood pressure Holter Monitor) are showing that some people living adjacent to turbine developments (distance of 3 to 4 km = 1.9 to 2.5 mi) are getting episodes of hypertension (high blood pressure) at night, sometimes dangerously high, while they are asleep and while the turbines are operating. As this will mostly be asymptomatic, people generally will be unaware that it is happening to them until this investigation is done on a night when the turbines are operating.
>
> Notice, these patients do not necessarily have previously diagnosed hypertension; they and their family physician might think their blood pressure is normal, since it is normal when measured in the doctor’s office, during the day, well away from the turbines.

Dr Laurie points out that there is “peer reviewed published experimental evidence which shows that infrasound can cause elevations in blood pressure and heart rate of humans.” She refers to Qibai and Shi, 2007 (see Bibliography).

Dr Laurie continues:

> We suspect that infrasound emissions from the turbines may be involved, or there may be another mechanism which we are unaware of yet....
>
> Again, these impacts have been reported up to 4km away from the nearest turbines, and could well be happening for people who live farther away.

Dr Laurie points out that these results have not yet been published in any peer-reviewed journal. The purpose of the media release is to alert people to the issue, especially if they have noticed that their blood pressure has increased since wind turbines in their vicinity began operating.[lxxi]

It should be noted that Dr Laurie's findings are consistent with an observation made by Dr Robert Thorne. I referred earlier to Dr Thorne's table of correlations between complaints made by neighbours of the Waubra Wind Farm in Victoria and distances from turbines (see section on Thorne above). The table includes the item:

> [Complainants] 11. 3000-4600 metres. *Elevated blood pressure*, heart palpitations, ear pressure and earache, disrupted sleep, increasing frequent headaches, head pressure, vibration in body, mood swings, problems with concentration and memory. Awaken at night, sleep disturbance. [emphasis added][lxxii]

Summary and Conclusions

1. There is peer-reviewed literature linking wind turbines with the possibility of adverse health effects.

2. This is admitted by Health Canada, the Canadian Department for Public Health.

3. The peer-reviewed studies linking wind turbines and the possibility (and actuality) of adverse health effects, mentioned in this submission, are as follows: Keith et al., 2008; Pedersen and Halmstad, 2003; Pedersen and Persson Waye, 2008; Pedersen and Persson Waye, 2007; Pedersen and Persson Waye, 2004; van den Berg et al., 2008; Pierpont, 2009; Phipps, 2007; Thorne et al., 2010; Salt and Hullar, 2010.

4. In addition, other peer-reviewed studies discuss relations between noise and adverse health effects, relations that are relevant to wind turbine noise: WHO, 1999; Michaud et al., 2008; Niemann et al., 2006.

5. Dr Christopher Hanning, an international specialist in sleep disorders medicine, has written a comprehensive review, affirming the potentiality for wind turbine noise to cause sleep disturbance.

6. Dr Carl Phillips, a specialist in epidemiology, has affirmed in sworn testimony before the Public Service Commission of Wisconsin that there is ample scientific evidence to conclude that wind turbines cause serious health problems for some people living nearby.

7. Annoyance and sleep disturbance are both recognised as adverse health effects by the World Health Organization. That wind turbine noise can and does cause annoyance and sleep disturbance is documented in peer-reviewed studies.

8. Reports of adverse health effects are made world-wide: from North America, Britain and Ireland, Europe, Australasia, and Japan.

9. Besides annoyance and sleep disturbance, a cluster of symptoms designated Wind Turbine Syndrome is also reported on an international scale.

10. Credible hypotheses, in peer-reviewed studies by Dr Nina Pierpont and Dr Alec Salt, have been proposed to show how low frequency sound (audible) and infrasound (inaudible) generated by wind turbines, can have adverse health effects, mediated by the balance system of the human body, and especially by the inner ear.

11. A preliminary study has monitored elevated blood pressure levels amongst the neighbours of wind farms in Australia.

12. It must be considered that there is ample evidence to justify a serious concern relating to the adverse health effects of wind turbines, and to justify further research, not to establish these effects, but to define fully their scope.

13. There is ample evidence in the form of peer-reviewed studies, other studies, and the reports of complainants to believe that some neighbours of existing wind farms in Australia *are already being adversely affected in their health* by these wind farms.

14. In view of the above, the rational course of action to pursue is to make a temporary halt to further wind farm development in Australia until independent, third-party research is carried out to investigate thoroughly the adverse health effects of wind turbines, with a view to establishing setback distances adequate to protect residents.

15. The impacts of existing wind farms in Australia should be re-investigated, in the light of recent research into low frequency noise, infrasound, and their adverse health effects, with a view to providing relief to those currently suffering from the impacts of such wind farms.

Since the adverse health effects are mainly due to wind turbine noise (although blade glint and shadow flicker can be contributing factors with badly located wind farms), it is necessary now to give an account of wind turbine noise, and to explain how it can produce adverse health effects. On this subject there is also peer-reviewed literature.

Noise and Noise Guidelines

Wind Turbine Noise in General

Wind turbines produce two kinds of sound: mechanical and aerodynamic. The mechanical sound is produced by the gearbox, generator, and computer controls housed in the nacelle at the top of the tower.[lxxiii] Aerodynamic sound is produced by the movement of the blades through the air. There is general agreement that mechanical noise has been much reduced with modern turbines, and that it is aerodynamic noise that is the main source of the problems of annoyance, sleep disturbance and the other adverse health effects.[lxxiv]

Aerodynamic noise from wind turbines is broadband sound, i.e. it is a spectrum of sounds at different frequencies, ranging from high frequency sound through mid frequency sound and low frequency sound to infrasound.[lxxv] As the spectrum of sound is continuous, there is some variation amongst commentators about where the divisions between high frequency, mid frequency, low frequency, and infrasound ought to be drawn. There is also some variation in terminology between commentators: some use the term ‘low frequency’ to mean infrasound; others distinguish between low frequency and infrasound. In order to avoid ambiguity and confusion, I shall follow the terminology and divisions used by Dr Robert Thorne.

Dr Thorne uses the following classification:

- Infrasound below 20 Hz (Hertz, or cycles per second)
- Low frequencies 20 Hz to 250 Hz
- Mid frequency 250 Hz to 2000 Hz
- High frequency 2000 to 20,000 Hz.[lxxvi]

It is commonly held that infrasound below 20 Hz is inaudible, while sounds above 20 Hz (up to 20,000 Hz) are audible. However, as Dr Thorne points out, even infrasound can be audible to some people with sensitive hearing.[lxxvii]

Aerodynamic noise from wind turbines also has special characteristics. Generally, it can be said to have a pulsing or “impulsive” character. Dr Thorne distinguishes between the smooth sound of wind, and the quite different sound of wind turbine noise:

> The research documented to date for this paper indicates “ordinary” wind has a laminar or smooth infrasound and low-frequency flow pattern when analysed over short periods of time. Wind farm activity appears to create a “pulsing” infrasound and low-frequency pattern.[lxxviii]

When wind conditions are optimal, and the noise is steady, people will describe it as sounding like an airplane passing overhead, but never leaving. In some circumstances, at some locations around a wind farm, a sound can be heard that is commonly described as a “swish-swish-swish”. In other circumstances, the fluctuation appears even noisier, and is commonly described as a "whoosh-whoosh-whoosh", or even a "thump-thump-thump". These fluctuations are what is known as *amplitude modulation*, and we shall consider them below.[lxxix]

But, the sound from wind turbines inevitably changes as wind conditions change. This leads Dr Thorne to sum up:

> Wind farms and wind turbines are a unique source of sound and noise. The noise generation from a wind farm is like no other noise source or set of noise sources. The sounds are often of low amplitude (volume or loudness) and are constantly shifting in character ("waves on beach", "rumble-thump", "plane never landing", etc).[lxxx]

Although wind farm noise is not especially loud, in comparison with other varieties of industrial and transportation noise, it is particularly annoying, as we saw above (and as documented by Pedersen and others).[lxxxi] The source of annoyance, to judge from victims' reports, is undoubtedly the character of the noise. What causes people 'annoyance', or – to express it more accurately – what drives people to anger and depression and increased use of medications, is partly the endless repetition of low-frequency fluctuations (like the bass of a rock band at an all-night party), and partly the continual failure of expectation of the "airplane that is passing but never passes".[lxxxii] In this respect, wind farm noise does appear to be unique, and its uniqueness ought to be taken into account, if local residents are to be protected effectively from it.

Measuring Wind Turbine Sound

Before we proceed to discuss the low frequency sound and amplitude modulation, and other characteristics of wind turbine sound, it is necessary to understand how wind turbine sound ought to be measured, because it is not being measured as it ought to be.

Sound can be measured on various scales according to the frequency of the sound that is to be measured. These scales are also known as weightings, and the scales relevant to the measurement of wind turbine sound are the A-weighting, the C-weighting, the G-weighting, and the Z-weighting. With any of these scales the sound-pressure level (SPL) can be measured in decibels. Thus, with the A-weighting scale the units of measurement are dB(A), or decibels (measured on the A scale). Correspondingly, with the C-weighting scale the units are dB(C). With the G-weighting dB(G). With the Z-weighting dB(Z).

The A scale was developed to imitate the frequency response of human hearing. So it captures and emphasises sound at those frequencies normally used for human hearing, and it filters out sound at lower frequencies that is not used, for example, for human speech. Specifically, it enhances sound between 1000 Hz and 6000 Hz, while below 800 Hz it progressively filters out the sound, until at 100 Hz it captures only 1/1000 of the sound energy present. At 31 Hz it captures only 1/10,000 of the sound present. At 10 Hz it captures only one ten-millionth of the sound energy present.[lxxxiii]

The C scale captures sound equally over most of the audible range, down to 31 Hz. Below 31 Hz it gradually filters out the sound. At 10 Hz it still captures 1/25 of the sound energy present.[lxxxiv]

The G scale emphasises infrasound between 1 Hz and 20 Hz.[lxxxv]

The Z scale gives a flat (or equal) response to sounds between 10 Hz and 20,000 Hz.[lxxxvi]

The relevance of these scales is that all noise guidelines regulating wind farm development, not just in Australia but globally, stipulate only measurements in dB(A). And there is widespread agreement that the A-weighting scale is inadequate for predicting or measuring wind turbine sound, because of the low frequency and infrasound components present in wind turbine sound.[lxxxvii] As we shall see later, some authorities propose using both A-weighing measurements and C-weighting measurements, and noting the difference between them.[lxxxviii] Some propose using the G-weighting scale to measure the infrasound components.[lxxxix] Dr Robert Thorne tends to use the Z-weighting scale.

