SUBMISSION

OF

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to the

Australian Senate Inquiry

into

Excessive Noise from Wind Farms

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Contents

Summary

Section 1 sets out my expertise in sleep medicine and physiology, the scope of the report and source material.

Section 2 reviews the basic physiology of sleep. Noise can disturb sleep by causing awakenings, which are remembered and arousals, which are not recalled but are more likely. Both disrupt sleep making it unrefreshing. Research on the effects of wind turbine noise has concentrated on remembered awakenings and has thus underestimated the effects.

Inadequate or poor quality sleep has many health consequences apart from daytime sleepiness and fatigue. These include obesity, poor memory, increased risk of diabetes, heart disease and high blood pressure. Vulnerable groups such as children, particularly those with autistic spectrum disorder and the elderly may be at greater risk.

Section 3 reviews research on wind turbine noise, sleep disturbance and health to support the assertion that wind turbines placed too close to human habitation are harmful to the health and well being of the occupants.

Two recent studies from New Zealand and the USA are reviewed in detail.

It is concluded that there is compelling evidence that wind turbine noise can and does disturb sleep and impair the health of those living too close and that current guidance is inadequate protection.

Section 4 considers the contrary views, especially those of ACANWEA and Professor Simon Chapman and concludes that they are offer no convincing evidence to counter that offered in Section 3.

Section 5 presents the conclusions of the report that industrial wind turbine noise constitutes an unacceptable risk to health and sleep disturbance.

Section 6 lists the documents cited in support of this paper.

1. Introduction

1.1 The author

1.1.1. My name is Dr Christopher Hanning, Honorary Consultant in Sleep Disorders Medicine to the University Hospitals of Leicester NHS Trust, based at Leicester General Hospital, having retired in September 2007 as Consultant in Sleep Disorders Medicine. In 1969, I obtained a First class Honours BSc in Physiology and, in 1972, qualified in medicine, MB, BS, MRCS, LRCP from St Bartholomew's Hospital Medical School. After initial training in anaesthesia, I became a Fellow of the Royal College of Anaesthetists by examination in 1976 and was awarded a doctorate from the University of Leicester in 1996. I was appointed Senior Lecturer in Anaesthesia and Honorary Consultant Anaesthetist to Leicester General Hospital in 1981. In 1996, I was appointed Consultant Anaesthetist with a special interest in Sleep Medicine to Leicester General Hospital and Honorary Senior Lecturer to the University of Leicester.

1.1.2. My interest in sleep and its disorders began over 30 years ago and has grown ever since. I founded and ran the Leicester Sleep Disorders Service, one of the longest standing and largest services in the country, until retirement. The University Hospitals of Leicester NHS Trust named the Sleep Laboratory after me as a mark of its esteem. I was a founder member and President of the British Sleep Society and its honorary secretary for four years and have written and lectured extensively on sleep and its disorders and continue to be involved in research. My expertise in this field has been accepted by the civil, criminal and family courts. I have been accepted as an expert on sleep disturbance related to wind turbine noise by the Ontario High Court and Environmental Review Tribunals. I chaired the Advisory panel of the SOMNIA study and sit on the Advisory panel for the Medicated Sleep and Wakefulness study, both major projects investigating sleep quality in the elderly, and sit on Advisory panels for several companies with interests in sleep medicine. I am an Associate Member of the General

Medical Council, chairing Investigation Committee hearings. In 2010, I was invited to join the Board of the Society for Wind Vigilance.

1.1.3. I live in Ashby Magna, Leicestershire, UK which is within 1km of the Low Spinney Wind Farm.

1.2. Scope of report.

1.2.1. This report centres on the effects of industrial wind turbine noise on sleep and consequent effects on health as this is the particular area of expertise of the author.

1.3. Source material

1.3.1. A full list of the publications cited and other source material is given in Section 7 and are cited in the text. Where several articles come to the same conclusion, only the most recent may be cited, in the interests of brevity. As far as possible, articles published in peer reviewed journals are cited. However, it is inevitable that some of the material is available only on the internet reflecting the paucity of government sponsored research.

2. Background

2.1. Introduction

2.1.1. 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. A recently published peer reviewed editorial in the British Medical Journal (Hanning, 2012) states: "*A large body of evidence now exists to suggest that wind turbines disturb sleep and impair health at distances and external noise levels that are permitted in most jurisdictions, including the United Kingdom." "When seeking to generate renewable energy through wind, governments must ensure that the public will not suffer harm from additional ambient noise".* An Ontario Environmental Review Tribunal heard evidence from over 20 expert witnesses (including the author) in 2011 and concluded "*… the debate should not be simplified to one about whether wind turbines can cause harm to humans. The evidence presented to the Tribunal demonstrates that they can, if facilities are placed too close to residents. The debate has now evolved to one of degree." (Case Nos. 10-121 and 10-122. p 207).* In reviewing potential health impacts of sustainable energy sources, three leading members of the National Institute of Environmental Health Sciences, part of the US National Institutes of Health, state: *"Wind energy will undoubtedly create noise, which increases stress, which in turn increases the risk of cardiovascular disease and cancer."* (Gohlke et al. 2008). Section 5.1.1 of New Zealand standard on wind farm noise, 2010, states: *"Limits for wind farm noise are required to provide protection against sleep disturbance and maintain reasonable residential amenity."* Reports from many different locations and different countries have a common set of symptoms and have been documented by Frey and Hadden (2012). New cases are documented regularly on the Internet. The symptoms include sleep disturbance, fatigue, headaches, dizziness, nausea, changes in mood and inability to concentrate and have been named "wind turbine syndrome" by Dr Nina Pierpont (2009). The experiences of the Davis (2008) family from Lincolnshire, UK whose homes were around 900m from wind turbines make salutary reading. The noise, sleep disturbance and ill health eventually drove them from their homes. The Davises subsequently took the developers and land owners to the High Court. An out of court settlement was reached before judgement had been made. Similar stories have been reported from around the world, usually in anecdotal form but in considerable numbers.

2.1.2. Phillips, an epidemiologist, has reviewed all of the anecdotal cases and case series and, in a peer reviewed journal, contends that the quantity, consistency and ubiquity of the complaints is *prima facie* epidemiological evidence of a causal link between wind turbine noise, sleep disruption and ill health (Phillips 2011).

2.1.3 The World Health Organisation Environmental Burden of Disease – European countries project (WHO EBoDE) (WHO, 2011) selected nine environmental stressors for study, including noise (S6). *“The health effects of environmental noise were selected to cover psychosocial (sleep disturbance), cardiovascular effects (elevated blood pressure, Ischaemic Heart Disease including myocardial infarction) and learning performance.”* These choices emphasise the importance that WHO place upon the effects of environmental noise on sleep disturbance.

2.2. Sleep, sleep physiology and the effects of noise

2.2.1. Sleep is a universal phenomenon. Every living organism contains, within its DNA, genes for a body clock which regulates an activity-inactivity cycle. In mammals, including humans, this is expressed as one or more sleep periods per 24 hours. Sleep was previously thought to be a period of withdrawal from the world designed to allow the body to recuperate and repair itself. However, modern research has shown that sleep is primarily by the brain and for the brain. The major purpose of sleep seems to be the proper laying down and storage of memories, hence the need for adequate sleep in children to facilitate learning and the poor memory and cognitive function in adults with impaired sleep from whatever cause.

2.2.2. 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.

2.2.3 Humans have two types of sleep, slow wave (SWS) and rapid eye movement (REM). SWS is the deep sleep which occurs early in the night while REM or dreaming sleep occurs mostly in the second half of the night. Sleep is arranged in a succession of cycles, each lasting about 90 minutes. We commonly wake between cycles, particularly between the second and third, third and fourth and fourth and fifth cycles. Awakenings are not remembered if they are less than 30 seconds in duration. As we age, awakenings become more likely and longer so we start to remember them.

Even while deeply asleep, the brain is processing sounds and deciding whether they merit awakening either because the sound has meaning or constitutes a threat. For example, at the same noise level, awakening is more likely when one's name is called rather than a non-specific noise. Similarly, a mother will wake when her baby cries but not for a passing car.

