SUBMISSION

SENATE STANDING COMMITTEES
on
ENVIRONMENT & COMMUNICATIONS

THE RENEWABLE ENERGY (ELECTRICITY) AMENDMENT (EXCESSIVE NOISE FROM WIND FARMS) BILL 2012

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November 2012

SUBMISSION TO:

Committee Secretary
Senate Standing Committees on Environment and Communications
PO Box 6100
Parliament House
Canberra, ACT 2600

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STATEMENT OF SUPPORT

We support the proposed amendments to the Renewable Energy (Electricity) Amendment (Excessive Noise from Wind Farms) Bill 2012.

In supporting this Bill we also make the statement:

1. It is important and necessary that the powers of the Regulator include the directive to ensure that accredited wind power generators, either in whole or in part, do not create excessive noise.

2. It should be mandatory that the Regulator withdraw accreditation in the event that the wind power creates excessive noise. Such withdrawal of accreditation should include the non-payment of any associated government payments and subsidies.

3. It is critical that the definition and measurement of "excessive noise" be comprehensive and appropriate, and that it takes into account low frequency noise and infrasound, for the reasons laid out in this document.

4. It is crucial that continuous real-time full spectrum noise monitoring be placed on the appropriate Regulator's website for the public to access.

5. The Government must not financially support or subsidise any industry that is in breach of the law by exceedingly the regulatory guidelines for that industry. This is especially important with respect to wind generation because continuing breach of the regulations may damage human health.

6. The Government's duty of care to its citizens must transcend all other considerations and where doubt exists or the science is unproven then the World Health Organisation (WHO) principles prudently dictate that the precautionary principle must apply.

EXECUTIVE SUMMARY

1. The definition for “excessive noise” accepts the limit as background noise plus 10 dB(A). This is far too high. Recall that an additional 10 dB(A) will double the human perception of sound. Even the stipulated limits in guidelines currently in use in Australia set a limit of background noise plus 5 dB(A)[1,2,3]

2. It is illogical to measure noise using the criteria of dB(A) when it so conclusively excludes or minimises the measurement of low frequency noise and infrasound (ILFN). With the research increasingly demonstrating the importance of ILFN it critical that additional measurement criteria be made mandatory to obtain an accurate full spectrum noise profile emanating from an IWT; dB(C), dB(G) and dB(Z) measurements are also required.

3. Noise limits using these various measurement criteria should be developed and be incorporated into the operational conditions of consent for IWTs.

4. There should be a universal protocol in place with respect to noise to which operators of IWTs must adhere. This must include adequate background monitoring prior to any application for approval and modelling of sound that includes all measurement criteria listed above.

5. Compliance sound monitoring after operation commences must be comprehensive with real time data being available for public scrutiny on the appropriate Regulator’s website.

6. Sound measurements should include:

   (i) Measurements for daytime, evening and night time noise (night time noise for instance will often be quite different because of temperature inversions particularly in winter);

   (ii) In addition to noise at IWTs, or a random distance from them, there should be measurement of noise at residences, particularly where there are noise complaints. Noise received at residences will be influenced by weather conditions, wind direction, temperature, noise attenuation (depending on the frequencies emitted by the IWT), terrain, distance from IWT, and number and configuration of IWTs in proximity (debatably 2, 5 or 10 kilometres).

   (iii) Measurements should be made both outside and inside houses or relevant buildings (eg. Schools, meeting halls, work place etc). With audible noise there is considerable doubt that Australian rural homes comply with the WHO prediction that noise attenuates by 15 dB(A) between outside and inside the building; 3-5 dB(A) is considered to be a more realistic figure in the Australian context. With ILFN there is the added factor that it can penetrate the fabric of a building and also can resonate such that the noise level can actually increase.

(iv) Temperatures should be measured at IWTs and homes. Temperature inversions are more likely in a valley where homes are located compared to ridgelines where IWTs are operating.

(v) IWTs often demonstrate elements of amplitude modulation and tonality which can raise noise levels above acceptable limits and can also create greater annoyance. These need to be measured.

INTRODUCTION

Essential and fundamental to the sense and effectiveness of the bill is the definition of “excessive noise”.

The bill states “a wind farm creates excessive noise if the level of noise is attributable to the wind farm exceeds background noise by 10 dB(A) or more when measured within 30 metres of any premises:

(a) That is used for residential purposes; or
(b) That is a person’s primary place of work; or
(c) Where persons habitually congregate.”

There is now significant national and international research and disquiet indicating that an undeniable health problem exists for people whose residences are sited in close proximity to industrial wind turbines. Undoubtedly there are multifactorial causes, but the most consistently demonstrated association is that of intrusive noise both audible and inaudible. Inaudible noise is both low frequency noise and infrasound.