At present, all this is a delicate issue for the wind energy industry, and their public statements can only be described as disingenuous. For example, the AWEA/CWEA *Expert Panel Review* hints at the inadequacy of A-weighting measurements for wind turbine noise, but cannot bring itself to admit this. In Appendix C 'Measuring Sound' it states:

> With respect to other effects, such as annoyance, A-weighting is acceptable if there is largely middle and high frequency noise present, but if the noise is unusually high at low frequencies, or contains prominent low frequency tones, the A-weighting may not give a valid measure.

At this point it ought to admit candidly that the low frequency components in wind turbine noise are strong enough to cause considerable annoyance, at the very least (setting aside the question of other adverse health effects). As we shall see below, A-weighted measurements underestimate the levels of low frequency noise and infrasound to a very high degree. However, the *Expert Panel Review* cannot admit this, and slides off into irrelevance and evasion. It concludes lamely:

> Compared with other noise sources, wind turbine spectra, as heard indoors at typical separation distances, have less low frequency content than most other sources.[xc]

'Most other sources' are not in question. What matters here is whether low frequency noise from wind turbines is present in sufficient quantity to render A-weighted measurements inadequate. And the answer is: yes, it is.

The Sonus report for the Clean Energy Council is similarly evasive. It goes even further in hinting that the A-weighting scale is inadequate for measuring the low frequency noise from wind turbines. It notes that sounds of different frequencies have different rates of decay, low frequency sound persisting longest:

> Noise reduces over distance due to a range of factors including atmospheric absorption. The mid and high frequencies are subject to a greater rate of atmospheric absorption compared to the low frequencies and therefore over large distances, whilst the absolute

level of noise in all frequencies reduces, the relative level of low frequency noise compared to the mid and high frequency content increases.

It even goes so far as to admit:

> This effect is exacerbated in an environment that includes masking noise in the mid and high frequencies, such as that produced by wind in nearby trees.

The report is now silently screaming at us: "At two kilometres or more, the wind in the trees won't mask the noise. The low frequency noise will be so prominent, you won't be able to avoid hearing it!" The report now collapses into honesty:

> A typical separation distance between wind farms and dwellings is of the order of 1000 m. At similar distances, in an ambient environment where wind in the trees is present, it is possible that only low frequencies remain audible and detectable from a noise source that produces content across the full frequency range [i.e. a wind farm!!!]. This effect will be more prevalent for larger wind farms because the separation distances need to be greater in order to achieve the relevant noise standards. A greater separation distance changes the dominant frequency range from the mid frequencies at locations close to the wind farm to the low frequencies further away, due to the effects described above.

This report, paid for by the Clean Energy Council, a lobby group for the wind energy industry, is telling its readers that large wind turbines will cause problems with low frequency noise, even if the noise guidelines are observed!

But, one can only go so far, if one's professional services are being hired. The report now retreats into disingenuousness. Pointing us towards the necessity for C-weighting, it lapses into silence at the last moment:

> The low frequency content of noise from a wind farm is easily measured and can also be heard and compared against other noise sources in the environment. Low frequency sound produced by wind farms is not unique in overall level or content and it can be easily measured and heard at a range of locations well in excess of that in the vicinity of a wind farm. The C-weighting network (dB(C)) has been developed to determine the human perception and annoyance due to noise that lies within the low frequency range.[xci]

This is disingenuous. Yes, the low frequency noise from wind turbines can be measured by C-weighting. But the report does not point out the obvious fact that wind farm developers never measure it on the C scale, that no noise guidelines anywhere in the world require it to be measured on the C scale, and that the wind energy industry has lobbied in North America not to be required to take measurements on the C scale. [xcii]

The Sonus report is similarly disingenuous with infrasound. It notes that the "G-weighting has been standardised to determine the human perception and annoyance due to noise that lies within the infrasound frequency range (ISO 7196, 1995)." But it fails to point out that noise guidelines globally do not require the wind energy industry to measure in dB(G), and that as a matter of fact it does not.[xciii]

At this point we may refer again to the World Health Organization's *Guidelines for Community Noise* (1999). WHO is clear about the inadequacy of A-weighting measurements, when low frequency noise is to be measured:

> When prominent low-frequency components are present, measures based on A-weighting are inappropriate. However, the difference between dBC (or dBlin) and dBA will give *crude information* about the presence of low-frequency components in noise. If the difference is more than 10 dB, it is recommended that a frequency analysis of the noise be performed. [emphasis added][xciv]

Notice that even comparing A-weighted measurements and C-weighted measurements only provides "crude information" about the presence of low frequency noise in the noise mix. And WHO recommends that if the difference between the A-weighted measurement and the C-weighted measurement is more than 10 dB, then a full frequency analysis should be undertaken, in order to make an accurate estimate of the low frequency noise really present. Later in this submission we shall see that the difference between dB(A) and dB(C) measurements for wind turbine noise is commonly around 20 dB. We shall also see that in the case of infrasound A-weighting can produce an enormous de-emphasis of 140 dB! [dB(lin) was a flat response weighting that was superseded by dB(Z) in 2003.][xcv]

Low Frequency Noise

The Sonus report for the Clean Energy Council, quoted above, testifies to the fact that as the distance from turbines increases, the low frequency components in the wind turbine noise begin to predominate over the mid and high frequencies, the explanation for this being that low frequency sound is attenuated at a slower rate than mid frequency sound, and high frequency sound. And, as the report also testifies, the effect is increased in a rural environment, because the wind in the trees will tend to mask the mid and high frequency sound, but not the low frequency sound.[xcvi] To put it simply, at a residence 2 km away from turbines the low frequency components within the overall turbine noise will be more noticeable than at a residence 1 km away, even though the overall volume of sound at 2 km is less than at 1 km. This explains the well known fact that wind turbine noise can be less disturbing if one stands under the turbines than if one is living several hundred kilometres away.

Low frequency sound is not only less attenuated by distance, but is less likely to be kept out by the walls of a house. One only has to think of the experience of listening to the music coming from an all-night party, as one tries in vain to fall asleep: one cannot hear the melody of the music, but one can certainly hear the bass. An article in the *Journal of Low Frequency Noise, Vibration and Active Control* states:

> Unlike higher frequency noise issues, LFN [low frequency noise] is very difficult to suppress. Closing doors and windows in an attempt to diminish the effects sometimes

> makes it worse because of the propagation characteristics and low-pass filtering effect of structures. Individuals often become irrational and anxious as attempts to control LFN fail, serving only to increase the individual's awareness of the noise, accelerating the above symptoms.[xcvii]

Dr Robyn Phipps adds some further characteristics of low frequency noise (drawing on Casella 2001):

> [I]nside 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.
>
> [O]lder people's hearing is proportionally more acute at low frequencies than other mid or high frequencies ....
>
> [L]ow frequency noise can cause lightweight elements of a building structure to vibrate, such as a vibrating or rattling window.[xcviii]

Because the low frequency components of wind turbine noise predominate with distance, and because low frequency noise tends to produce all these undesirable effects (quite apart from the annoyance of amplitude modulation – see below) it becomes of vital importance that the real magnitude of the low frequency noise should be accurately estimated.

Dr Phipps presents a set of graphs depicting the noise output of a V52 turbine. One graph depicts the unweighted sound levels. A second graph overlays the A-weighted levels onto the unweighted levels. A third graph strikingly shows the volume of sound that the A-weighted measurements do not register. At around 300 Hz (mid frequency) the A-weighted measurement and the unweighted measurement are the same, about 47 dB. But below 300 Hz the two measurements diverge. At 100 Hz (low frequency) the A-weighting gives about 37 dB(A), but the unweighted measurement gives about 58 dB. At 40 Hz (low frequency) the A-weighting gives about 24 dB(A), but the unweighted measurement gives 70 dB.[xcix]

At 100 Hz the difference is 58 – 37 = 21 dB. At 40 Hz the difference is 70 – 24 = 46 dB. At this point it should be remembered that a difference of 10 dB is perceived by human beings as twice as loud. So, a difference of 20 dB is perceived as four times as loud. A difference of 40 dB is perceived as 16 times as loud. A difference of 50 dB is perceived as 32 times as loud.[c] Therefore, the real low frequency noise produced by the V52 turbine at 100 Hz is four times as loud as the A-weighting scale says it is. And the real low frequency noise produced by the turbine at 40 Hz is about 24 times as loud as the A-weighting scale says it is. Clearly, using the A-weighting scale to measure wind turbine noise is wildly inappropriate. The fact that it is used globally can only be due to the unjustifiable influence of the wind farm lobby with government.

Dr Robert Thorne has taken measurements in dB(Z) at residences around the Waubra Wind Farm in Victoria. The Z-weighting scale (in fact, unweighted) gives a flat response to sound of all frequencies between 10 Hz and 20,000 Hz.[ci]

One of Dr Thorne's graphs (p. 20) shows the sound character *inside* a residence with some of the nearest visible turbines (500 to 1500 m distant) slowly moving. The measurements were taken at 2.32 pm. At 25 Hz the maximum sound level is about 62 dB(Z), and the minimum about 27 dB(Z). At 100 Hz the maximum sound level is about 41 dB(Z), and the minimum about 16 dB(Z). At 200 Hz the maximum sound level is still 44 dB(Z), while the minimum is 13 dB(Z).[cii] These are sound levels that would inevitably keep anyone awake.