2.2.4. 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. It is clear also that some types of noise are more annoying than others. Constant noise is less annoying than irregular noise which varies in frequency and loudness, for example, snoring, particularly if accompanied by the snorts of sleep apnoea (breath holding). The swishing or thumping impulsive noise associated with wind turbines seems to be particularly annoying as the frequency and loudness varies with changes in wind speed and local atmospheric conditions and the character of the noise may be perceived as threatening. While there is no doubt of the occurrence of these noises and their audibility over long distances, up to 3-4km in some reports, the actual cause has not yet been fully elucidated (Bowdler 2008). Despite recommendations by the UK Government's own Noise Working Group, UK government sponsored research in this area has been stopped, although the Ontario government has recently announced a consultation for a research programme. Stigwood (2008), an independent noise consultant, has demonstrated that this noise pattern is common with large turbines.

2.2.5. 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.

2.2.6. 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". Arousals are associated not just with an increase in brain activity but also with physiological changes, an increase in heart rate and blood pressure, which are thought to be responsible for the increase in cardiovascular risk. A clear relationship between high blood pressure and aircraft noise exposure has been shown by the HYENA consortium (Jarup 2008) and between traffic noise and high blood pressure for adults (Barregard 2009) and, worryingly, for preschool children (Belojevic 2008).

The MESA study has suggested a link between exposure to traffic and alterations in heart function (Van Hee 2009) and Selander and colleagues (2009) have suggested a link with myocardial infarction (heart attack) but neither could separate noise effects from pollution. Arousals occur naturally during sleep and increase with age (Boselli 1998), as do awakenings which may make the elderly more vulnerable to wind turbine noise. Arousals may be caused by sound events as low as 32 dB(A) and awakenings with events of 42dB(A) (Muzet and Miedema 2005). Arousals in SWS may trigger a parasomnia (sleep walking, night terrors etc.). Pierpont (2009) notes that parasomnias developed in some of the children exposed to turbine noise in her study group.

2.2.7. Arousals are caused by aircraft, railway and traffic noise. In one study of aircraft noise, arousals were four times more likely to result than awakenings and resulted in daytime sleepiness (Basner 2011). Freight trains are more likely to cause arousals than passenger trains, presumably because they are slower, generating more low frequency noise and taking longer to pass (Saremi 2008). The noise of wind turbines has been likened to a “passing train that never passes” which may explain why wind turbine noise is prone to cause sleep disruption. A recent study of over 18000 subjects has shown a link between exposure to traffic noise and “the risk of getting up tired and not rested in the morning (de Kluizenaar, 2009). This study, together with that of Basner (2011) confirms that excessive noise disturbs sleep sufficiently to impair its restorative properties and adds credence to the anecdotal reports of those living near wind turbines.

2.2.8. Noise character is an important factor in determining whether an arousal occurs. Solet and colleagues (Solet et al. 2010) in a study of the effects of noise on hospital inpatients determined the likelihood of an arousal at different sound levels for a range of sounds from telephone, intravenous fluid pump alarm, conversation, door closing, a jet aircraft passing and a helicopter landing (Figure 1, see end of text). Those sounds with an impulsive quality (telephone and alarm) were much more likely to cause an arousal than steadier noises such as conversation. The noise least likely to cause an arousal was the jet aircraft. Note too that for the most arousing noises, at $40dBLA_{eq10sec}$, 80-90% of the stimuli caused an arousal. It is evident that arousals will still occur at noise levels well below 35dBA.

2.2.9. Studies of different alarm signals have shown that arousals and awakenings occur at lower sound levels with low frequency sounds than those of higher frequency (Bruck 2009). Repeated short beeps of 400-520Hz were most intrusive, leading to arousal and awakening. Wind turbine noise often has a considerable low frequency component and has an impulsive nature which may, in part, explain its adverse effect on sleep. A recent laboratory study of the effects of air, road and rail traffic noise on sleep showed that the differences were explained by sound pressure level rise time, faster rises being more likely to arouse (Basner 2011). A characteristic of wind turbine noise is the rapid rise time which may explain, in part its propensity to disturb sleep.

2.2.10. It is often claimed that continual exposure to a noise results in habituation, i.e. one gets used to the noise. There is no research to confirm this assertion. A recent small study (Pirrera et al. 2009) looking at the effects of traffic noise on sleep efficiency suggests that habituation does not occur. Griefahn and colleagues (2008) have found that the increases in heart rate with traffic noise induced arousals show no habituation.

2.2.11. Sleep disturbance and impairment of the ability to return to sleep is not trivial as almost all of us can testify. The elderly may be more vulnerable, not just because they have more spontaneous awakenings than the young but because their high frequency hearing loss may remove some of the masking of the lower frequency noise characteristic of wind turbines. In the short term, the resulting deprivation of sleep results in daytime fatigue and sleepiness, poor concentration and memory function. Accident risks increase. In the longer term, sleep deprivation is linked to depression, weight gain, diabetes, high blood pressure and heart disease. There is a very large body of literature but please see the 2009 WHO/EU Night Noise Guidelines for Europe (WHO, 2009) for a fuller consideration.

2.2.12. Sleep spindles are short bursts of high frequency oscillation seen in the brain's electrical activity (electroencephalogram, EEG) during SWS and are a marker of sleep stability. Recent research has shown that subjects with a higher spindle rate are less likely to show an arousal in response to a transient noise than a subject with a lesser rate and are less likely to report that noise disturbs their sleep (Dang-Vu et al., 2010). The spindle rate decreases with age, explaining the vulnerability of the elderly to noise induced sleep disruption. Insomniacs, when asleep, do not have necessarily have reduced spindle counts, thus suggesting that sensitivity to noise while asleep is not purely psychological but has a physical basis thus confirming the finding that noise sensitivity is, to a large degree, inherited.

A plot of sound level against the probability of stable sleep is presented (Figure 2 see end of text). This is effectively an inverted dose-response curve of log sound pressure against the likelihood of an arousal. The study only examined noise stimuli of 40-70dB(A). However, it is reasonable to extrapolate backwards to lower noise levels. For subjects with a low spindle rate, even at a stimulus level of 35dB(A) there would be an approximate 50% probability of an arousal and a 30% probability at 35dB(A). The subjects were 26.3 (± 7.5) years of age. Older subjects would be expected to have even fewer spindles and to be even more sensitive to noise. This study confirms the findings of Solet that sleep disturbance can occur at sound levels below 35dBA.

2.3. Psychological factors and noise sensitivity

2.3.1. There is considerable interaction between the psychological response to noise and sleep disturbance, each worsening the other. It is well recognised that psychological factors and personality traits influence the response to noise. Approximately 15% of the population are noise sensitive and have both a lowered annoyance level and an enhanced cortisol response, a physiological marker of stress. Noise sensitivity is considered to be a stable, partly heritable, personality trait; the noise sensitive being at one end of a continuum with the noise tolerant at the other. It is often implied that those who are highly annoyed by noise, including wind turbine noise, are motivated simply by a dislike of the noise source or are psychologically disturbed in some way. This is simply not the case, the response of the noise sensitive being as normal a reaction as that of the noise tolerant.

2.3.2. The noise sensitive are more likely to have stress related disorders, anxiety, headaches and poor sleep than the average. They are more likely to be found in the countryside where noise disturbance is less. Pedersen (2004) reported that 50% of her rural subjects were rather or very noise sensitive. Noise sensitivity is more likely in those with brain injury, psychological disorders such as dyslexia and Autistic Spectrum Disorder (see Section 2.4) and increased community noise may exacerbate depression in susceptible individuals.

Flindell and Stallen (1999) listed factors influencing the degree of annoyance to noise:

- Perceived predictability of the noise level changing
- Perceived control, either by the individual or others
- Trust and recognition of those managing the noise source
- Voice, the extent to which concerns are listened to
- General attitudes, fear of crashes and awareness of benefits
- Personal benefits, how one benefits from the noise source
- Compensation, how one is compensated due to noise exposure
- Sensitivity to noise
- Home ownership, concern about plummeting house values
- Accessibility to information relating to the noise source

to which may be added:

- Perceived value of the noise source
- Expectation of peace and quiet
- Visual impact

Disempowerment and loss of control is a common theme from reports of those subjected to excessive wind turbine noise. The impulsive character of the noise is perceived as threatening and it can not be escaped being audible within the home, the usual source of refuge and quiet to permit restoration (Pedersen 2008), a considerable loss of amenity. The end result is fear and anger at loss of control over the living environment with increased stress responses including increased difficulty in initiating and maintaining sleep. The increased wakefulness at night and the lower quality sleep increase the impact of nocturnal turbine noise on sleep, increasing the daytime fatigue and stress and so on in a reinforcing cycle.