Infrasound, while not actively “heard” is perceived by the highly sensitive outer hair cells of the vestibular apparatus of the inner ear as a vibration. Human vibration detection is many times more sensitive than that of sound. Infrasound is sound of less than **20 Hertz** and some of the frequencies in this range are associated with synchronisation of brain waves particularly the theta waves with cycles of 5 to 8 cycles per second. The mechanism of ill health is mediated by repeated stimulation during sleep to a wakeful or alerted state resulting in chronic sleep deprivation. As with motion sickness, it appears to affect some members of the community more than others. Human hearing never sleeps, hence the disruptive nature of intrusive sound and why for, example, we use noise emitting smoke alarms at night for warning rather than some other alerting device.

There are known at-risk associations such as age (both the young and people over 50 years) and sufferers of migraine, tinnitus, motion sickness or people with previous middle ear problems, either through disease or degenerative change.

Also, adverse health effects seem to worsen with prolonged exposure to infrasound and are thus thought to be ***cumulative*** in effect.

To fully understand the relationship of industrial wind turbines (IWT) and ill health it is necessary to understand the particular characteristics of IWT noise and the physiological effects likely to be produced in human recipients. Background information is provided in the following section within an historical and current context.

INDUSTRIAL WIND TURBINES, SOUND MEASUREMENT AND HUMAN SOUND PERCEPTION

1. **Industrial Wind Turbines** (IWTs) are significant structures of human engineering. Current models consist of a tower at the top on which are three rotor blades attached by a hub to gears and a generator. These sit in a box (nacelle) at the top of the tower. The tower is anchored to a steel reinforced concrete foundation. A motor turns the nacelle to face into the wind. The blades spin upwind of the tower and blade angles are adjustable. When the rotor spins, it turns a shaft. The shaft spins magnets inside copper coils. This induces a current in the coils. The frequency and voltage of the electricity so generated is modified by circuitry and the current is transferred to the relevant Grid.

2. There has been a significant increase in the height and size of turbines since original construction. Initial tower heights were about 15 metres in the 1980's with a power output of about 50 kW. By 1990, towers were up to 40 metres, doubling to 80 metres by 2000. Power output had increased to 2000 kW. The turbines presently proposed in most developments in Australia are approximately 162 metres in overall height with tower heights of up to 100 metres and blade lengths of over 60 metres. Prototype turbines are now 193 metres in height. As the wind industry has developed with government renewable energy targets and subsidies, the variety of terrains into which the turbines have been located has extended.

3. The **human body** however, is a vastly more complex piece of engineering than an IWT. The capacity of the human organism to function depends on its capacity to react to its external and internal environment. We possess refined sensory receptors – our skin, our ears, our eyes, our motion and balance senses amongst others – which allow us to do this. These receptors transmit detailed information via our neural pathways to our brains which in turn process this information and co-ordinate our bodies' responses to it. As would be expected for survival, many of these responses occur automatically, without conscious control. Each night, we sleep and the cognitive processes of the brain are consolidated. It is not surprising, indeed it is completely predictable, that if our sensory input or our sleep is disturbed in a prolonged manner, we may, and will, become sick. Our capacity to hear persists even during sleep as opposed to other sensory modalities.

4. Operating IWTs emit sound energy which is transmitted as waves. The science of sound and its associated physics is far from simple but an understanding of the physical principles of sound and its effect on human health arising from IWT projects is central to this document.

   The spectrum of sound waves is continuous but is commonly divided into the classifications of **infrasound**, **low frequency sound**, **mid-frequency sound** and **high frequency sound**. Although variable classifications exist the one used here is after Dr Robert Thorne and consists of:

Infrasound	20 Hz and below
Low Frequencies	20 Hz to 250 Hz
Mid frequencies	250 Hz to 2000 Hz
High frequencies	2000 Hz to 20,000 Hz[4]

5. The Hertz measurement refers to the cycles per second at which the wave is travelling, (referred to as sound pressure level - **SPL**) is measured in **decibels (dB).**

6. There are a number of scales available to measure sound energy. Some of these scales give weight (i.e. give preference or filter) to particular frequencies in their measurements. The sounds of all frequencies are not heard equally well by humans.

   The **A scale** was developed to deal with **human hearing**. Most studies of community noise have accordingly used the A weighted scale. This scale weights the contributions of sound waves in the 1,000 Hz to 6,000 Hz range. It progressively **reduces** contributions from about 500 Hz down and 7,500 Hz up[5,6]. Pierpont[7] states that the effect of the weighting is to reduce sound measured by about 30 dB at 100 Hz, and about 40 dB at 31 Hz. So the A weighted scale **does not give**, or purport to give, a pure measure of frequencies outside the range of hearing of the human ear and ***increasingly*** **distorts** the contribution of lower frequencies as it moves down the spectrum[8].