It is also worth remarking on the varying level of the sound. As commentators have observed, average sound levels can be very misleading. The human ear does not average.[ciii]

Dr Thorne has another graph (p. 15) for a house about 2000 metres from the turbines. This graph depicts sound levels within one of the bedrooms of the house. The graph depicts measurements taken at 7.40 pm. At 25 Hz maximum is about 44 dB(Z), minimum about 25 dB(Z). At 40 Hz maximum is about 40 dB(Z), minimum about 21 dB(Z). At 125 Hz maximum is about 22 dB(Z), minimum about 11 dB(Z). It is striking that the average level of noise across all frequencies is only 32.5 dB. But if the low frequency components of the noise predominate, the residents will hear sound levels in the mid 40s dB, not 32.5 dB.[civ]

Dr Thorne points out that it is next to impossible to separate out background noise from the noise of the turbines. Unless one can turn the turbines off, measure the background sound level, turn the turbines back on, and re-measure, all one has to measure is a single quantity of sound. However, he insists: "it is easy for people to hear wind farm noise within 'ordinary' ambient sound."[cv]

We can conclude that low frequency noise from wind turbines is higher, sometimes much higher, than the standard dB(A) measurements suggest; that in rural situations it is likely to predominate in what residents actually hear; that it can resonate rooms and rattle windows; that it is especially audible to older people; and that it is particularly annoying, because no attempts to keep it out are likely to succeed.

Audible low frequency noise is known to be associated with adverse health effects. An article called *Effects of low frequency noise up to 100 Hz* by M Schust in the online journal *Noise & Health* (2004) is a comprehensive review of the medical literature up to 2004. Schust writes:

> LFN [low frequency noise] can cause a lot of non-specific physiological reactions, subjective complaints and an impairment of the performance.[cvi]

Like Pierpont and Salt, Schust propounds and discusses hypothetical explanations for the recorded symptoms:

> Hypothetically, effects of LFN may be mediated through different ways: (1) vibration of the eardrum, leading to a hearing sensation through pressure changes in the cochlear endolymph, activation of the hair cells and the acoustic nerve, (2) direct energetic transmission of the airborne acoustical sound wave into the cochlear endolymph or into the acoustic nerve .. (3) excitation of the vestibular system, (4) excitation of receptors

> and/or nerve fibres in the skin or in any other kind of tissue or blood vessels within the organism.[cvii]

It will be noticed that hypotheses (1) and (2) above overlap with Salt's hypothesis concerning the effect of wind turbine infrasound, while hypotheses (3) and (4) above overlap with Pierpont's hypothesis concerning the effect of low frequency wind turbine sound.[cviii]

In 2003 Dr Geoff Leventhall, the enthusiast for psychotherapy, was acting as consultant to the UK Department for Environment, Food and Rural Affairs [Defra]. He was the principal author of *A Review of Published Research on Low Frequency Noise and its Effects*, published by Defra. Dr Leventhall writes:

> Low frequency noise causes extreme distress to a number of people who are sensitive to its effects. Such sensitivity may be a result of heightened sensory response within the whole or part of the auditory range or may be acquired. The noise levels are often low, occurring in the region of the hearing threshold, where there are considerable individual differences. There is still much to be done to gain a fuller understanding of low level, low frequency noise, its effects, assessment and management.[cix]

Dr Leventhall refers to

> ... the very real low frequency noise difficulties faced in a number of environmental noise problems, where low frequency noise occurs at low levels, often in the region of an individual's hearing threshold. The noise, typically classed as "not a Statutory Nuisance", causes immense suffering to those who are unfortunate to be sensitive to low frequency noise and who plead for recognition of their circumstances.[cx]

The response of Dr Leventhall and the British government to this immense suffering is, it seems, psychotherapy.

Low frequency noise can be disregarded by the British government (and other governments) as "not a Statutory Nuisance", because, as Punch et al (2010) point out, infrasound and low frequency noise are still not recognised as disease agents. They state:

> Because ILFN [infrasound and low frequency noise] is not yet recognized as a disease agent, it is not covered by legislation, permissible exposure levels have not yet been established, and dose-response relationships are unknown (Alves-Pereira, 2007).[cxi]

It is surely reasonable to suspect that governments around the world are deliberately avoiding recognizing ILFN as a disease agent so as not to deter investment in industrial plant which produces low frequency noise, including, and perhaps especially, wind farms. Why put billions of dollars of investment at risk, when one can provide psychotherapy sessions instead?

At this point it is worth returning to Dr Nina Pierpont's hypothesis concerning the physiological mechanisms mediating Wind Turbine Syndrome. The specific low frequency of 100 Hz plays a key role in Dr Pierpont's hypothesis. 100 Hz is the frequency at which some part of the vestibular system is “tuned” to stimulus by low frequency sound, transmitted through the bone. She writes (referring to Todd et al., 2009):

> Studies of both the VEMP [vestibular evoked myogenic potential] and – a second measure of vestibular function – the ocular vestibular evoked myogenic potential (OVEMP) show that the tuning (best frequency response) for both VEMP and OVEMP for air-conducted sound lies between 400 and 800 Hz. Whereas with bone-conducted sound (vibration), the best frequency response for both VEMP and OVEMP is at 100 Hz.[cxii]

She continues (referring to Todd et al., 2008):

> Most exciting, Todd et al. provide direct experimental evidence that at the 100 Hz tuning peak, the vestibular organs (probably utricle, as above) of normal humans are *much more sensitive than the cochlea* to low frequency bone-conducted sound/vibration. [emphasis in original][cxiii]

She concludes:

> Thus, the potential exists, in normal humans, for stimulation of balance signals from the inner ear by low frequency noise and vibration, even when the noise or vibration does not seem especially loud, or even cannot be heard. In the presence of pre-existing inner-ear pathology, thresholds for vestibular stimulation by noise or vibration are even lower than in normal subjects [referring to Colebatch et al 1998].[cxiv]

In another place Dr Pierpont notes that while in humans the detection of low frequency sound by the otolith organs of the vestibular system is only known to occur by bone conduction, the latest research shows that in mice low frequency sound that is *air-borne* is detected by the otolith organs [referring to Jones et al, 2010].[cxv] This is an area of ongoing research. However, it is perhaps relevant here to quote from a study by the chief author of WHO’s *Guidelines for Community Noise*, Birgitta Berglund. In an article from 1996 Dr Berglund states:

> Low frequency noise (infrasound included) is the superpower of the frequency range: it is attenuated less by walls and other structures; it can rattle walls and objects; it masks higher frequencies more than it is masked by them; it crosses great distances with little energy loss due to atmospheric and ground attenuation; ear protection devices are much less effective against it; *it is able to produce resonance in the human body*; and it causes greater subjective reaction (in the laboratory and in the community studies) and to some extent physiological reactions in humans than mid- and high frequencies. [emphasis added][cxvi]

Whether airborne or bone-conducted, it seems to be possible that, one way or another, low frequency noise may be impacting on the vestibular systems of the neighbours of wind farms. There is surely sufficient evidence for serious concern, and for the urgent need for more research to be recognized.

Infrasound

Infrasound is sound below the frequency of 20 Hz. Infrasound is generally inaudible, but, as commentators point out, some especially sensitive persons may be able to hear it. According to the Sonus report for the Clean Energy Council, the threshold of audibility for infrasound is commonly taken to be 85 dB(G). In other words, the sound level of infrasound has to reach 85 dB(G) before it can be heard, by most people.[cxvii]

Like low frequency sound, infrasound is less attenuated by distance, can penetrate the walls of buildings, can rattle windows and doors, can defy the power of ear protection devices, can induce resonance in the human body, etc, etc. [see Berglund above]

Like low frequency sound, it is likely to become prominent in any noise mix, as distance from noise source increases, because it is less attenuated by distance, and because it can penetrate the walls of buildings.

The wind energy industry claims that infrasound cannot be a problem, because it is inaudible. But, as we saw in our section on Adverse Health Impacts above, Dr Alec Salt of the Cochlear Fluids Research Laboratory at Washington University, St Louis, authoritatively refutes this. Infrasound can affect the human body, even though it is not heard.[cxviii]

The A-weighing scale is wildly inaccurate in the measurement of infrasound. In his conference paper *Infrasound: your ears "hear" it but they don't tell your brain*, presented to the First International Symposium on the Global Wind Industry and Adverse Health Effects (Picton, Ontario, 29-31 October, 2010), Dr Salt presents a graph for Wind Turbine Noise Spectra, on which is depicted a wind turbine noise spectrum taken from van den Berg (2006), and the equivalent spectrum measured on the A-weighting scale. What the graph shows is that the A-weighting scale de-emphasises the infrasound components by 140 dB.[cxix] A difference of 10 dB is heard by human beings as twice as loud, a difference of 20 dB as four times as loud, etc. This means that in this case of a discrepancy of 140 dB, the real magnitude of sound energy present is 16,384 times as big as what the A-weighting scale says is present! Clearly, to attempt to measure infrasound by the A-weighting scale is insane.

I referred earlier to two graphs of wind turbine noise at residences around the Waubra Wind Farm in Victoria, presented by Dr Robert Thorne. On the first of those graphs (inside the residence, 500 to 1500 metres from turbines), the following levels for infrasound are recorded: at 10 Hz a maximum of about 73 dB(Z) and a minimum of about 24 dB(Z); at 20 Hz a maximum of about 64 dB(Z) and a minimum of 24 dB(Z).[cxx]

On the second graph (inside a bedroom, 2000 metres from turbines) the following levels for infrasound are recorded: at 10 Hz a maximum of 55 dB(Z) and a minimum of 29 dB(Z); at 20 Hz a maximum of 56 dB(Z) and a minimum of 37 dB(Z).[cxxi]

The wind energy industry and government would dismiss readings such as these because they fall below the threshold of audibility. The Sonus report points out that the Queensland

Department of Environment's draft *Guideline for the Assessment of Low Frequency Noise* sets 85 dB(G) as the "acceptable level of infrasound in the environment to protect against the potential onset of annoyance". It also points out that this is consistent with the approach of DEFRA in the UK, as advised by, inevitably, Leventhall (2003).[cxxii] However, the recent work of Salt and his colleagues suggests that this approach is quite misguided. Salt insists that it is not true that a sound cannot affect one if it is inaudible. As I mentioned earlier, he invokes the analogy of ultra-violet light. (He also invokes taste, and asks, "Can you taste salmonella?")[cxxiii]

In his conference paper Salt points out that the Outer Hair Cells of the Cochlea are stimulated at 60 dB(G), well below the audibility threshold for infrasound. He also presents a table of wind turbines and the level of noise that they generate at various distances, from 100 metres out to 2100 metres. In 17 of the 18 cases in his table the infrasound level is 60 dB(G) or above, in most cases well above.[cxxiv] This clearly leaves open the possibility that the Outer Hair Cells may be overstimulated, and overworked by the infrasound coming from turbines, even though no one can hear it. The sound pressure in the physical environment, and in the human body is what it is, regardless of whether it can be heard.