2.3.3. The psychological response to noise and noise sensitivity is a complex area and an excellent review is given by Shepherd, a psychoacoustician (Shepherd 2010).

2.4. Autistic spectrum disorder

Noise sensitivity is a particular problem for those with Autistic Spectrum Disorders (ASD). In a survey of over 17,000 children with ASD, over 40% were hypersensitive to sounds (Cortesi, 2011, Steigler and Davis, 2010). This does not seem to be due to any physical changes in hearing but due to an increased perception of loudness, a psychoemotional-behavioural difference; a fear of sound stimuli, accompanied by hyper-reactive avoidance behaviours. Avoidance behaviours include covering the ears, crying, tantrums, fleeing the area, humming or vocalising, trembling, increased muscle tone, hyperventilation (over breathing) and self injury in the form of blows to the ears. Individual responses vary but it is quite clear that a significant proportion of subjects with ASD have a reaction to environmental sounds that is distressing and potentially harmful.

Behavioural therapy can be helpful in mitigating the harmful responses but requires the sound to be presented in a controlled manner. Clearly this is not possible with wind turbine noise.

Some subjects with ASD have an abnormal and distressing fixation with rotating objects. This is recognised as a diagnostic feature of ASD and can therefore be presumed to be common. Two UK planning inquiries took account of such subjects in their decisions and I am aware of a further application that was withdrawn.

A recent case from County Clare, Ireland, serves to demonstrate that this concern is real (Danaher, 2012). The mother of a 23yr old man with ASD claimed that a wind turbine had had a devastating impact on her son, affecting his sleep and causing great distress. The rated power of the turbine is not stated but from the information given, would seem to be 20kW. The turbine, which has a blade diameter of about 9m is installed about 120m from the young man's bedroom.

2.5. Masking of turbine noise

2.5.1. One of principles of most guidelines/regulations controlling wind turbine noise is that background noise masks turbine noise. This is not the case as has been shown by a number of studies.

2.5.2. Nelson (2007), in a small laboratory based study examined the ability of background noise to mask turbine noise. When background noise and turbine noise where adjusted to the same loudness, the residual perceived loudness of the turbine noise was approximately half of its unmasked value (1.8sone). Even when the background noise was increased from 41 to 49dB(A) the turbine noise was not fully masked. Hayes, of the Hayes McKenzie Partnership, a leading UK acoustician, (Hayes 2007) has interpreted this by stating in evidence that: *"one would expect the wind turbine (warranted to be free of tonal noise) to be audible even if the turbine noise was 10 - 15 dB below the background noise level".* It can be inferred that if tonal noise is present, the turbine noise will be audible at a greater level below background noise.

2.5.3. Bolin (2009) has reported an experimental study of the masking of wind turbine noise by vegetation noise (e.g. leaves rustling). Subjects were exposed to vegetation noise in a laboratory and turbine noise introduced at varying sound pressures and vice versa and a threshold for detection determined. The results were compared with the Moore and Glasberg methods for calculating masking. The results suggest that: *"....existing models of partial masking overestimate the ability to conceal wind turbine noise in ambient sounds."* In other words, wind turbine noise is not masked as well as current models predict and is thus more intrusive. This is in accord with the work of Nelson, van den Berg, Miedema and Pedersen (2010) who show that traffic noise does not mask wind turbine noise as well as predicted.

2.5.4. It is quite clear that Hayes' evidence that turbine noise is audible 10-15dB below background is entirely correct

2.5.5. Sound with the impulsive characteristics of wind turbine noise is chosen for alarm systems because of its audibility below background noise as well as well as its ability to arouse a sleeper. These characteristics of wind turbine noise are probably the reason why it is more annoying than other noise sources such as road traffic and why it appears to cause more sleep disturbance.

3. Wind turbine noise, sleep and health

3.1. Introduction

3.1.1. The evidence above demonstrates that it is entirely plausible that wind turbine noise has the potential to cause arousals, sleep fragmentation and sleep deprivation. As noted above, the New Zealand standard on wind farm noise acknowledges that sleep disturbance is the major adverse consequence of wind turbine noise for humans.

3.1.2 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.

3.1.3. In my expert opinion, the weight of evidence is that large (>1.5MW) industrial wind turbines pose an unacceptable risk to the sleep quality and health of receptors who live within 1.5km.

3.1.4. I base my opinion on the following groups of evidence:

1. Epidemiological studies and anecdotal reports of harm following exposure to wind turbine noise.
2. Opinions from other experts as to appropriate setback distances.
3. Studies of health related effects such as annoyance. Some of these studies have commented on the effects of sleep but have not used appropriate outcome measures.
4. Studies of health effects and sleep disturbance.

3.2. Epidemiological and anecdotal studies.

3.2.1. There are a large number of anecdotal reports and surveys. In the interests of brevity, they will not be detailed here but are described in an online review (Hanning 2010). One survey is particularly worthy of mention, WindVoice (Krogh 2011), as the results have been published in a peer-reviewed journal. WindVoice is a self-reporting survey of communities affected by wind turbine noise. As of July 2010, 144 responses had been received of which 118 reported one or more health effects. 84 (58%) reported sleep disturbance and 85 (59%). There were no age differences between those that reported sleep disturbance (51.5 yr (19-79)) and those that did not (52.2 yr (26-86)). All bar five of those reporting sleep disturbance live within 1500m of the turbines adding further support to a minimum setback of at least that distance.

3.2.2. The anecdotal reports are commonly dismissed in industry sponsored reviews (for example, Colby et al. 2009) as not acceptable evidence. Phillips, an epidemiologist, in a peer reviewed article (Phillips 2011) has examined these claims, reviewed the evidence and concluded:

"There is overwhelming evidence that wind turbines cause serious health problems in nearby residents, usually stress-disorder type diseases, at a nontrivial rate. The bulk of the evidence takes the form of thousands of adverse event reports. There is also a small amount of systematically-gathered data. The adverse event reports provide compelling evidence of the seriousness of the problems and of causation in this case because of their volume, the ease of observing exposure and outcome incidence, and case-crossover data. Proponents of turbines have sought to deny these problems by making a collection of contradictory claims including that the evidence does not "count", the outcomes are not "real" diseases, the outcomes are the victims' own fault, and that acoustical models cannot explain why there are health problems so the problems must not exist. These claims appeared to have swayed many non-expert observers, though they are easily debunked."

3.2.3. The weight of epidemiological evidence is that wind turbine noise adversely effects health at distances of at least 1.5km.

3.3. Expert opinion

3.3.1. The opinions on setback distances for 17 groups of scientists, legislators and acousticians are shown in Table II (Hanning 2010). The mean (range) setback distance recommended is 2.08km (1-3.2). Other recommendations are given in the text.

3.3.2. Thorne, an Australian acoustician who has investigated wind turbine and their health effects concludes: *"A sound level of LAeq 32 dB outside a residence and above an individual's threshold of hearing inside the home* *are identified as markers for serious adverse health effects affecting susceptible individuals."* (Thorne 2011).

3.3.3. The weight of expert opinion is that wind turbine noise adversely effects health at distances of at least 1.5km.

3.4. Studies of health related effects.

3.4.1. Phipps and others (2007) surveyed 1100 New Zealand households sited up to 3.5 km from a wind farm, 604 responded. 75% of all respondents reported being able to hear the noise. Two separate developments have placed over 100 turbines with capacities from 600kW to 1.65MW in a hilly to mountainous area. It has been suggested that mountainous areas may allow low frequency noise to travel further which may explain the long distance over which the turbines were heard. This suggestion tends to be confirmed by a recent study which is detailed below for convenience.

Phipps (2007a) has reported a further analysis of this data. All subjects lived more than 2km from the turbines, 85% living within 3.5km. 13% of 284 respondents heard the turbines at night either frequently or most of the time. 42 households reported occasional sleep disturbance from turbine noise and 26 were disturbed either frequently or most of the time. Phipps concludes that the (1998) New Zealand Standard for Wind Turbine Noise should be modified so that "the sound level from the wind farm should not exceed, at any residential site, and at any of the nominated wind speeds, the background sound level (L_{95}) by more than 5 dBA, or a level of 30 dBA L_{95}, whichever is less."