7. The **C scale** captures sound equally (i.e. without weighting) over most of the audible range down to 31 Hz. After this, it has a decreasing response. The **Z scale** is an unweighted scale (sometimes called **"Lin"** or **"Flat"**) which gives an equal response to sounds between 10 Hz and 20,000 Hz in acoustical standards. The **G weighted scale** measures infrasound frequencies. Some researchers prefer the G scale for infrasound measurement although Dr Thorne uses the **Z scale** in conjunction with the C weighted scale. The following figure effectively demonstrates how the use of dBA units fails to measure infrasound frequencies.

8. The relationship between our perception of sound and the measurement of sound is interesting. If we can hear sound, we do not necessarily hear in accordance with what is measured.

9. *Firstly*, it is usual for sound measurements to be ***averaged*** over time. If the time period over which sound is measured is short, unique noise events will be captured. But over a longer period, unique events are averaged away[11]. As it is often said, the human organism does not perceive averages.

10. *Secondly*, sound is perceived against a background of other sounds. The relevance of background noise in determining the perception of noise is well recognized[12]. Sound may, in some circumstances, be masked by other sounds and we do not perceive it notwithstanding its presence. Conversely, it is widely accepted that sound is likely to be perceived more loudly if it is heard against a quieter background. ***A difference of 10 dB is perceived by human hearing as twice as loud.***

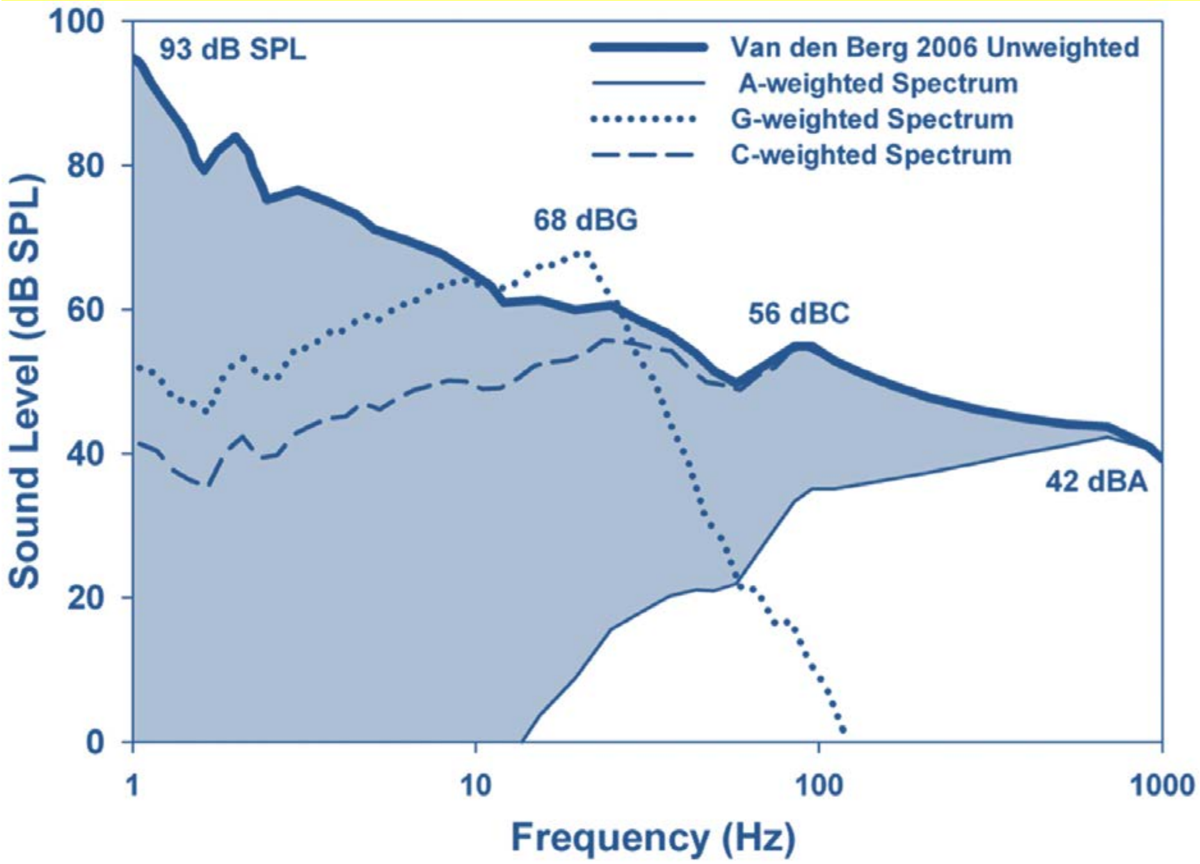

Figure 1: from Salt and Kaltenbach[9]: Low-frequency components of wind turbine sound spectrum (below 1 kHz) before and after A-weighting. The original spectrum was taken from Van den Berg (2006)[10]. The shaded area represents the degree of alteration of the spectrum by A-weighting. A weighting (i.e., adjusting the spectrum according to the sensitivity of human hearing) has the effect of ignoring the fact that low-frequency sounds can stimulate the OHC (outer hair cells) at levels that are not heard. Representing this sound as 42 dBA, based on the peak of the spectrum ignores the possibility that low-frequency components down to frequencies as low as 5 Hz are stimulating the OHC. Also shown are the spectra after G-weighting (dotted) and C-weighting (dashed) for comparison.