That infrasound can have adverse health effects has already been indicated in a case reported by Pierpont. In Germany in 1996 a couple began to experience symptoms similar to those of Wind Turbine Syndrome. Eventually, this was connected to infrasound. Pierpont states:

> In time, the symptoms were correlated with intensity of noise below 10 Hz. The couple's symptoms and the intensity of noise below 10 Hz both varied with the wind and weather, and were worse in winter. ...Symptoms occurred when the sound pressure level at 1 Hz was 65 dB, well below hearing threshold. None of the frequencies responsible for the symptoms, all below 10 Hz, had sound pressure levels above 80 dB...The authors [Feldmann and Pitten, 2004] hypothesized that infrasound, with its very long wavelengths (10 Hz, for example, has a 34 m wavelength in air) causes strong pressure fluctuations in relatively small closed rooms – pressure fluctuations that are detected more by the whole body and its inner organs than by the ears.[cxxv]

Salt (reporting Alves-Pereira and Castelo Branco, 2007) tells us that the idea that inaudible sound cannot affect the human body is not based on any medical or scientific research whatever, but was put forward in a newspaper article in 2001 by a sound engineer (Campanella)![cxxvi] So, it is in fact an urban myth.

As with low frequency noise, we must conclude that there are grounds for serious concern, and that the need for further research is urgent. We must also conclude that the current approach of government is misguided and incautious.

Amplitude Modulation

Amplitude modulation is also known as aerodynamic modulation, and as the modulation of aerodynamic noise. Amplitude is the pressure level of the sound energy present, and when the sound of the aerodynamic noise (the noise of the blades moving through the air) is audible, a higher sound pressure level means a louder noise. So, basically, as far as audible sound is concerned, amplitude means volume or loudness. Consequently, amplitude modulation is simply a fluctuation in the loudness of the sound generated by the turbines (but also a fluctuation in the sound pressure level of the inaudible sound, as well).[cxxvii] So, there is a tendency for wind turbines to get louder and softer, louder and softer, louder and softer ... As I have already mentioned, these fluctuations are commonly described by the neighbours of wind farms as "swish-swish-swish", or "whoosh-whoosh-whoosh", and when it is at its worst, as "thump-thump-thump".[cxxviii]

Thorne says of one example of amplitude modulation that he has recorded: "The sound ... can be described as a steady rumble with a mixture of rumble-thumps."[cxxix] He presents a graph of this modulation. It is striking that the modulation between maximum sound level and minimum sound level has a peak at the audible low frequency of 125 Hz. At 125 Hz the maximum level is 55 dB(Z), while the minimum level is about 27 dB(Z).[cxxx] This is a fluctuation of 28 dB. This means that the louder end of this fluctuation would be heard as almost 8 times as loud as the softer end. This is sound that was heard within the residence. At 125 Hz it is low frequency sound that can penetrate walls, defy ear protection devices, etc, etc,, and is bound to be very annoying – to put it mildly.

The same graph shows fluctuations in the infrasound part of the spectrum. At 6.3 Hz the maximum level is 65 dB(Z), while the minimum level is 40 dB(Z)[cxxxi] – a fluctuation of 25 dB, a difference of sound pressure of 6 times. At this point we might hazard an amateur medical opinion. Dr Salt tells us that the Outer Hair Cells of the cochlea are set off at about 60 dB.[cxxxii] But, since this infrasound is fluctuating between 65 dB and 40 dB every second or so, presumably the poor Outer Hair Cells are being turned on, turned off, turned on, turned off, turned on ...

Punch et al, 2010 refer to studies that affirm that amplitude-modulated sound is more annoying than constant sound:

> Studies carried out in Denmark, The Netherlands, and Germany (Wolsink and Sprengers, 1993; Wolsink et al, 1993), a Danish study (Pedersen and Nielsen, 1994), and two Swedish studies (Pedersen and Persson Waye, 2004, 2007) collectively indicate that wind turbines differ from other sources of community noise in several respects. These investigators confirm the findings of earlier research that *amplitude-modulated sound is more easily perceived and more annoying than constant-level sounds* (Bradley, 1994; Bengtsson, et al, 2004) and that *sounds that are unpredictable and uncontrollable are more annoying than other sounds* (Geen and McCown, 1984; Hatfield et al, 2002). [emphasis added][cxxxiii]

Some remarks by John Powell, physics professor and composer, in his recent book *How Music Works* seem to be relevant. Powell is referring to the different responses of the human brain to continuous and changing sounds:

> ...if a note is played for several tens of seconds, then its loudness will appear to decrease as the brain begins to stop noticing it so much. This effect, of diminishing intensity for a

> continuous stimulus, also happens with our other senses, particularly our sense of smell ... The reason why the sound appears to diminish after a while is that your brain is constantly monitoring your senses for danger signals. If a sound is continuous, and nothing bad is happening, your brain loses interest because the noise is obviously not important to your well-being. *Your brain is primarily interested in any sudden changes in the sounds you are hearing,* which is why you sit up and take notice if a long-lasting sound suddenly stops – the 'deafening silence' effect. [emphasis added][cxxxiv]

Powell seems to have provided the explanation for the fact that pulsing low frequency noise is especially annoying, and why some victims of wind farm noise assert that they can't stop listening to it, that it gets inside them, etc (see the section above, The Victims Speak). This also explains why victims insist that one cannot get used to the noise.

Whatever the truth of this may be, we should note Dr Thorne's observation that both the low frequency sound of wind turbines and the infrasound are subject to amplitude modulation: "Wind farm activity appears to create a 'pulsing' infrasound and low frequency pattern."[cxxxv] It seems reasonable to surmise that just as this modulation is obviously related to the conscious annoyance that victims feel, so it may be the key to the other, involuntary adverse health effects to which victims are subjected. This is a subject that demands research.

Some relevant research has been done on other sources of modulated sound. Punch et al (2010) provide another useful reference:

> Waye et al (1997) found that exposure to dynamically modulated low frequency ventilation noise (20-200 Hz) – as opposed to midfrequency noise exposure – was more bothersome, less pleasant, impacted work performance more negatively, and led to lower social orientation.[cxxxvi]

In view of the seriousness of amplitude modulation it is unfortunate, to say the least, that the explanation for its occurrence has not been finally determined. It used to be thought that it arises as a result of an interaction between the blades and the tower, but it appears that this explanation has been superseded.[cxxxvii] Various theories have been put forward, and they are reviewed by Dick Bowdler, a British acoustician, in *Amplitude Modulation of Wind Turbine Noise: A Review of the Evidence*, published in *Acoustics Bulletin* in 2008. As a result of his review Bowdler propounds the hypothesis that there are in fact two kinds of amplitude modulation, which require to be distinguished from each other. One of these, the less severe kind, is commonly described as "swish-swish-swish". The other kind, arising from different causes, is the more severe kind, the one commonly described as "beat-beat-beat" or "thump-thump-thump". Following Oerlemans (2005, 2007), Bowdler explains "swish" as occurring when the turbine blade passes the horizontal position in a downward direction. "Thump", on the other hand, seems to be due to the blades passing through air turbulence. Following van den Berg (2004 a & b), Bowdler notes that this air turbulence, a mixture of varying speeds and directions, can itself be due to a variety of causes: wind shear, meteorological turbulence, turbulence created by topography, or turbulence created by the location of multiple turbines relative to one another.[cxxxviii] We shall return to this phenomenon below.

Bowdler's article was published in 2008. In it he refers to earlier studies which suggest that amplitude modulation occurs most prominently in a range of frequencies between 500 Hz and 2000 Hz. If this were true, then we should have to conclude that it is mainly a problem at mid frequencies, and not at low frequencies or in the infrasonic range. However, as we have seen above, Thorne has recorded amplitude modulation in both the low frequency and infrasonic range. This is an instance of new research extending our understanding year by year, and it should provide a warning that there are aspects of wind turbine impacts that are still imperfectly understood. This is also true of the medical research bearing on wind turbine impacts, as Salt's work demonstrates.

Bowdler points out that "swish" will be heard at some locations and not others around a wind farm, since the perception of it depends on wind direction. If one's house happens to be in the wrong spot, one will hear it, even though at another house, some distance away, it will not be heard.[cxxxix]

Similarly, Thorne proposes the notion of a Heightened Noise Zone in relation to the phenomena associated with multiple turbines. Wake effects travel downwind from a cluster of turbines, whose vortices interact and become enhanced, and impact upon one residence in their path, while having no impact on another residence that may be only metres away.[cxl]

Although "swish" is a mid frequency sound, it can still cause sleep disturbance. Bowdler quotes British testimony to this effect. The complainant described the sound as a "swish", and explicitly stated that it was not a thump.[cxli]

In other testimony cited by Bowdler the complainants describe "swish" and "thump" as distinct sounds. They state that thumping is normally accompanied by swishing, but swishing is not usually accompanied by thumping. [Presumably, this odd way of putting it means that thumping and swishing can occur together, but swishing, unlike thumping, can occur by itself.][cxlii]

Bowdler concludes that future research might help to reduce thump, but that swish seems to essential to wind turbine technology.[cxliii] However, both require far more care in the planning and siting of wind farms than is currently being exercised by planning authorities.