3.4.2. Van den Berg (2004) found that residents up to 1900 m from a wind farm expressed annoyance with the noise, a finding replicated in his more recent study reported below. Dr Amanda Harry (2007), a UK GP, conducted surveys of a number of residents living near several different turbine sites and reported a similar constellation of symptoms from all sites. A study of 42 respondents showed that 81% felt their health had been affected, in 76% it was sufficiently severe to consult a doctor and 73% felt their life quality had been adversely impacted. This study is open to criticism for its design which invited symptom reporting and was not controlled. While the proportion of those affected may be questioned it nevertheless indicates strongly that some subjects are severely affected by wind turbine noise at distances thought by governments and the industry to be safe.

3.4.3. Project WINDFARMperception. van den Berg and colleagues (2008) from the University of Groningen in the Netherlands have published a major questionnaire study of residents living within 2.5km of wind turbines, Project WINDFARMperception. A random selection of 1948 residents were sent a similar questionnaire to that used by Pedersen in her studies in Sweden (2003, 2004, 2007 and 2008), questions on health, based on the validated General Heath Questionnaire (GHQ), were added. 725 (37%) replied which is good for a survey of this type but, nevertheless, may be a weakness. Non-respondents were asked to complete a shortened questionnaire. Their responses did not differ from full respondents suggesting the latter are representative of the population as a whole.

Questions on wind turbine noise were interspersed with questions on other environmental factors to avoid bias. The sound level at the residents' dwellings was calculated, knowing the turbine type and distance, according to the international ISO standard for sound propagation, the almost identical Dutch legal model and a simple (non spectral) calculation model. The indicative sound level used was the sound level when the wind turbines operate at 8 m/s in daytime -that is: at high, but not maximum power. Ground absorption was set to 1.0, a 100% sound absorbing surface. Typical values are around 0.5 and thus the sound levels may have been under-estimated. Noise exposure ranged between 24 and 54dB LAeq. It is worth noting that the wind industry was approached for assistance in the research but refused. Complaints such as annoyance, waking from sleep, difficulty in returning to sleep and other health complaints were related to the calculated noise levels.

Relevant conclusions include. *"Sound was the most annoying aspect of wind turbines"* and was more of an annoyance at night. Interrupted sleep and difficulty in returning to sleep increased with calculated noise level as did annoyance, both indoors and outdoors. Even at the lowest noise levels, 20% of respondents reported disturbed sleep at least one night per month. At a calculated noise level of 30-35dB LAeq, 10% were rather or very annoyed at wind turbine sound, 20% at 35-40dB LAeq and 25% at 40-43dB LAeq, equivalent to 38-41dB LA_{90}, less than the permitted minimum ETSU-R-97 night time level.

Project WINDFARMperception further found that *"Three out of four participants declare that swishing or lashing is a correct description of the sound from wind turbines. Perhaps the character of the sound is the cause of the relatively high degree of annoyance. Another possible cause is that the sound of modern wind turbines on average does not decrease at night, but rather becomes louder, whereas most other sources are less noisy at night. At the highest sound levels in this study (45 decibel or higher) there is also a higher prevalence of sleep disturbance."* The lack of a control group prevents this group from making firmer conclusions about turbine noise and sleep disturbance but it is clear that any guidance which permits an exterior night time noise level of 45dB will guarantee disturbed sleep for many of those living nearby.

van den Berg concluded also that, contrary to industry belief, road noise does not adequately mask turbine noise and reduce annoyance and disturbance. In addition, the authors compared their results with studies by Miedema on the annoyance from road, rail and air related noise. Wind turbine noise was several times more annoying than the other noise sources for equivalent noise levels (**Fig 3**). Similar data is given by Pedersen (2004) (**Fig 4**) – **see end of text**.

With regard to health it was concluded that: *"There is no indication that the sound from wind turbines had an effect on respondents' health, except for the interruption of sleep. At high levels of wind turbine sound (more than 45* *dB(A)) interruption of sleep was more likely than at low levels. Higher levels of background sound from road traffic also increased the odds for interrupted sleep. Annoyance from wind turbine sound was related to difficulties with falling asleep and to higher stress scores. From this study it cannot be concluded whether these health effects are caused by annoyance or vice versa or whether both are related to another factor."* The conclusions regarding general health are not justified from the data for the reasons given below and must be disregarded.

Project WINDFARMperception is currently the largest study in this field but the study is not without considerable flaws. The study may be criticised for using calculated noise levels and for not having a control group (residents not living near turbines). While several of the contributors have expertise in the investigation of health matters, none has specific expertise in the physiology and pathophysiology of sleep. The purpose of the study, as its title suggested, was the public perception of wind turbines and their noise. Health questions were added but were of a very general nature. The small number of respondents suggests that any conclusions as to the apparent lack of an effect on health must be regarded as tentative.

The analysis of reported sleep interruption and wind turbine sound levels is flawed by the use of subjects exposed to calculated external turbine sound levels of <30dB(A) (p53) as the "controls". It has been noted by several studies that calculated turbine noise is often less than measured noise and that levels as low as 30dB(A) can cause annoyance (Pedersen 2007). Examination of the odds ratio for different calculated sound levels (van den Berg Table 7.42) shows that it increases progressively with increasing sound levels starting at 30-35dB(A) and becomes statistically significant for levels >45dB(A). If, as is not impossible, the "control" group had its sleep disturbed by wind turbine noise then the actual effect would be underestimated.

The major objection to the conclusions on health is that the study is grossly under-powered (insufficient subjects were studied for any degree of statistical confidence). Marked ill-health, “Wind turbine syndrome”, to the degree reported by Pierpont (2009), does not seem to be common even amongst those exposed to high noise levels. The study tried to detect chronic disease with the GHQ, which is a fairly crude instrument. Assuming that “wind turbine syndrome” affects 1% of those exposed to calculated sound levels >45dB(A) and that 25% of the general population suffer from chronic disease (p47) then at least 30,000 subjects would need to be studied in each group (>45dB(A) v <30dB(A)) to be able to prove a difference with 95% certainty. Even if a prevalence of “wind turbine syndrome” of 5% of those exposed to >45dB(A) is assumed, then there must be at least 1250 subjects in each group. It is possible also that those with a degree of ill health are more vulnerable and more likely to develop symptoms. A general health questionnaire will not detect such people and symptom specific surveys will be required. This study therefore can not conclude that wind turbines do not cause ill health of any degree, it can not even make conclusions about severe ill health.

3.4.4. Pedersen, van den Berg and others (Pedersen 2009a&b) have further analysed the data in an attempt to model a generalised dose-response relationship for wind turbine noise. A noise metric, Lden, was calculated. Lden is based on long-term equivalent sound pressure levels adjusted for day (d), evening (e) and night). Penalties of 5 and 10dB are added for evening and night hours respectively to reflect the need for quietness at those times. dB(A) LAeq values for wind turbines may be transformed to Lden values by adding 4.7±1.5 dB (van den Berg 2008). Annoyance is used as the principal human response to wind turbine noise in this analysis. In this context, “annoyance” is more than simply irritation but is a measure of lack of well-being in a wider sense (Pedersen 2009a) and is contrary to the WHO definition of health.

Annoyance increased with increasing sound levels, both indoors and outdoors. The proportion who were rather and very annoyed at different sound levels are shown in Table I. In summary, when outside, 18% were rather or very annoyed at sound levels of 35-40 and 40-45 dB LAeq compared to 7% at 30-35dB LAeq and 2% at <30dB LAeq. When inside, the equivalent figures were 1% at <30dB LAeq, 4% at 30-35dB LAeq, 8% at 35-40dB LAeq and 18% at 40-45dB LAeq. Those respondents who had an economic interest in the turbines had lower levels of annoyance while negative views of the visual impact of turbines increased the likelihood of annoyance.

Although the authors do not seek to recommend minimum sound levels, they do note that turbine noise was more annoying than other sources, with the possible exception of railway shunting yards and was more noticeable at night. They conclude that: *"...night time conditions should be treated as crucial in recommendations for wind turbine noise limits."* Nevertheless, it is clear from this analysis that external predicted turbine sound levels should be less than 35dB LAeq (33dB LA_{90}), considerably less than those permitted by most guidance/regulations, in order to reduce effects on nearby residents to acceptable levels.