11. Sounds are not constant. Just as we may perceive a contrasting sound as louder than measured, we perceive increases in sound from a single sound source as **greater** than the actual change in decibels[4]. Again a 10 dB increase from a single sound source is likely to be perceived as twice as loud as the original sound.

12. Leaving aside audibility, sound waves in the **low frequency** and **infrasound frequency** ranges share characteristics which differ from sound in the **mid to higher frequencies** and which are pertinent to the IWT/adverse health debate. In particular, infrasound and low frequency sound waves **attenuate** at slower rates. They **travel further** and **fall away less quickly**. At distance, when sound emanates from a broadband source, the lower frequency components will **dominate**. Lower frequencies are less easily masked by noise in the mid to high frequency ranges[13]. Low frequency waves, with their longer wavelengths, are **<u>not effectively filtered by buildings</u>[14].** Nor is hearing protection effective[8]. The following table demonstrates the length of infrasound wavelengths.

Table 1: Infrasound Frequency and Wavelength in Metres.

Frequency (Hertz)	Wavelength (metres)	Frequency (Hertz)	Wavelength (metres)
20	17.20	3	114.60
15	22.93	2	172.00
10	34.40	1	344.00
5	68.80	0.1	3,400.00
4	86.00	0.001	344,000.00

13. In relation to the human perception of lower frequencies, low frequency sound may be audible. Older people's hearing is proportionally more acute at low frequency ranges than mid to higher frequencies[8]. Infrasound is generally regarded as **inaudible** but research has established that there is in fact a **threshold for audibility**. The World Health Organization states that noise with low frequency components requires **lower guideline values** in view of health effects being **<u>more severe</u>** than for community noises in general[37].

14. Audible or not, the ear is **sensitive to infrasound**. Recent American studies have confirmed that the ear of higher mammals responds to infrasound waves below audible levels[9,15,16,17,18,19,20]. The research suggests that this may occur in a number of ways – by stimulation of the Outer Hair Cells of the Cochlea (the Inner Hair Cells respond to sound which we hear), by affecting the ear's response to higher frequency sounds, by stimulation of the vestibular hair cells or by influencing the volume of the fluid in the inner ear (the endolymph). This research highlights that the ear is both the organ of **hearing** and the organ of **balance**. Any effect on the vestibular system will impact on the body's balance and equilibrium.

15. Note also, that sound waves are **energy waves**. In addition to allowing humans to hear when they impact on the ear, they may cause vibrations in other organs as well as in external structures. Just as low frequency noise can cause vibrations of walls or windows, the bones, organs and tissues of the body are capable of vibration and resonance also. Various organs and tissues will resonate at different frequencies

INDUSTRIAL WIND TURBINES OPERATING CHARACTERISTICS

1. What happens to sound waves and vibrations when IWTs are anchored into place in varying numbers in different locations and are "turned on"? The immediate answer is "we don't know" with any real specificity or accuracy.

   The adequacy of wind industry modelling and pre-construction predictions has been criticized in peer reviewed literature. Wind farm compliance measures are carried out by the wind industry to the **minimum extent necessary to comply** with development conditions. This means the extent of comprehensive and detailed independent studies is usually very limited.

2. When turbine blades rotate, they produce soundwaves through the broadband spectrum ranging from infrasound, through the lower frequencies and the mid and high frequencies. As the blades rotate through the air, the **pressure (amplitude)** of the waves so created **fluctuates** or changes. This is referred to as **amplitude modulation**. With audible waves we hear the modulation often described as louder/softer, louder/softer or swish/swish/swish. Some evidence indicates that this variation is heard when the blades pass from the horizontal position going down. When the blade comes up, it is passing through varying degrees of air turbulence and the change in frequency is audible as a thump or a beat[9,15,16,17,18,19,20]. The fluctuations in the sound waves are occurring across all frequencies but it is common for people living near wind farms to describe an audible "swish/thump", "swish/ thump" with variations in the "thump."