[Dick Bowdler was a member of the Noise Working Group advising the British government. In 2007 he resigned from the Noise Working Group in protest at the inadequacy of a report, commissioned by the government, into amplitude modulation. The report had recommended, and the government had accepted that no further research into amplitude modulation was needed. A subsequent Freedom of Information request exposed the gross methodological flaws of the report. See Hanning, 2010, pp. 27-29]

Enhancement of Wind Turbine Noise

There is a considerable discrepancy between manufacturers' accounts of wind turbines' capacity to generate noise, and the actuality of the noise experienced by neighbours of wind farms. The Acoustic Ecology Institute's report *Wind Energy Noise Impacts* states: "...most modern industrial wind turbines are designed to keep noise levels at or below 45 dB at 350 metres, which should drop to 35 – 40 dB at 1000 metres."[cxliv] As we have seen from the investigations of Thorne, such figures can bear no relation to reality. There is general agreement amongst independent commentators that the pre-construction predictions of the noise impacts from wind turbines, using computer modelling, are likely to be inaccurate, seriously underestimating the volume of the noise actually generated, once the turbines are built.[cxlv] The computer modelling only takes account of the sound power level of the turbine, and the distance from turbine to receptor. But the actual noise 'immitted' (or received) at the receptor also depends on several other factors: the location of multiple turbines in a cluster, the terrain in which the wind turbines and neighbouring residences are located, atmospheric conditions, and amplitude modulation.[cxlvi]

Thorne sums up:

> Wind farm noise level predictions can therefore be considered as only approximations of sound levels and can not be given any weight other than this. The reasons are due to the highly complex nature of the sound created by each individual turbine and the cumulative effects of a number of turbines. Unfortunately noise predictions are often taken as being 100% true by naive approving authorities. This sense is often bolstered by consultants claiming their predictions are 'conservative' when in fact they are nothing of the kind. A conservative set of predictions includes all assumptions and uncertainties for different times of day/night, different weather/wind conditions, and the cumulative influence of the whole wind farm.[cxlvii]

When turbines are grouped together, it is possible in some circumstances for them to operate in phase with one another. This is known as synchronicity. Thorne states that a variation of 6 to 7 dB(A) from the predicted noise values can occur, even in the absence of any adverse wind or weather conditions, as a result of two or more turbines operating in phase, and with a light breeze blowing towards the residence. [10 dB, it will be remembered, is perceived as twice as loud.][cxlviii]

As we have seen, Thorne discusses the creation of Heightened Noise Zones. Such a zone can exist at one residence, and not at another not far away, because of the precise direction of the wind. The wakes from several turbines interact, creating turbulence and enhancing the noise.

With terrain, two different conditions, both of which tend to enhance noise at a distance, can be distinguished. The Acoustic Ecology Institute writes of the first kind:

> Sloping landforms can create unusual sound propagation conditions, especially in consort with atmospheric fluctuations. Near Vancouver airport, hills rising from a flat plain caused sound levels to be 20 dB higher at 5500m than at 4000m, because of the way the increasing ground angles caused sounds to combine, more than nullifying what, in a standard model, would be expected to be a 3 dB decrease over that distance.[cxlix]

The other kind of enhancement of noise by terrain occurs when the noise source, as for example a wind farm, is located on a ridge, while residences are located in the flat land or valley beneath the ridge. In this situation the wind speed on the ridge will be considerably greater than that on the ground below, so that there is no masking effect of the turbine noise by the wind. This effect has been reported at the Mars Hill Wind Farm in Maine, USA.[cl] Thorne notes that this condition is found both at the Waubra Wind Farm in Victoria, and at the West Wind Wind Farm in New Zealand.[cli] It is reasonable to expect that this condition will be found at the sites of most, if not all wind farms, existing and proposed, in Australia. Certainly, in NSW, where wind farms are planned up and down the length of the Great Dividing Range, it is likely to be the case. Where settlement has taken place, houses are likely to have been built in the lee of ridges, precisely so that the ridge can protect the house from the wind. So, the very protection from the wind that the ridge provides will leave the residences open to assault by the turbines.

Wind turbine noise is also enhanced by atmospheric conditions, principally by what is called a stable atmosphere. The AEI report explains the phenomenon as follows:

> In the daytime, warming air rises, both carrying sound aloft and creating turbulence that scatters turbine noise, as well as creating more ground-based ambient noise that masks turbine sounds. At night, however, when the air stabilizes it appears that noise from wind turbines can carry much farther than expected. This effect can occur with light winds at turbine height and the ground, or, with light winds at turbine height and very little or no wind at ground level.
>
> **With light and steady breezes capable of spinning the turbines, but not stirring up much ambient noise, sound levels measured at homes a half mile to nearly two miles away are often 5-15 dB higher than models would suggest**. Making matters worse, this same atmospheric stability tends to allow multiple turbines to settle into a synchronous rhythm (in more turbulent conditions, small differences in wind between the turbines keeps them out of synch). In this case, the "whish" of the blades as they pass the tower often turns into a more annoying rhythmic "thump"; in quantitative terms, the change in sound level creating the whish or thump can rise from 2 dB to 5 dB or as high as 9 dB, making a clearly audible rhythmic pattern. These rhythmic pulses are likely the strongest factor in annoyance. [bold in original][clii]

The figures 5-15 dB come from G P van den Berg's study *The Sounds of High Winds: The Effect of Atmospheric Stability on Wind Turbine Sound and Microphone Noise* (2006).[cliii] This is in fact van den Berg's PhD thesis. It is widely regarded as the definitive treatment of its topic. As a result, this phenomenon of noise enhancement in stable atmosphere is known as the van den Berg Effect. The Effect has been measured for homes half a mile to two miles from turbines, that is to say, at distances of 800 metres to 3.2 kilometres. This is consistent with the observations of Thorne, and of Bakker that wind turbine noise can disturb the sleep of residents up to 3 kilometres from turbines (and possibly further).[cliv]

The figures given for the fluctuation of sound level in amplitude modulation – 2 dB or 5 dB or 9 dB – are considerably lower than what has been recorded by Thorne. We saw above that Thorne has recorded a modulation at 125 Hz (low frequency noise) of 28 dB (a fluctuation of loudness of almost 8 times).

The more severe kind of amplitude modulation – "thump-thump-thump" – is probably due to the blades of the turbine passing through turbulence, consisting in different wind directions and velocities, as we saw earlier. It should be noted here that atmospheric conditions can contribute to this. When the air is at different temperatures at different heights from the base of the turbine to the point of its furthest upward extension, the wind can blow at different speeds at different heights. The blades of the turbine cannot cope with the need for continual readjustment, and the result is the beating or thumping noise. This phenomenon is known as wind shear.[clv]

We should also note again that the low frequency components of wind turbine noise can become prominent in what neighbours actually hear, because low frequency noise is less attenuated with distance, is not masked by the wind in the trees, and can penetrate the walls of houses.

We should also note again that wind farm noise fluctuates very considerably, so that any figures for average noise (e.g. 35 dB(A)) are likely to be very misleading about what noise levels neighbours will actually hear. The human ear does not average.

For all these reasons the assertions of the wind energy industry and of government planners concerning noise levels should be regarded very sceptically.

The Inadequacy of Noise Guidelines

It must be stated as clearly and emphatically as possible that *the noise guidelines for wind farms in use in Australia are completely inadequate, and offer no protection whatever to the neighbours of wind farms.* This is not an exaggeration. The simple explanation is that the noise guidelines require only noise measurements on the A-weighted scale, in dB(A). As we have seen, the A-weighted scale is *hopelessly* inadequate for measuring low frequency noise and infrasound.

As we have seen, the low frequency components of wind turbine noise tend to predominate with distance, owing to the lower rate of attenuation with distance than that of mid and high frequency noise. Low frequency noise is not masked by the noise of the wind in trees, as mid and high frequency noise is. Low frequency noise can penetrate the walls of buildings, and ear protection devices. Low frequency noise can set up resonances within rooms. Low frequency noise can resonate the organs of the human body. Low frequency noise can rattle windows and doors. For all these reasons, low frequency noise is more annoying than mid and high frequency noise – a fact documented by scientific studies, as well as the complaints of victims.

Infrasound also is less attenuated with distance. It can also penetrate the walls of buildings, and ear protection devices. It can also set up resonances within rooms. It can also resonate the organs of the human body. It can also rattle windows and doors. It has only been discounted by the wind energy industry and planning authorities because of the false belief that inaudible sound cannot affect the human body – a false belief now authoritatively refuted.

The South Australian Noise Guidelines, in use in SA and NSW, deny that infrasound is a problem:

> Infrasound was a characteristic of some wind turbine models that has been attributed to early designs in which turbine blades were downwind of the main tower. The effect was generated as the blades cut through the turbulence generated around the downwind side of the tower.
> Modern designs generally have the blades upwind of the tower. Wind conditions around the blades and improved blade design minimise the generation of the effect. The EPA has consulted the working group and completed an extensive literature search but is not aware of infrasound being present at any modern wind farm site.[clvi]

If Dr Robert Thorne's investigations of the Waubra Wind Farm in Victoria are valid, then the above assertions cannot be correct, and show a misunderstanding of the nature of wind turbine noise. According to Thorne, wind turbine noise includes both low frequency and infrasound components, simply because ordinary wind does. The presence or absence of infrasound has nothing to do with wind turbine design. As we have seen, Dr Thorne has measured high infrasound levels at residences around the Waubra Wind Farm. [It sounds suspiciously as if the SA Guidelines are confusing infrasound with amplitude modulation.[clvii]]

In this situation it is insane that wind farm developers are only required to predict and measure wind farm noise in dB(A).

The other important issues that the noise guidelines do not consider adequately are the fluctuating nature of noise levels in wind turbine noise, and amplitude modulation.