3.4.5. Pedersen (2009a&b) has recently combined the datasets from three studies (Pedersen 2004 (SWE00)) and 2007 (SWE05) and van den Berg 2008 (NL07)) as they used similar questionnaires giving a total of 1764 subjects. A strong correlation was seen in all studies between calculated A weighted sound pressure levels and outdoor annoyance as noted above.

Even at sound pressures of 30-35 dB LAeq, 5-12% of subjects were very annoyed. Correlations were found also between annoyance and symptoms of stress (headache, tiredness, tension and irritability) confirming that "annoyance" is more than irritation and is a marker of impaired health. The sleep disturbance question did not ask causation of the sleep disturbance and a background level would therefore be expected from other causes (traffic noise, weather, etc). Nevertheless, there was a clear increase in levels of sleep disturbance with A-weighted sound pressure in studies SWE00 and NL005. (Figure 5, See end of text). Pedersen states *"In the first Swedish study (SWE00) the increase of respondents that reported sleep interruption appears to be between the sound level interval 35-40 dB(A) and*

40-45 dB(A). The increase came at higher sound levels in the Dutch study (NL07); between the interval 40-45 dB(A) and >45 dB(A)". All values are LAeq. There is no true measurement of background levels of sleep disturbance as no study had a control group, it is difficult therefore to determine at what sound pressure level turbine noise begins to have an effect. but even the conservative levels suggested above are less than those permitted by most guidance.

3.4.6. The weight of evidence of the health related consequences of wind turbine noise is that it adversely effects health at distances of at least 1.5km.

3.5. Sleep disturbance and health effects.

3.5.1. The Pedersen and van den Berg studies cited above, showed that a significant proportion of receptors are affected at noise levels less than those permitted by EPA guidance, even though they used an insensitive measure of sleep disturbance. The studies by Shepherd and Nissenbaum and colleagues show convincingly that wind turbine noise levels permitted under EPA guidance have a serious adverse effect on sleep.

3.5.2. Dr Daniel Shepherd, (2011) a psychoacoustician from the University of Auckland, New Zealand, has published, in a peer reviewed journal, a case-control study of the health status of residents living within 2km of the Makara windfarm. Health related quality of life (HRQoL) was measured using the WHO QOL-BREF which has four subscales, physical, including sleep, psychological, social and environmental. The questionnaire was disguised as a general health survey by adding questions on neighbourhood problems, amenity and noise and air pollution annoyance as distractors.

34% (39) of those living within 2km of the Makara turbines responded and were compared with 158 subjects from a socio-economic matched group who lived at least 8km from a turbine. Examination of a map of the area (Shepherd 2011, page 335) shows that the residences are between 800m and 2km from the turbines, the mean being about 1.4km. While noise levels were not measured simultaneously with the study, earlier measurements showed outdoor noise levels of between 20 and 50dBA $L_{95(10min)}$ depending on meteorological conditions.

The turbine group had significantly lower (*P* = 0.017) mean physical HRQOL domain scores than the comparison group. This was due to a difference in perceived sleep quality between the two areas (*P* = 0.006) and between self-reported energy levels (*P*= 0.028). The turbine group had significantly lower (*P* = 0.018) environmental QOL scores than the comparison group. The turbine group considered their environment to be less healthy ($P < 0.007$) and were less satisfied with the conditions of their living space (*P* = 0.031). Thirdly, mean ratings for an overall quality of life item was significantly lower (*P* =0.019) in the turbine group.

There were no differences between groups for traffic or neighbourhood annoyance. A comparison between ratings of turbine noise was not possible, but the mean annoyance rating for turbine group individuals who specifically identified wind turbine noise as annoying (*n*=23) was 4.59 (SD = 0.65), indicating that the turbine noise was perceived as extremely annoying.

This carefully conducted, controlled peer-reviewed study clearly demonstrates that living within 2km of wind turbines is harmful to health. To quote the authors: *"Demonstrably, our data have also captured the effects of wind turbine noise on sleep, reinforcing pervious studies suggesting that the acoustic characteristics of turbine noise are well suited to disturb the sleep of exposed individuals."* and *"..we conclude that night-time wind turbine noise limits should be set conservatively to minimise harm and, on the basis of our data, suggest that setback distances need to be greater than 2km in hilly terrain."*

3.5.3. Botha (2011) reports on sound monitoring carried out at the Makara wind farm. He notes that noise complaints were received immediately after the site became operational in 2009. The operators adjusted the turbines to reduce the tonal character of the noise shortly thereafter. Botha states that the sound levels recorded were within those permitted by the then current New Zealand standard. It is important to note that Shepherd's study was conducted **after** the adjustments to the turbines that were intended to eliminate noise complaints and that the sleep and health impairments occurred at levels permitted by NZ standards which are lower than those permitted in many jurisdictions.

3.5.4. Nissenbaum (2010) has presented the preliminary results of a study of residents living downwind and within 300-1100m (mean 800m) of a wind farm at Mars Hill, Maine, USA. The 28 1.5MW turbines are sited on a 200m high ridge overlooking the homes. 22 of about 35 adult residents have been interviewed so far and compared with a randomly selected control group living a mean 6km away. 18/22 reported new or worsened sleep onset disturbance at least twice a week, for 9 at least 5 times per week (controls 1/28). 8/22 reported new or worsened headaches (controls 1/28) and 18/22 reported new or worsened mental health symptoms (stress 12/22, anger 18/22, anxiety 8/22, hopelessness 12/22, depression 10/22) (controls 0/28).

The 22 subjects received 15 new or increased prescriptions from their physicians in the 18 months between the start of turbine operation and the study, the majority for psychoactive medication (controls 4 prescriptions, none for psychoactive medication). 21/22 reported reduced quality of life and 20/22 considered moving away (controls 0/28 for both).

As a result of the complaints, noise monitoring during turbine operation was undertaken at the community test sites at which background noise monitoring and calculated turbine noise levels had been derived during the planning stage. The residents surveyed generally lived between the 40-45dB contours, two lived within the 45-50dB contours. Noise control regulations in Maine call for test sites to be more than 500ft from "protected properties". Six test sites are relevant to the study group and the results are given below.

Site No.	Model estimate (dB)	Range of measured sound levels (dB)
1	51	42-52
5	39	39-40
6	43	39-45
6A	42	38-44
7	40	39-44
8	47.5	41-50

It can be seen that model estimates generally underestimated the actual maximum noise levels by between 1 and 4dB. It is clear that the majority of residents were living at distances and sound levels that would be permitted under most guidance/regulations but nevertheless report high levels of sleep disturbance and health impairment.

The study may be criticised for its relatively small numbers of subjects but the presence of a control group, well matched for age and gender, adds considerable power. All differences between the groups are statistically highly significant. The turbine noise levels may be enhanced by the high concentration of turbines and the geography but the severe sleep disturbance, psychiatric symptomatology and increased medication requirement in the study group confirms the potential of wind turbine noise to adversely affect health at distances claimed to be safe.

3.5.4. A second study, published in a peer-reviewed journal (Nissenbaum et al. 2012) was conducted at two sites, Mars Hill and Vinalhaven, Maine, USA. In contrast to Mars Hill, the Vinalhaven site comprises three 2.5MW turbines on a flat tree covered island.

A questionnaire was offered to all residents meeting inclusion criteria living within 1.5 km of an IWT and to a random sample of residents meeting inclusion criteria living 3 to 7 km from an IWT between March and July of

2010. The questionnaire comprised validated instruments relating to mental and physical health (SF-36v2) (QualityMetric Inc.), sleep disturbance (Pittsburgh Sleep Quality Index (PSQI) and the Epworth Sleepiness Scale (ESS), in addition to headache functional inquiry questions and a series of attitudinal questions relating specifically to changes with exposure to IWT noise. The PSQI asks a series of questions about sleep and daytime functioning over the preceding few weeks to give an overall score of sleep quality. The ESS asks subjects to rate their likelihood, over the past few weeks, of falling asleep in eight situations on a 0-3 scale. A typical score is about 5 and scores >10 are deemed significantly sleepy.

33 and 32 adults were identified as living within 1,500 m of the nearest IWT at the Mars Hill (mean. 805 m, range 390-1,400) and Vinalhaven sites (mean 771 m range 375-1,000) respectively. 23 and 15 adults at the Mars Hill and Vinalhaven sites respectively completed questionnaires. Recruitment of control group participants continued to approximately the same number as study group participants, 25 and 16 for Mars Hill and Vinalhaven respectively.