3. In relation to frequencies that are audible, **amplitude modulated** noise is more **easily perceived and more annoying** than a constant level of noise[4]. Swedish researchers have shown that audible noise from IWTs is more annoying than other kinds of industrial/transportation noise levels for this very reason[37]. Residents have been shown to be highly annoyed by wind turbine noise at 38 dBA while aircraft noise has to reach 57 dBA, and road traffic noise, 70 dBA *to produce similar annoyance*. Audible wind turbine sound waves vary in amplitude within relatively short spaces of time, and without cessation, even at night. They are likely to be far more intrusive to the central nervous system than a pure amplitude measurement would suggest.

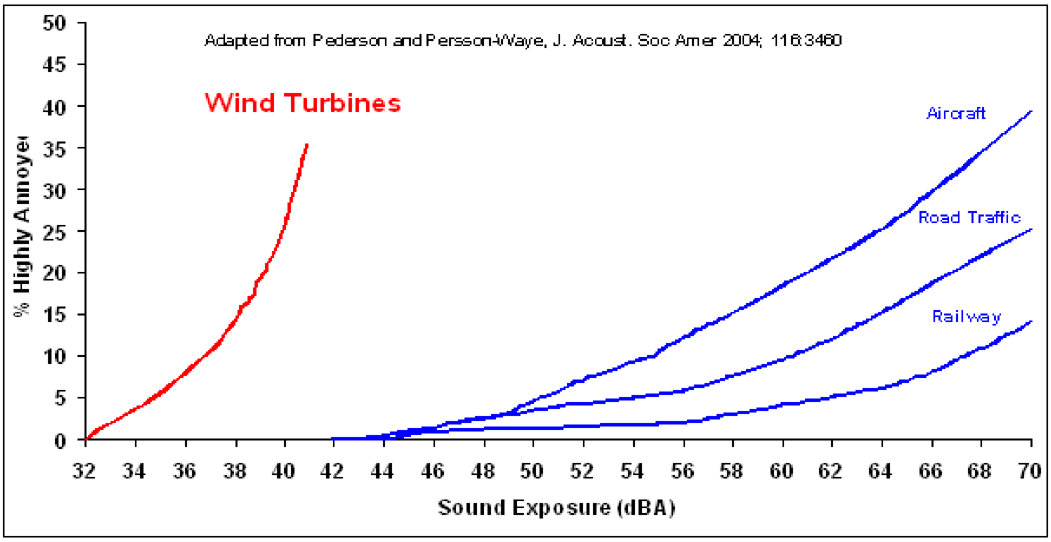

Figure 2 from Pederson and Persson-Waye[21]. The relationship between annoyance and different noise sources.

It is clear that wind turbine noise is clearly "different" from other types of noise. Compared with aircraft, automobile or rail traffic wind turbine noise at about 30 dB lower levels (40 dBA rather than 68 dB A or higher) annoys 30 % of people. There are attempts to justify the increased annoyance by other (e.g. visual) factors but the possibility remains that the noise itself could be more annoying, due to the **infrasound that is present in the noise but which is excluded from the A-weighted measurement.**

4. When multiple turbines are placed together and are operating, what is occurring to the energy waves? Dr Robert Thorne[22] suggests that with two or more turbines in phase together and a light breeze, there can be a variation (i.e. an increase) of 6 – 7 dBA arising from the synchronicity of the blades. Recall that a 10 dBA change in a sound source is likely to be perceived as twice as loud. Alternatively, if the blades are not operating in synchronicity or there is turbulence with different wind velocities and directions (a common occurrence with ridgeline wind turbines), the "thump" produced by the upward blade movement is exacerbated. The blades cannot be continuously and sufficiently adjusted to cope with the turbulence.

5. Further, Dr Thorne and others have shown that downwind from a cluster of turbines, vortices interact and sound is enhanced. Thorne describes these areas where sound is amplified as **Heightened Noise Zones (HNZ)**[22]. There can be significant variations in residences reasonably close to each other if one falls within a Heightened Noise Zone, receiving higher amplitude of waves temporarily, and the other does not. As wind directions change, so do the Heightened Noise Zones. The same residence may be in a HNZ at some times and not at others.

6. The audible amplitude can also be markedly affected by terrain. The most productive land based wind sources can be along ridge lines with houses nestled in adjacent valleys. It is along ridgelines that **noise enhancement** also occurs. Partly, this can be as simple as the fact that a house is built in an area protected from the usual wind in the area. The masking effect which the wind might otherwise have on the audible turbine noise is absent. Remember that noise perceived depends partially on background and masking noise. More importantly, wind turbine noise is enhanced by the atmospheric conditions which frequently occur in ridges and valleys. Warm air rises. At night, the air stabilizes. With a light wind blowing at turbine height, sound levels at homes 800 to 3200 metres away in the valley have been measured at 5 – 15 dBA higher than the models would otherwise suggest[22]. These conditions are likely to occur at night when families are asleep and can be prolonged with foggy, still weather or a temperature inversion (van den Berg effect).