When the South Australian Noise Guidelines set a noise limit for wind turbine noise of 35 dB(A), or background noise + 5 dB(A); or when the New Zealand Standard NZS 6808: 1998, in use in Victoria, sets a noise limit of 40 dB(A) or background noise + 5 dB(A); it is important to realise that these are *average* levels.[clviii] As I have stated repeatedly, the human ear does not average. It hears whatever audible noise level is present. As we have seen, Thorne has taken readings where the average level across all frequencies inside a residence was 32.5 dB(Z), but the maximum low frequency levels were in the mid 40s dB(Z). Those living in that residence are going to hear the levels in the mid 40s. They won't be inaudible, because the noise consultant for the developer has averaged them away, with the consent of the Victorian government.

A further problem is that even the average level of wind turbine noise can vary from day to day, making it impossible to determine whether the wind farm is complying with the noise limit or not. Thorne presents a table depicting average noise levels for daytime, evening and night-time, over a period of eleven days. The average levels fluctuate continually between 25dB and 40 dB. Thorne comments:

> The levels, at approximately 2000 metres from the turbines, show the impossibility of determining when or if the wind farm is exceeding a background level of 35 dB(A) or 40 dB(A). It can be inferred that for some of the time the wind farm is in compliance but at other times it might not [be].[clix]

With amplitude modulation, as we have already seen, the sound level between maximum and minimum levels can vary enormously. As we saw above, the commonly accepted view is that the fluctuation can be of the order of 2 dB or 5 dB or 9 dB. But Thorne has recorded a fluctuation of 28 dB.

The South Australian Guidelines claim to have taken amplitude modulation into account in setting its noise limit of 35 dB(A) or background + 5 dB(A).[clx] But such an average level is useless to protect people from fluctuations whose maximum level may be in the 40s or 50s dB. The maximum level will still be heard, especially in the low frequency range. (And the infrasound fluctuations will still be impacting on the human body, even though they are not heard.)

Dr Robyn Phipps, writing in 2007, criticizes NZS 6808: 1998 for lack of consideration of : low frequency noise and infrasound; atmospheric effects; cumulative noise; and the impulsive nature of wind turbine noise [i.e. amplitude modulation]. She says that the standard was due for review in 2006, but the revision had not occurred when she was writing in 2007.[clxi] I have no had time to research this further, and am unable to say what the current state of NZS 6808: 1998 is. However, I can cite here Dr Thorne's criticism. In his report on the Waubra Wind Farm Thorne states:

> It is concluded that wind farm noise prediction, as implemented under NZS 6808 (the New Zealand wind farm standard) is not adequate in assessing potential adverse effect, and implementation of the standard does not and will not provide an acceptable level of amenity. Application of the standard does not provide a conservative assessment of sound levels that may be experienced under different meteorological conditions.[clxii]

There is a specific issue of detail on which both the South Australian Noise Guidelines and NZS 6808: 1998 need to be criticised for the same reason. The SA Noise Guidelines set their noise limit in the following way: 35 dB(A) or background noise + 5 dB(A), *whichever is greater*. Similarly, NZS 6808: 1998 sets a limit of 40 dB(A) or background noise + 5 dB(A*), whichever is greater*.[clxiii] The qualifying phrase "whichever is greater" is of crucial importance. It is also very undesirable. There is general agreement amongst independent commentators that in rural areas the night-time background noise level can fall to below 30 dB (A), and may fall as low as 20 dB(A) [or even lower?].[clxiv] If the background noise is as low as 20 dB(A), then background + 5 dB(A) will be 25 dB(A). However, this will *not* be the authorised limit, because 35 dB(A) is *greater*. In other words, the wind farm will be allowed to generate noise up to the level of 35 dB(A). The difference between 20 dB(A) and 35 dB(A) is 15 dB. And as we have seen, a difference of 10 dB is perceived by human hearing as twice as loud. So, the wind farm will be perceived as *three* times as loud as the background noise. This is hardly a situation conducive to falling asleep. (And this is quite apart from considerations of noise fluctuations above the average level, and amplitude modulation.) In Victoria, where the limit is 40 dB(A) or background + 5 dB(A), whichever is greater, the situation is correspondingly worse. 40 dB(A) is 20 dB greater than 20 dB(A). So, in this case the wind farm is perceived as *four* times as loud as the background noise. How is anybody to sleep?

There is one final issue concerning noise guidelines: compliance monitoring. Setting aside Thorne's point that a wind farm may comply on one day and not on the next, we have to note that the procedure for monitoring is likely to fail some residents. In the SA Guidelines, at least, monitoring for compliance is to take place *only* at those residences where the original background noise logging took place.[clxv] But as we have seen from Thorne's work, the greatest noise impacts may be experienced at one residence in a Heightened Noise Zone, and not at another residence not far away. If the residence in the Heightened Noise Zone was not amongst the residences where the original noise logging was done, then it will not be one of the residences where compliance monitoring is done. So, its complaint will go unmonitored. Compliance only has to be achieved at the selection of residences where the original noise logging was done. This provision fails to take into account the variability of noise impacts from a wind farm, and so leaves open the possibility of injustice.

It should be remembered that the prediction of wind turbine noise by computer modelling is inaccurate, and is likely to underestimate seriously the actual noise that neighbours will experience after the wind farm is built. If and when this happens, will planning authorities really enforce the noise limit and shut down turbines? Is this credible, given the hundreds of millions of dollars of investment in the building of the wind farms? If the planning authorities give so little consideration to the interests of residents and the problematical aspects of wind farms *before* a wind farm is built, is it likely that they will give this consideration *after* the wind farm is built, when the wind farm company's money is spent, and the company must get a return on its capital?

There are already existing wind farms in Australia, approved under the noise guidelines, where local residents are suffering adverse noise impacts and adverse health effects. This is so at Waubra in Victoria, studied in detail by Dr Robert Thorne. It is also true of Crookwell One, Cullerin, and Capital in NSW. The victims have names and contact details. Their suffering proves the inadequacy of the planning process for wind farms in Australia, especially the inadequacy of the noise guidelines.

We can conclude that the noise guidelines for wind farms in use in Australia are completely inadequate, and provide no protection to the neighbours of wind farms.

What Is To Be Done?

Various proposals have been made to re-regulate wind farm development, but, as we shall see, none is completely adequate. I shall discuss the proposed revision of noise guidelines by some respected noise engineers, WHO's latest proposals for night-time noise, an International Standard, and various proposals for setback distances.

George Kamperman and Rick James are respected American noise engineers. They have proposed a complex set of noise limits for wind turbine noise, which is certainly a vast improvement on the SA Guidelines and NZS 6808. But what they propose still falls short of what is required, given the latest medical and acoustic research.

Kamperman and James propose the following limits:

- Background noise + 5 dB(A)
- Background noise + 5 dB(C)
- 35 dB(A)
- 55 dB(C) for quiet rural environment
-difference between background + 5 dB(A) and dB(C) not to exceed 20 dB
- prominent tone penalty of 5 dB(A)/5 dB(C)

It must be noted that *none* of these limits is to be breached. In other words, all the alternatives are to be followed by the words: *whichever is lower*.[clxvi]

Moreover, background noise is to be measured in the quietest part of the night, and is to exclude not only all passing sounds but also the sound of the wind.[clxvii] This is certainly to take night-time noise seriously. However, after all this (which the wind energy industry would resist with all its strength) Kamperman and James conclude that these limits would result in a minimum setback distance of 1 kilometre.[clxviii] As we have seen from the work of Thorne and of Bakker, 1 kilometre would be completely inadequate for the hilly terrain of Australia and New Zealand.

It must also be noted that Kamperman and James make no mention of the necessity of using dB(G) to make accurate measurements of infrasound. Moreover, to bridge the gap between 20 Hz (the upper limit of infrasound measured by dB(G)) and 31 Hz (the lower limit for dB(C)) measurement in dB(Z) would also be necessary.

The *Guidelines for Community Noise* (1999) of the World Health Organization recommend an indoor night-time noise level of 30 dB(A), and a lower level still if low frequency noise is prominent. It states:

> The more intense the background noise, the more disturbing is its effect on sleep. Measurable effects on sleep start at background noise levels of about 30 dB LAeq. [i.e. the average level measured in dB(A)]. Physiological effects include changes in the pattern of sleep stages, especially a reduction in the proportion of REM sleep. Subjective effects have also been identified, such as difficulty in falling asleep, perceived sleep quality, and adverse after-effects such as headache and tiredness. Sensitive groups mainly include elderly persons, shift workers and persons with physical or mental disorders.
>
> Where noise is continuous, the equivalent sound pressure level should not exceed 30 dBA indoors, if negative effects on sleep are to be avoided. When the noise is composed of a large proportion of low-frequency sounds a still lower guideline value is recommended, because low-frequency noise (e.g. from ventilation systems) can disturb rest and sleep even at low sound pressure levels.[clxix]

Unfortunately, WHO does not give any specific limits for night-time low frequency noise indoors.

In 2009 WHO, Europe published *Night Noise Guidelines for Europe*. From the point of view of anyone interested in wind farm regulation this is a disappointing document. It distinguishes between a No Observed Effect Level (NOEL) and a Lowest Observed Adverse Effect Level (LOAEL). It sets 30 dB as the NOEL. That is to say, it asserts that no adverse biological effects are observed if the outside noise level is 30 dB. Curiously, it does not specify on what scale the 30 dB is to be measured – A, C, G, or Z. It then sets 40 dB as the LOAEL. That is, above 40 dB [unspecified] outside, adverse health effects are observed. Of the range from 30 dB to 40 dB it makes the following extraordinary statement:

> A number of effects on sleep are observed from this range: body movements, awakening, self-reported sleep disturbance, arousals. The intensity of the effect depends on the nature of the source and the number of events. Vulnerable groups (for example children, the chronically ill and the elderly) are more susceptible. However, even in the worst cases the effects seem modest.