There were no significant differences between the groups with respect to household size, age, or gender.

Table 1. Demographic data

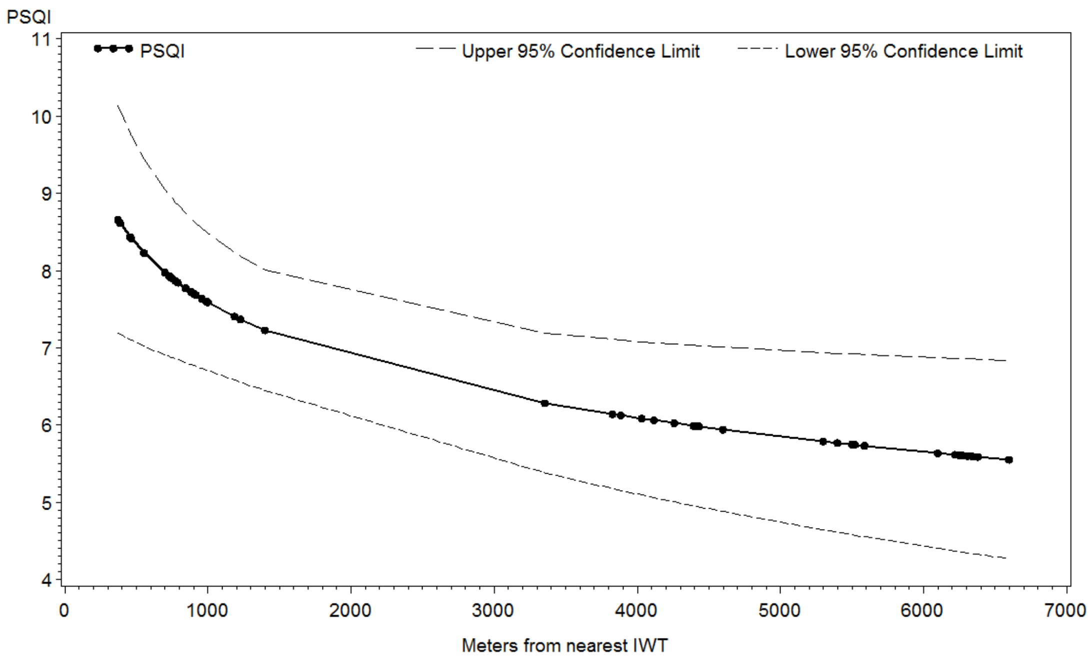
	Distance range from residence to nearest IWT (mean) in meters			
Parameter	375-750 (601)	751-1,400 (964)	3,300-5,000 (4,181)	5,300-6,600(5,800)
Sample size	18	20	14	27
Household clusters	11	12	10	23
Mean age	50	57	65	58
Male/Female	10/8	12/8	7/7	11/16

The study group had worse sleep as evidenced by significantly higher mean PSQI and ESS scores and a greater number with PSQI >5 (Table 2). More subjects in the study group had ESS scores >10 but the difference did not reach statistical significance (p=0.1313). The study group had worse mental health as evidenced by significantly higher mean mental component score of the SF36. There was no difference in the physical component scores.

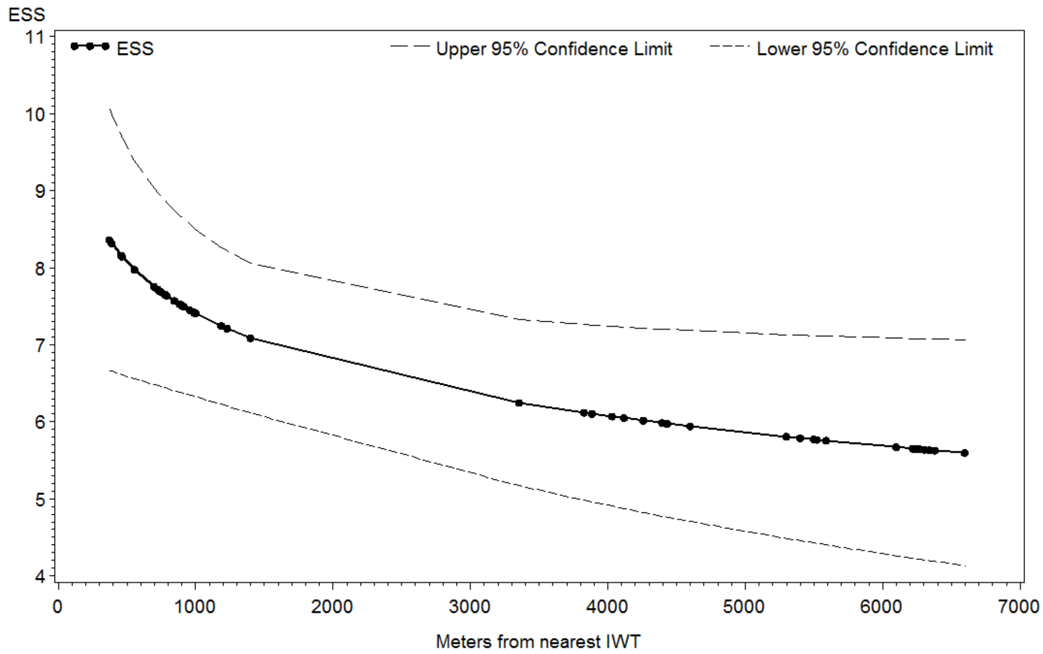
Table 2. Sleep and mental health parameters

Parameter	Distance to IWT: Range (mean) m		p
	375-1,400 (792)	3,000-6,600 (5,248)	
PSQI Mean (LSmean)	7.8 (7.6)	6.0 (5.9)	0.0461
% PSQI >5	65.8	43.9	0.0745
ESS Mean (LSmean)	7.8 (7.9)	5.7 (5.7)	0.0322
% ESS >10	23.7	9.8	0.1313
SF36 MCS Mean (LSmean)	42.0 (42.1)	52.9 (52.6)	0.0021

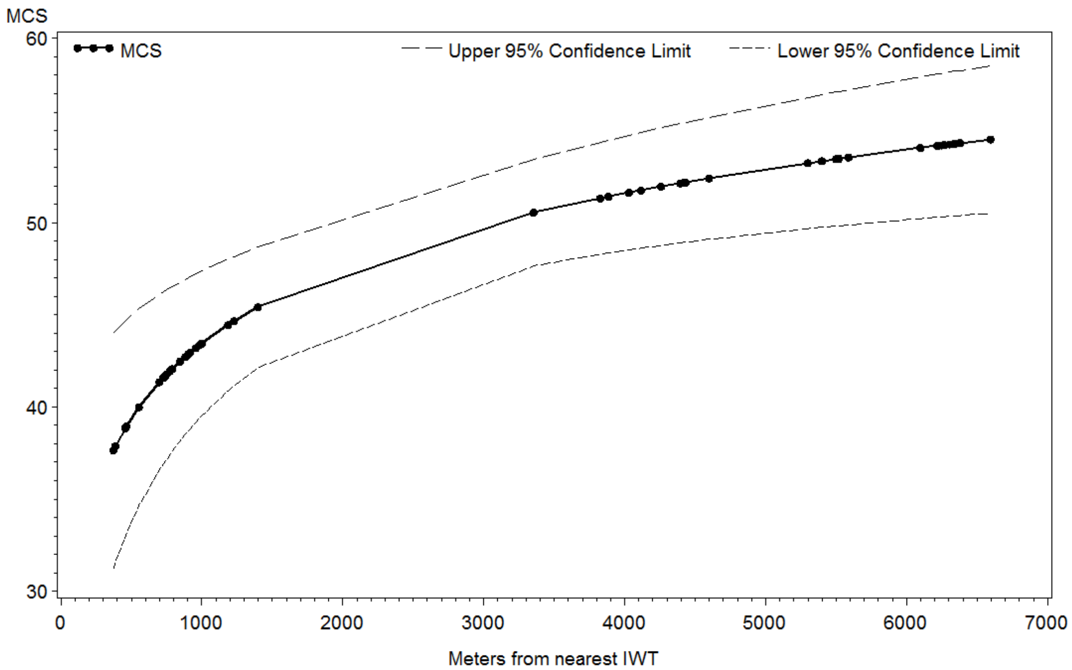
ESS, PSQI and SF36 scores were modeled against distance from the nearest IWT using the equation: Score = ln(distance) + gender + age + site [controlled for household clustering] and are shown in Graphs 1-3. In all cases, there was a clear and significant relationship with the effect diminishing with increasing distance from the IWT.