7. All of these factors suggest that audible noise produced by IWTs can and will be **far greater** than manufacturer's specifications suggest and **compliance monitoring detects**. This fact is well known. Dr M Swinbanks, an applied mathematician with extensive experience in the theory and practice of aerodynamic sound generation, states that this was well known to NASA by 1990 [23]. NASA and their subcontractors calculated sound levels generated by ideal turbine blades operating in clean airflow and identified how, inevitably, turbulence resulted in unsteady blade loadings, thus increasing sound levels. They then extended the work to consider the effect of wind gradient (i.e. wind velocity varying with height across the face of a turbine). This generated substantially higher noise levels. Finally, they subjected people to impulsive wind turbine noise under laboratory conditions and showed that the hearing threshold could be almost 20 dB lower than the conventionally accepted noise threshold. Swinbanks has stated:

   > "During this period [i.e.1980-1990], NASA and NASA sub-contractors identified almost all of the specific issues relating to wind-turbine noise, that now is being re-learned the hard way, by bitter experience" [23]

8. It seems probable that the wind industry itself is aware of this issue. In his presentation in May 2010, Erik Sloth stated "Current modelling techniques were developed when turbine projects consisted of one or two turbines."[24] He went on to comment that in relation to new projects requiring detailed noise study including **wind speed**, **wind direction** and **directional transmission paths**, "*No modelling tools are at present available to do this kind of modelling, but tools are probably on the way*."[24]

9. The Finnish acoustics engineer, Denis Siponen has suggested that as **turbines get larger**, so will the complexities of amplitude modulation[5]. Because the blade length of modern wind turbines can be more than 60 metres, the difference in wind speed at different blade positions can be several metres per second. Growing the size of the turbines and the diameter of the blades is likely to yield increasing problems with **amplitude modulation and tonality**: "As wind turbines are still getting larger and their rated power higher, the number of complaints of wind turbine noise is also quite likely to

be increased."[5] **Blade tip speed is now in excess of 400 km. per hour and *increasing*.**

10. Concerning infrasound and low frequency sound, the picture is even more interesting. Because infrasound and low frequency sound waves attenuate at slower rates than higher frequencies, it is predictable that they **will predominate** in the sound waves produced by IWTs **at distance** – for example at 2-3 kilometres c.f. 500 metres. It is predictable that residences located at distances from operating IWTs are being exposed to low frequency sound and infrasound. We know that these waves can travel through buildings and cause walls, windows and people to vibrate. Resonations can be set up. What then are the levels of infrasound and low frequency waves actually generated by operational IWTs? **We do not know**. The wind industry measures sound on the useless **A weighted scale only.** This is consistent with current development requirements which are **now totally inadequate** and **do not safeguard public health.**

11. Available recent studies strongly indicate that low frequency and infrasound generated by IWTs are greater than previously acknowledged and likely to be greater still with increases in the height and size of turbines. Robert Thorne[4,22] uses the C weighted scale in conjunction with the Z scale.; Pedersen and colleagues[21,24] use the G scale. These studies show that the lower frequency sound waves generated by IWTs indeed **predominate at distance**. They are modulated and are present at very significant levels. By way of example, measurements taken inside a residence at Waubra, Victoria by Dr Thorne reveal that there are infrasound waves occurring in Australian residences near wind farms in the 50 to 70 dB(Z) range. There are also high levels of amplitude modulated low frequency waves which may be **audible** (as well as felt) to some individuals.

12. In his presentation to the 4th International Meeting on Wind Turbine Noise at Rome in April 2011, Dr Swinbanks presented evidence indicating that conventional techniques of assessing low frequency and infrasound waves have underestimated their impact and that typical wind turbine infrasonic and low frequency noise can be "readily audible at very much lower levels that has hitherto been acknowledged."[23] He again points out that these results are consistent with the extensive work carried out by NASA in the decade between 1980 and 1990. NASA identified and reported increases in low frequency impulsive sound patterns from modern upwind rotor configuration turbines in 1989. NASA attributed the increase to wind-gradients and shadowing effects. At the same meeting, Denis Siponen noted that the increase in the low frequency noise component with large turbines is higher than the increase in the A weighted sound levels[5]. **Larger wind turbines emit higher noise levels at low frequencies and this would seem where the future of industrial wind turbines lies.**

HEALTH AND AUDIBLE SOUND

It is an indictment of the wind energy industry that it continues with health impacts denial when there is a rapidly growing body of more recent, independent material published by respected academic researchers and medical practitioners which strongly indicates the opposite view. These health impacts are more pronounced as wind turbines become taller and more powerful with larger rotor diameters and hence sound propagation.