It then recommends the LOAEL, 40 dB Lnight, outside as the outside night noise limit, despite observed instances of sleep disturbance, and the vulnerability of special groups.[clxx]

Dr Christopher Hanning, the specialist in sleep disorders medicine, points out that failing to classify body movements, awakenings, self-reported sleep disturbance and arousals as adverse health effects contradicts the WHO definition of health. Dr Hanning calls the recommendation of Lnight, outside 40 dB “perverse”. He points out that the assumption that the attenuation of noise from outside to inside will be as great as 21 dB does not correspond to the usual assumption that it is 10 to 15 dB.[clxxi] However, we must go even further than this, and recall the greater penetrating power of low frequency sound and infrasound, and note that the *Night Noise Guidelines* make no allowance for this. These night noise guidelines will give no relief to people in Europe suffering from night-time wind turbine noise and sleep disturbance.

Pierpont tells us of sleep disturbance that body movements and low-level arousals occur at 32 dB(A); Arousals that register on an EEG occur at 35 dB(A); conscious awakenings occur at 42 dB(A).[clxxii]

The international standard ISO 1996: 1971 recommends for rural areas the following noise limits: daytime 35 dB(A); evening (7-11 pm) 30 dB(A); night-time (11 pm – 7 am) 25 dB(A).[clxxiii] Although this is a vast improvement on WHO, Europe’s recommendation, it is still an average level, and consequently provides no protection from the fluctuations of wind turbine noise. It also takes no account of the prominence of low frequency noise or amplitude modulation.

Various setback distances have been recommended. I will only mention some of them.

Frey and Hadden	2 kilometres
Harry	2.4 kilometres
Pierpont	minimum of 2 km; 3.2 km in hilly terrain
French National Academy of Medicine	1.5 kilometres
Kamperman and James	1 kilometre

Acoustic Ecology Institute	1.5 kilometres
NSW General Purpose Standing Committee No. 5	2 kilometres[clxxiv]

Of these only Pierpont's takes account of the increased propagation of wind turbine noise in hilly terrain. However, the work of Thorne in Victoria suggests that wind turbine noise may disturb sleep at 4 kilometres, or even 5 kilometres. Dr Sarah Laurie's measurements of blood pressure also suggest that adverse health impacts from wind turbine noise may be felt as far out as 4 kilometres.

Even Dr Robert Thorne's proposal seems impractical. Dr Thorne proposes the following:

> No large-scale wind turbine should be installed within 2000 metres of any dwelling or noise sensitive place unless with the approval of the landowner.
>
> No large-scale wind turbine should be operated within 3500 metres of any dwelling or noise sensitive place unless the operator of the proposed wind farm energy facility, at its own expense, mitigates any noise within the dwelling or noise sensitive place identified as being from that proposed wind farm energy facility, to a level determined subject to the final approval of the occupier of that dwelling or noise sensitive place.[clxxv]

This leaves open the possibility of residents acting against their own best interest out of ignorance of the effects of wind turbine noise. It also seems to envisage a situation where turbines might be built, and then have to be shut down, if the satisfactory mitigation of adverse impacts could not be achieved. It also fails to take account of the fact that it is very difficult, if not impossible, to seal residences against the penetration of low frequency noise and infrasound.

Given that the maximum distance at which adverse health impacts from wind turbine noise can occur is still unknown, and given that research into the adverse health effects of low frequency noise and infrasound (especially if dynamically modulated) is ongoing and incomplete, it is impossible to recommend any specific noise limits for wind turbine noise, or any specific setback distances. While we know enough to be concerned, we do not know enough to make any final determinations for imposing limits.

We can only draw the same conclusions that we drew at the end of our section on adverse health impacts, that is to say:

The rational course of action to pursue is to make a temporary halt to further wind farm development in Australia until independent, third party research is carried out to investigate thoroughly the adverse health effects of wind turbines, with a view to establishing setback distances adequate to protect residents.

The impacts of existing wind farms in Australia should be re-investigated, in the light of recent research into low frequency noise, infrasound, and their adverse health effects, with a view to providing relief to those currently suffering from the impacts of such wind farms.

Addendum: one example of official action can and should be imitated immediately. In 2009 a French court ordered that a French wind farm be shut down at night to prevent the sleep disturbance that local residents had been suffering.[clxxvi] Existing wind farms in Australia should be shut down at night to enable their neighbours to sleep.

Summary

1. Aerodynamic noise is the main source of the problems of annoyance, sleep disturbance and the other adverse health effects of wind turbine noise.

2. Aerodynamic noise from wind turbines is broadband noise, including sound of high frequency, mid frequency, low frequency and infrasound.

3. Aerodynamic noise from wind turbines has a pulsing character.

4. Aerodynamic noise from wind turbines is subject to amplitude modulation, which has less severe and more severe forms.

5. Wind turbine noise is constantly shifting in character.

6. All noise guidelines require only noise measurements on the A-weighted scale, But the A-weighted scale is completely inadequate for measurement of wind turbine noise, since A-weighted measurements seriously underestimate the magnitude of low frequency noise and infrasound.

7. Low frequency noise should be measured on the C-weighted scale. Infrasound should be measured on the G-weighted scale. It may be necessary also to take measurements on the Z-weighted scale.

8. Low frequency noise has a lower rate of attenuation with distance. Low frequency noise is not masked by the noise of wind in trees. Low frequency noise can penetrate the walls of a house. Low frequency noise can penetrate ear protection devices. Low frequency noise can resonate rooms, and rattle doors and windows. Low frequency noise can resonate the organs of the human body. The low frequency components of wind turbine noise are likely to predominate as distance increases.

9. Low frequency noise from wind turbines has been measured inside Australian residences in the 40s, 50s and 60s dB(Z) These levels would prevent anyone from sleeping.

10. Low frequency noise is known to cause high annoyance, and stress, and is regarded as the cause of “immense suffering” for some.

11. Low frequency noise is suspected of disturbing the vestibular and other systems of the human body.

12. Infrasound is commonly inaudible below 85 dB(G), but some noise sensitive people may be able to hear it.

13. Infrasound shares the characteristics of low frequency noise in 8. above, except that it is inaudible.

14. Infrasound is massively de-emphasised by A-weighted measurements, and needs to be measured on the G-weighted scale.

15. Infrasound from wind turbines has been measured inside Australian residences in the 50s and 70s dB(Z).

16. Dr Alec Salt states that the Outer Hair Cells of the Cochlea are stimulated by 60 dB(G). Dr Salt shows evidence of wind turbines capable of generating 60 dB(G) or more, at residences at common setback distances.

17. Infrasound is known to cause symptoms similar to Wind Turbine Syndrome.

18. Amplitude modulation is commonly said to involve fluctuations of 2 dB, 5 dB, or 9 dB. But low frequency amplitude modulation has been measured inside an Australian residence of 28 dB (almost 8 times as loud) . And infrasonic amplitude modulation has been measured inside an Australian residence of 25 dB (6 times as loud). The maximum level was 65 dB(Z), above the level at which the Outer Hair Cells are stimulated.

19. Amplitude modulated sound is known to be more easily perceived, and more annoying than constant sound.

20. The explanation of amplitude modulation has not been finally determined. The latest account distinguishes between “swish” and “thump”. Swish occurs as the blade passes the horizontal position on the downswing. Thump is caused by the movement of the blade though turbulence. Turbulence can be created by wind shear, atmospheric conditions, terrain and the spatial relation of multiple turbines.

21. Amplitude modulation of both kinds may be heard at one residence, and not at another residence not far away.

22. Both kinds of amplitude modulation can cause sleep disturbance.

23. Computer modelling of wind turbine noise to predict noise impacts is generally held to be inaccurate, and to underestimate the magnitude of noise that will actually be produced.

24. Actual wind turbine noise depends on the location of multiple turbines, terrain, atmospheric conditions, and amplitude modulation, as well as sound power level and distance from turbines.

25. Wind turbine noise can be enhanced by synchronicity, or several turbines moving in phase

26. Terrain can enhance wind turbine noise by (i) rising ground away from the turbines, and (ii) if the turbines are on high ground while residences are on low ground.

27. Wind turbine noise can be enhanced by a stable atmosphere. This is known as the van den Berg Effect.

28. The noise guidelines for wind farms in Australia are completely inadequate, and offer no protection whatever to residents. This is because they require measurements only in dB(A).; they do not consider adequately low frequency noise; they do not consider adequately infrasound; they rely on averages, and do not consider adequately fluctuating noise levels; they do not consider adequately amplitude modulation.

29. Given the fluctuating levels of wind turbine noise, it can be impossible to state finally that a wind farm is complying with the noise limits, or that it is not complying with the noise limits.

30. The noise guidelines in use in Australia have the defect of allowing wind farms to produce noise up to the *greater* level of 35 (or 40) dB(A) and background + 5 dB(A). This is especially inappropriate for limiting night-time noise.

31. Compliance monitoring is limited to the same residences where the original noise logging took place (at least according to the SA Guidelines). This fails to take account of Heightened Noise Zones.

32. There are existing wind farms in Australia, approved under the noise guidelines, where residents are already suffering adverse noise and health impacts. This proves the inadequacy of the noise guidelines.

33. Kamperman and James' revised noise guidelines are still inadequate for Australian conditions.

34. WHO, Europe's *Night Noise Guidelines for Europe* are inadequate to protect residents from wind turbine noise in Australian conditions.

35. ISO 1996: 1971 takes no account of the prominence of low frequency noise, or of amplitude modulation.

36. Various proposed setback distances do not allow for recorded sleep disturbance, and other adverse health effects as far out as 3 kilometres from turbines in Australia, and possibly 4 or 5 kilometres.

37. Given our imperfect knowledge of the scope and limits of adverse noise and health impacts from wind turbines, it is impossible to recommend any specific noise limits or setback distances.

Overall Conclusions

Given our still imperfect knowledge, and the ongoing nature of acoustic and medical research:

The rational course of action to pursue is to make a temporary halt to further wind farm development in Australia until independent, third party research is carried out to investigate thoroughly the adverse health effects of wind turbines, with a view to establishing setback distances adequate to protect residents.