Graph 1. Modeled PSQI vs Distance. (mean, 95 % confidence limits), p-value=0.0198



Graph 2. Modeled ESS vs Distance (mean, 95 % confidence limits), p-value=0.0331



Graph 3. Modeled SF36 MCS vs Distance (mean, 95 % confidence limits), p-value=0.0014

Those living within 1.4km of IWT suffered sleep disruption which is sufficiently severe as to affect their daytime functioning and mental health.

Both the ESS and PSQI are averaged measures, i.e. they ask the subject to assess their daytime sleepiness and sleep quality respectively, over a period of several weeks leading up to the present. For the ESS to increase, sleep must have been shortened or fragmented to a sufficient degree on sufficient nights for normal compensatory mechanisms to have been overcome. It must be concluded that at least some of the residents living near the Vinalhaven and Mars Hill IWT installations have suffered serious harm to their sleep and health.

Both studies have been accepted for publication in peer reviewed journals and have been presented at a major international meeting on noise and health, ICBEN 2011 (Nissenbaum 2011). Peer review by the organising committee of the meeting led to acceptance and allocation to oral presentation rather than poster presentation. In addition, the data was presented as evidence to the Kent Breeze Environmental Review Tribunal, Ontario, Canada where it was subjected to intense scrutiny by experts commissioned by the developers, Suncor, and the Ontario Ministry of the Environment. This scrutiny exceeded by a considerable margin the degree of peer-review undertaken by academic journals which rarely, if ever, examine the raw data and the calculations as occurred here. The tribunal concluded: *"This case has successfully shown that the debate should not be simplified to one about whether wind turbines can cause harm to humans. The evidence presented to the Tribunal demonstrates that they can, if facilities are placed too close to residents. The debate has now evolved to one of degree."* (p. 207).

The Tribunal was required to find that "serious" harm be caused to receptors, a requirement of Ontario law, before allowing the appeal. While it was convinced that harm occurs, it could not be persuaded that it met the definition of "serious". The wind farm commenced operations in May 2011 and the first law suit by residents has already been filed (Seglins 2011). The affected family who live 1.1km from the turbines claim *"the wind turbines have caused debilitating vertigo, sleep disturbance, headaches and ringing in the ears, as well as stress, depression and even suicidal thoughts."*

3.5.5. The weight of evidence from investigations of the effects of wind turbine noise on sleep and health is conclusive that it causes adverse effects at distances of at least 1.5km.

3.6. Conclusions

It is abundantly clear that wind turbine noise adversely effects sleep and health at setback distances and noise levels commonly permitted in most jurisdictions. There is no evidence at all that wind turbines are safe at these distances and noise levels, not a single study. In contrast there is an increasing volume of studies outlined here to the contrary.

4 Contrary views

4.1. The ACANWEA publication (Colby, 2009) is cited commonly to justify assertions of the lack of health effects of wind turbine noise. The quality and authority of this review and its conclusions are open to considerable doubt (Horner, 2012). The medical members of the panel comprised a microbiologist, an otolaryngologist and an occupational health physician specialising in respiratory disease. From their biographies, none seems to have any expertise in sleep medicine or in psychology. The reference list shows that the literature review was far from complete. The panel admits that wind turbine noise causes annoyance which can lead to sleep disturbance but dismisses these findings. It is clear that they did not understand the significance of "annoyance" in a health context and neither did they comprehend the importance of sleep disturbance in causing ill-health.

The UK NHS Knowledge Service reviewed the paper (NHS 2010) and concluded: *"This research is unlikely to resolve the controversy over the potential health effects from wind turbines. This is mainly because the research on which the review was based is not sufficient to prove or disprove that there are health effects. The review itself also had some methodological shortcomings, and the reviewing group did not include an epidemiologist, usually a given for assessing potential environmental health hazards. Further research on this issue is needed."*

The Society for Wind Vigilance (Society for Wind Vigilance, 2010a&b) has reviewed the ACANWEA paper, publishing a detailed critique and concluded: *"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 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."*

It is clear that the Colby report is not to be relied upon. It was inaccurate and incomplete when written, with the publication of the evidence cited in this report it is evident that it is no justification for the harm proposed at the Straboy site. My recent peer-reviewed editorial in the British Medical Journal (Hanning, 2012) with Professor Alun Evans, Queen's University, Belfast, gives a balanced assessment of the current evidence and is quoted more fully above.

4.2. Professor Simon Chapman of Sydney University has contended that the symptoms associated with wind turbine noise are a result of hysteria and suggestion. A recent opinion published in New Scientist expresses his position (Chapman 2012). His assertions regarding the causation of the health effects of wind turbine noise are merely that, assertions. No evidence exists to support them. In contrast, there is a mass of hard evidence, summarised above which establishes a clear causal link between wind turbine noise and adverse effects on sleep and health.

Professor Chapman refers to a long list of symptoms which he claims have been attributed to wind turbine noise, many of which he regards as being unlikely to be so related, and asserts that such is proof that wind turbine noise does not affect health. The logical fallacy in this argument is self evident. To follow the same logic, because doubts have been raised over the evidence regarding the adverse effects of passive smoking, we should disregard all the evidence of the adverse effects of smoking and permit tobacco advertising in all its forms. Such an approach is clearly irrational as the evidence in favour of the adverse effects of cigarette smoking is solid as is the evidence in favour of the adverse effects of wind turbine noise set out above.

Professor Chapman makes much of a list he has compiled of 17 reviews which, in his opinion, support his assertions. Again, the list does not stand up to careful scrutiny. All of those dated prior to 2011 can be discounted as they are not up to date and do not consider the latest research. The Bolin paper accepts the effects of wind turbines on sleep and health but does not find the role of LFN proven. Bolin states: *"Wind turbine noise is causing noise annoyance and possible also sleep disturbance, which means that one cannot completely rule out effects on the cardiovascular system after prolonged exposure to wind turbine noise, despite moderate levels of exposure".* The Fiumcelli paper attempts to create a noise-effect dose response curve for wind turbine noise but uses inappropriate outcome measures (Hanning 2011). The Oregon paper concludes:

"Sound from wind energy facilities in Oregon could potentially impact people's health and well-being if it increases background sound levels by more than 10 dBA, or results in long-term outdoor community sound levels above 35-40 dBA. The potential impacts from wind turbine sound could range from moderate disturbance to serious annoyance, sleep disturbance and decreased quality of life.

Chronic stress and sleep disturbance could increase risks for cardiovascular disease, decreased immune function, endocrine disorders, mental illness, and other effects. Many of the possible long-term health effects may result from or be exacerbated by sleep disturbance from night-time wind turbine sound."

The 2012 Massachusetts paper is still in draft form. It is the only review to include a sleep specialist on the review panel. It has not been subject to independent review. Serious doubts have been raised about the independence of the panel and the methodology. The panel only met three times and the objectivity and even-handedness of the review process have been widely questioned. I have attached a copy of my submission which sets out my objections (Hanning 2012a). No definitive version of the review has been released and the published draft can therefore not be relied upon.

In summary, Professor Chapman's opinions do not constitute a serious rebuttal of the detailed, peer reviewed evidence set out above and summarised in my very recent BMJ editorial.

5. Conclusions

There is no published experimental evidence that wind turbines are safe with respect to sleep disturbance and health at the distances and noise levels permitted in Australia. Not a single paper can be offered, merely unsubstantiated assertions and assumptions. In contrast, there is good evidence, described above, that people living with 1.5km of industrial wind turbines are at significant risk of disturbance to their sleep and consequent effects on their health.

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Figure 1. Arousal probability threshold curve for non-REM2 (light sleep). X axis signifies A-weighted equivalent sound level measured over 10-seconds. From Solet 2010.