As stated above: In relation to frequencies that are audible, **amplitude modulated** noise is more **easily perceived and more annoying** than a constant level of noise[37]. Swedish researchers have shown that audible noise from IWTs is more annoying than other kinds of industrial/transportation noise levels for this very reason[15]. To reiterate, residents have been shown to be highly annoyed by wind turbine noise at 38 dBA while aircraft noise has to reach 57 dBA, and road traffic noise 70 dBA to produce similar annoyance. Audible wind turbine sound waves vary in amplitude within relatively short spaces of time, and without cessation, even at night. They are likely to be far more intrusive to the central nervous system than a pure amplitude measurement would suggest.

In discussing audible sound attenuation from outside a building to inside a building this is usually modelled as a reduction of 15 dB(A). Huson[26] has found that in Australia in a typical farm house it is more likely in the range of 3-5 dB (A). Cooper[26] in his measurement of noise inside and outside several houses at the NSW Capital Wind Farm found minimal differences in noise readings in a house very typical of Australian farm houses. It must be remembered that an increase of 10 dB(A) leads to a doubling in perceived noise. This has important ramifications for the accuracy in predicting noise inside residences.

Significant research has been performed on the adverse health effects of wind turbine noise[7,8,23,25,27,28,29,30,31,32,33]. The issue of the extremely adverse wind turbine noise impact on children's mental and physical health is dealt with in some detail by Bronzaft[34]. She discusses the "many studies [which] have demonstrated that intrusive noises such as those from passing road traffic, nearby rail systems, and overhead aircraft can adversely affect children's cardiovascular system, memory, language development, and learning acquisition." On the basis of this research into the adverse health effects of transportation noise she argues the need for research into the potential adverse health effects of industrial wind turbines on children's health, and on the health of their parents.

Noise is sometimes described as "annoyance" but physiological effects are concerning and include: headaches, tinnitus, ear pressure, dizziness, vertigo, nausea, visual blurring, tachycardia (rapid heart rate), hypertension, cardiovascular disease (including Tako Tsubo episodes with 3-6% mortality), irritability, confusion, reduced concentration and memory problems, panic episodes with severe depression and worsening control of pre-existing and previously stable medical conditions such as angina, diabetes.

Cappuccio et al (2011) summed up the health impacts from excessive noise[35]. One of the most significance consequences is that of sleep deprivation with physiological and psychological sequelae, including depression. A lack of sleep results in "detectable changes in metabolic, endocrine and immune pathways. Too little sleep …[is] associated with adverse health outcomes, including total mortality, type 2 diabetes, hypertension and respiratory disorders, obesity in both children and adults, and poor self-rated health. Both short and long duration sleep are predictors, or markers, of cardiovascular outcomes." It is also postulated, and with some early clinical observations, that chronic sleep deprivation may result in a clinical circumstance similar to if not identical to Post Traumatic Stress Disorder (PTSD).

Phillips[36] states in his study looking at epidemiologic evidence about the health effects of IWTs on nearby residents: "There is overwhelming evidence that wind turbines cause serious health problems in nearby residents, usually stress-disorder-type diseases, at a nontrivial rate." And further "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."

This is corroborated by McMurtry[32] in Canada: "Internationally, there are reports of adverse health effects (AHE) in the environs of industrial wind turbines .... The symptoms being reported are consistent internationally and are characterized by crossover findings or a predictable appearance of signs and symptoms present with exposure to IWT [industrial wind turbines] sound energy and amelioration when the exposure ceases. There is also a revealed preference of victims to seek restoration away from their homes."

A detailed examination of the references listed in this section, and indeed others not cited here, provides accumulating evidence that IWT noise does and will result in adverse health effects. Two conclusions are obvious:

1. Environmental assessments are usually not required to discuss health impacts and therefore this issue is not addressed, or is addressed poorly by any wind farm proponent.

2. There is an obvious need for both a **moratorium** and **increased research**. People are being harmed by IWTs. To deny this is to remove people's rights to health and safety. It is apparent that, with the construction of IWTs adjacent to residences (and now it is being shown out to 10 kilometres) people are being knowingly exposed to health risks. Research into the degree and the mechanisms is urgent and it is the responsibility of government to ensure that this occurs.

Although not necessarily directly related to audible sound seismic activity is also a source of concern.

The Styles et al study[14] unequivocally concludes that there is a clear seismic vibration issue out to distances of **greater than 18km** coming from relatively small turbines that have a generating capacity of 660kW. Further the research found that vibration is proportional to power generating capacity. Therefore a single 2.5 to 3.0MW turbine will produce a significant seismic vibration. A number of turbines combined will have a very significant impact out to a great distance, and the long term effects of chronic exposure to this vibration are unknown.