The impacts of existing wind farms in Australia should be re-investigated, in the light of recent research into low frequency noise, infrasound, and their adverse health effects, with a view to providing relief to those currently suffering from the impacts of such wind farms.

Addendum: existing wind farms in Australia should be shut down at night to enable their neighbours to sleep.

Notes

[i] Colby et al, 2009, p. 5-2
[ii] Sonus, 2010, p. 5
[iii] NHMRC, 2010, p. 8
[iv] CMOH, 2010, p. [3]
[v] SWV, AWEA/CWEA, p. 2
[vi] SWV, NHMRC, pp. 3-4
[vii] SWV, CMOH, p.3
[viii] Health Canada, p. 2
[ix] Health Canada, p. 2-3
[x] Hanning, 2010, p. 6
[xi] Phillips, 2010, Executive Summary
[xii] Minnesota, 2009, p. 25
[xiii] Harry, 2007, p. 16
[xiv] Harry, 2007, p. 21
[xv] Pierpont, 2009, pp. 26-125; 126-192; 193-255
[xvi] Phipps, 2007, pp. 4-9
[xvii] Phipps, 2007, p. 14
[xviii] Nissenbaum, 2010
[xix] Thorne et al, 2010
[xx] Thorne et al, 2010, p. 110
[xxi] Thorne et al, 2010, p. 113
[xxii] Thorne et al, 2010, p. 113
[xxiii] Thorne et al, 2010, p. 119
[xxiv] Items 1-12 from Harry, 2007
[xxv] Items 13-15 from Phipps, 2007
[xxvi] Items 16-18 from Thorne et al, 2010, pp. 110, 111, 117
[xxvii] Items 19-27 from WindVoice
[xxviii] WHO, 1999, 3.1
[xxix] WHO, 1999, 3.7
[xxx] WHO, 1999, 3.7
[xxxi] EPA (US), 2009
[xxxii] Niemann et al, 2006, Abstract
[xxxiii] Pedersen and Persson Waye, 2004, p. 3468; cf. Pierpont, 2009, pp. 112-113
[xxxiv] Van den Berg et al, 2008
[xxxv] Pedersen et al, 2009, p. 642
[xxxvi] WHO, 1999, 3.1
[xxxvii] WHO, 1999, 3.3
[xxxviii] WHO, 1999, 3.3
[xxxix] Krogh, 2010
[xl] Van den Berg et al, 2008
[xli] Bakker et al, 2009
[xlii] Hanning, 2010, p. 6
[xliii] Hanning, 2010, p. 7
[xliv] Hanning, 2010, pp. 8-9

[xlv] Hanning, 2010, p. 14
[xlvi] Leventhall, 2009
[xlvii] Colby, 2009; cited in SWV Primer
[xlviii] Countryside News, 2010
[xlix] Leventhall, 2004; quoted in Pierpont, 2009, p. 3
[l] Pierpont, 2009, p. 4
[li] Pierpont, 2009, pp. 26-125; 193-255
[lii] Pierpont, 2009, p. 13
[liii] Pierpont, 2009, p. 26
[liv] Pierpont, 2009, p. 229
[lv] Pierpont, 2009, p. 233
[lvi] Pierpont, 2009, pp. 230-233
[lvii] Pierpont, 2009, pp. 124-125
[lviii] Pierpont, 2009, pp. 38-41
[lix] Salt and Hullar, 2010
[lx] Salt, 2010a
[lxi] Salt, 2010b
[lxii] Salt, 2010b
[lxiii] Salt, 2010b
[lxiv] Leventhall, 2006; quoted in Salt, 2010a
[lxv] Salt, 2010a
[lxvi] Salt, 2010a and b
[lxvii] Salt, 2010a
[lxviii] Salt, 2010a
[lxix] Salt, 2010a
[lxx] Salt, 2010a
[lxxi] Laurie, 2010
[lxxii] Thorne et al, 2010, p. 113
[lxxiii] Colby et al, 2009, p. 3-3; Sonus, 2010, p. 7
[lxxiv] Colby et al, 2009, p. 3-3; Sonus, 2010, p. 7; Punch et al, 2010, pp. 22-23; AEI, 2009, p. 7
[lxxv] Thorne, 2010, p. 3
[lxxvi] Thorne, 2010, p. 3
[lxxvii] Thorne, 2010, p. 3
[lxxviii] Thorne, 2010, p. 3
[lxxix] Punch et al, 2010, p. 23; Bowdler, 2008
[lxxx] Thorne, 2010, p. 2
[lxxxi] Pedersen and Persson Waye, 2004; Pedersen and Persson Waye, 2007; Pedersen and Persson Waye, 2008; Pedersen et al, 2009; van den Berg et al, 2008
[lxxxii] Thorne et al, 2010, p. 74
[lxxxiii] Pierpont, 2009, pp. 214-215
[lxxxiv] Pierpont, 2009, p. 215
[lxxxv] Diracdelta, G; ISO 7196-1995
[lxxxvi] Diracdelta, Z; Punch et al, 2010, p. 27
[lxxxvii] Colby et al, 2009, p. C-1; Sonus, 2010, pp. 9-11; Pierpont, 2009, pp. 214-215; Salt, 2010a and b; Kamperman and James, 2008a and b
[lxxxviii] Kamperman and James, 2008a and b; Pierpont, 2009, pp. 215-216
[lxxxix] Salt, 2010a and b
[xc] Colby et al, 2009, p. C-1
[xci] Sonus, 2010, p. 9
[xcii] SWV, LFN, nn. 62-63
[xciii] Sonus, 2010, pp. 10-11
[xciv] WHO, 1999, 4.3
[xcv] Diracdelta, Z; Punch et al, 2010, p. 27
[xcvi] Sonus, 2010, p. 9
[xcvii] DeGagne et al, 2008, p. 116

[xcviii] Phipps, 2007, p. 20
[xcix] Phipps, 2007, p. 19
[c] Powell, 2010, pp. 247-248
[ci] Diracdelta, Z; Punch et al, 2010, p. 27
[ciicii] Thorne, 2010, p. 20
[ciii] Thorne et al, 2010, pp. 17-18
[civ] Thorne, 2010, p. 15
[cv] Thorne, 2010, p 4
[cvi] Schust, 2004
[cvii] Schust, 2004
[cviii] Salt, 2010a and b; Pierpont, 2009, pp. 26-125; 193-255
[cix] Leventhall, 2003, p. 4
[cx] Leventhall, 2003, p. 5
[cxi] Punch et al, 2010, p. 25
[cxii] Pierpont, 2009, pp. 85-86
[cxiii] Pierpont, 2009, p. 86
[cxiv] Pierpont, 2009, p. 87
[cxv] Pierpont, 2010, pp. 8, 17
[cxvi] Berglund et al, 1996, p. 2993; quoted in Pierpont, 2009, p. 104
[cxvii] Sonus, 2010, pp. 10-11
[cxviii] Salt, 2010a and b
[cxix] Salt, 2010a and b
[cxx] Thorne, 2010, p. 20
[cxxi] Thorne, 2010, p. 15
[cxxii] Sonus, 2010, p. 10
[cxxiii] Salt, 2010a
[cxxiv] Salt, 2010a
[cxxv] Pierpont, 2009, pp. 106-107
[cxxvi] Salt, 2010b
[cxxvii] Thorne, 2010, pp. 10-11; Punch et al, 2010, p. 23; AEI, 2009, p. 22; Bowdler, 2008
[cxxviii] Punch et al, 2010, p. 23; Bowdler, 2008
[cxxix] Thorne, 2010, p. 10
[cxxx] Thorne, 2010, p. 10
[cxxxi] Thorne, 2010, p. 10
[cxxxii] Salt, 2010a and b
[cxxxiii] Punch et al, 2010, p. 23
[cxxxiv] Powell, 2010, pp. 90-91
[cxxxv] Thorne, 2010, p. 3
[cxxxvi] Punch et al, 2010, p. 25
[cxxxvii] Bowdler, 2008
[cxxxviii] Bowdler, 2008
[cxxxix] Bowdler, 2008
[cxl] Thorne, 2010, pp. 7-8
[cxli] Bowdler, 2008
[cxlii] Bowdler, 2008
[cxliii] Bowdler, 2008
[cxliv] AEI, 2009, p. 6
[cxlv] Thorne, 2010, pp. 4-8; Kamperman and James, 2008a and b; AEI, 2009, p. 6
[cxlvi] Thorne, 2010, pp. 4-8
[cxlvii] Thorne, 2010, p. 8
[cxlviii] Thorne, 2010, p. 5
[cxlix] AEI, 2009, p. 20
[cl] AEI, 2009, p. 20
[cli] Thorne, 2010, pp. 23, 29
[clii] AEI, 2009, p. 21

[cliii] Van den Berg, 2006
[cliv] Thorne, 2010, p. 25; Bakker et al, 2009
[clv] Bowdler, 2008, referring to van den Berg, 2004a and b; Kamperman and James, 2008b
[clvi] SA Guidelines, 2009, p. 15
[clvii] Cf. AEI, 2009, p. 22
[clviii] SA Guidelines, p. 3; Phipps, p. 20
[clix] Thorne, 2010, p. 9
[clx] SA Guidelines, p. 15
[clxi] Phipps, 2007, pp. 16-17
[clxii] Thorne et al, 2010, p. 7
[clxiii] SA Guidelines, 2009, p. 3; Phipps, 2007, p. 20
[clxiv] Kamperman and James, 2008b; ISO 1996-1971
[clxv] SA Guidelines, 2009, p. 8
[clxvi] Kamperman and James, 2008b, p. 19
[clxvii] Kamperman and James, 2008b, pp. 15-17
[clxviii] Kamperman and James, 2008a, p.9
[clxix] WHO, 1999, 4.2.3
[clxx] WHO, 2009, 5.6
[clxxi] Hanning, 2010, p. 34
[clxxii] Pierpont, 2009, p. 102
[clxxiii] ISO 1996-1971
[clxxiv] Taken from Hanning, 2010, p. 68
[clxxv] Thorne, 2010, p. 37
[clxxvi] SWV, Sleep

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