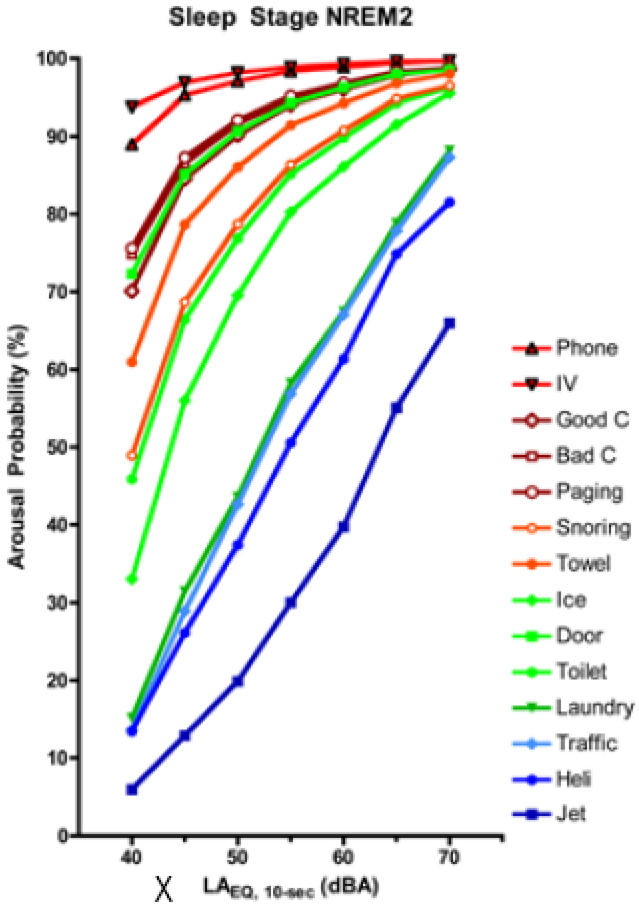


Figure 2. Spindle rate and sleep stability. Observations were pooled among subjects in the lower and upper halves of the spindle rate distribution (ranges 4.57-5.44 and 5.58-6.14 spindles/min respectively) based on EEG lead C3 during stage N2. Corresponding sleep survival curves were derived from each pool in stage N2 using the Kaplan-Meier (product-limit) method.

Backward extrapolation of the response curve for low spindle rate subjects shows only a 50% likelihood of stable sleep at noise levels of 35 dB(A) and 75% likelihood for those with high spindle rates. From Dang-Vu et al., 2010

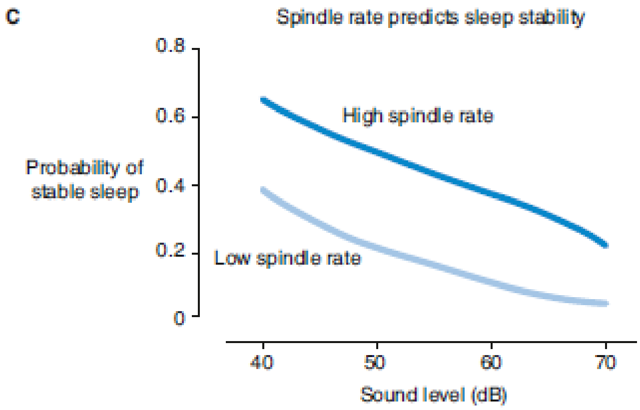


Figure 3. Sound level and annoyance for different noise sources (van den Berg 2008)

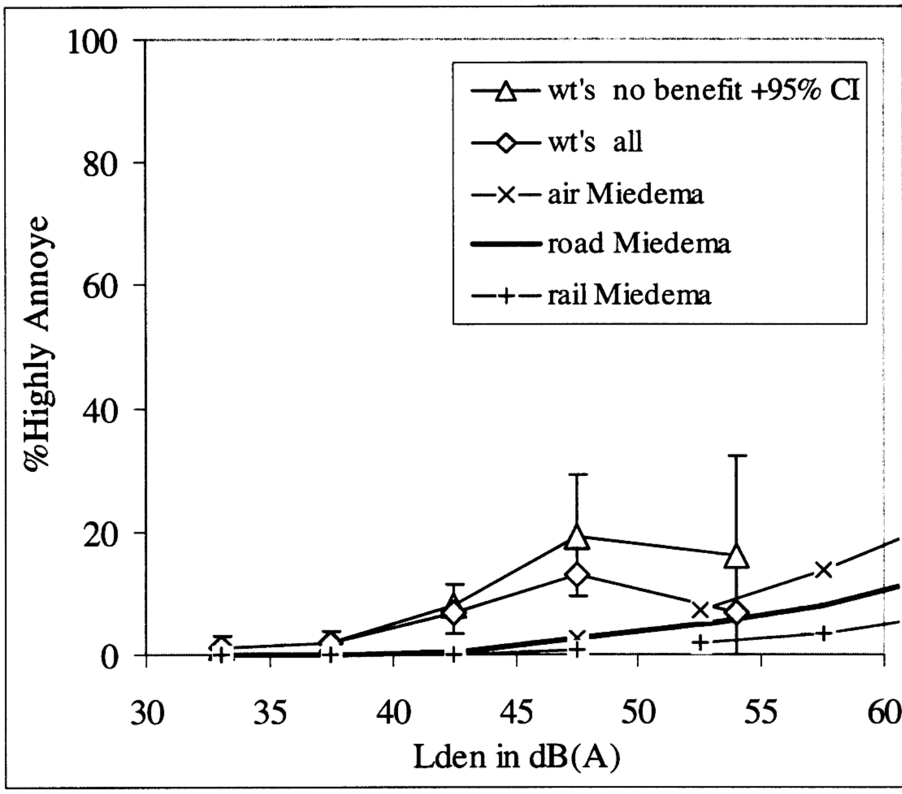
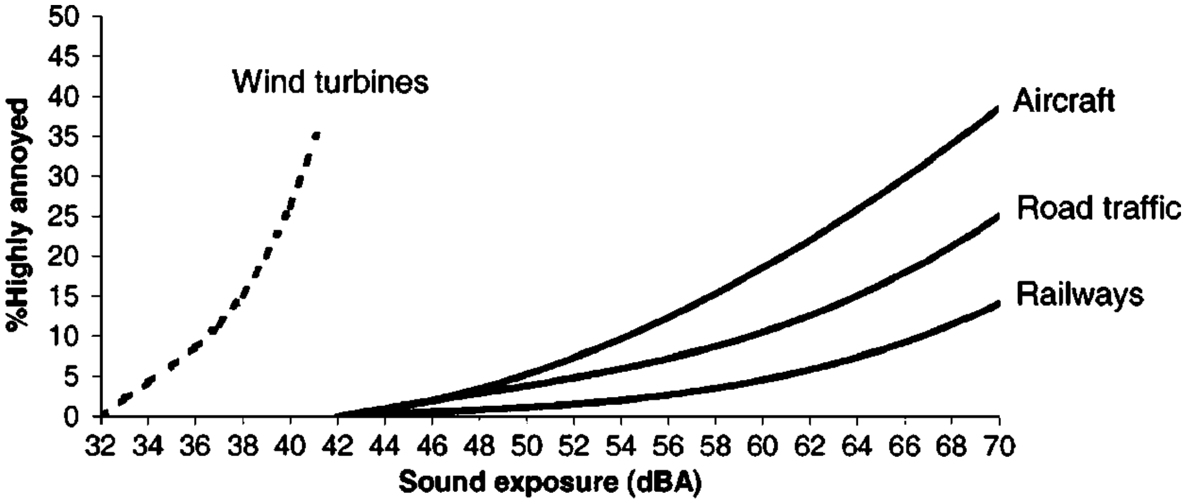


Figure 8.1: relation between sound level Lden and percentage highly annoyed residents exposed to that sound, for three transportation noise sources and for wind turbines; the relation is given for all respondents and for those that have no economical benefit from a wind turbine.

Bars denote 95% confidence interval for non-benefitters.

Figure 4. Sound level and annoyance for different noise sources (Pedersen E and Persson Waye, 2004)



Sound exposure is for wind turbines calculated A-weighted L_{eq} for a hypothetical time period and for transportation DNL.

Figure 5. Relationship between A-weighted sound pressure levels (equivalent levels at wind speed 8 m/s, 10 m over the ground) and proportion of respondents disturbed in the sleep by noise in three studies: SWE00 (*n* = 341), SWE05 (*n* = 746) and NL07 (only respondents that did not benefit economically from wind turbines; *n* = 593). (Pedersen 2009)