HEALTH AND INFRASOUND

Infrasound is usually considered to be non-audible sound (although this is not inevitably the case) but can be felt, and is usually considered to be less than 20 Hertz frequency.

There are two critical issues to consider:

1. **Do industrial wind turbines produce infrasound?**
2. **If they do, does infrasound from wind turbines have an adverse health impact?**

1. Do Industrial Wind Turbines produce infrasound?

Despite wind energy company denial there is now a considerable and growing body of work that has found that **wind turbines do produce infrasound**. Low frequency sound is likely produced by wind turbines with the displacement of air by the blades and the turbulence around the blade surface; and as the turbines grow larger the potential to produce infrasound increases.[6,9,19,38] In fact results confirm the hypothesis that the spectrum of wind turbine noise **moves down in frequency with increasing turbine size[39]**. Compared to medium and high frequencies, **low frequency levels decay slowly with distance**, are **less attenuated by conventionally designed structures (such as homes), cause certain building materials to vibrate** and can sometimes **resonate with rooms**, thereby undergoing **amplification.**[14] Thus infrasound is more likely to be an **indoor problem rather than an outdoor**. Recent work in Europe has found that infrasound and seismic activity can be measured out to **8-11 kilometres.**[40] **This has significant implications for the determination of a <u>*set back*</u> distance of residences from wind turbines**.

2. Does Infrasound from Wind Turbines have an adverse Health Impact?

Infrasound, like audible sound, will affect people in different ways, both as to susceptibility (about 15-25% of the population exhibit increased noise sensitivity) and symptoms (type and degree). The difference between audible sound and infrasound is that infrasound is felt rather than heard.

Lower frequencies correspond to resonating frequencies of our body organs and in their presence encourage them to vibrate. Shepherd[41] notes that the head resonates at 20-30 Hertz and the abdomen at 4-8 Hertz. The following table illustrates the effects of chronic low frequency vibration and subsequent physiological consequences[41].

The health impacts stemming from infrasound often mirror those health impacts associated with audible sound (see above section). Sleep deprivation and annoyance are certainly consequences of infrasound and will result in predictable health sequelae.

Table 2: Psychological and physiological sequelae resulting from low frequency vibrations

Frequency of vibration	Symptoms
4 – 9 Hz	Feeling of discomfort
5 – 7 Hz	Chest pains
10 – 18 Hz	Urge to urinate
13 – 20 Hz	Head aches

Infrasound however can add another dimension because of the element of body vibration. The symptoms associated with infrasound from IWTs are numerous because people react differently. The following lists some, but not all, of these symptoms which are basically associated with infrasound:

- Chronic fatigue, tiredness and malaise
- Heart ailments, palpitations, hypertension
- Chronic insomnia
- Repeated headaches
- Repeated ear pulsations, tinnitus, sensations of fullness and pressure
- Back and neck pain
- Shortness of breath, shallow breathing, chest trembling
- Frequent irritation, nervousness, anxiety
- Frustration, depression, indecision

There has been considerable research published in recent years confirming the health impacts of infrasound from wind turbines.[4,6,15,22,27,34,39,41] For instance **Chen and Narins**[42] examine studies that have found that inaudible infrasound can affect the human hearing system. They also considered surveys by acousticians which have correlated annoyance levels with different kinds of industrial noise. They cite a case where a family exposed to infrasound at 10 Hz of only 35 dB SPL (sound pressure level) complained of bodily pains, increased annoyance, and difficulties sleeping. They cite the well-known study of Jung and Cheung, which found that wind turbine infrasound below 20 Hz, could reach levels between 60 and 100 dB SPL.

They summarise their position by stating:

> "High levels of infrasound and low frequency sounds generated by wind turbines pose a potentially serious threat to communities near wind farms. .... With wind turbines generating substantial levels of infrasound and low frequency sound, modifications and regulations to wind farm engineering plans and geographical placements are necessary to minimize community exposure and potential human health risks."

Many of the symptoms attributed to IWTs are well known sequelae from sleep deprivation or **raised cortisol and adrenaline levels** due to stress[40]. Sleep deprivation can be caused by both conscious and unconscious arousal.

The physiological pathways that are affected by both audible and inaudible noise are well elucidated by Salt and others[9,15,16,17,18,19,43].

Ambrose and Rand[27] investigated the presence or otherwise of infrasound and low frequency noise (ILFN) in a home adjacent to an IWT in Massachusetts. They confirmed there were dynamically modulated low frequency acoustic amplitudes and tones produced by the nearby wind turbine. Dynamic amplitude modulations below 10 Hz were stronger indoors than outdoors. They also found that there were demonstrable adverse health effects from the ILFN. Interestingly the dB(A) and dB(C) levels and modulations did not correlate to the health effects. *However the strength and modulation of the un-weighted and dB(G)-weighted levels increased indoors consistent with the worsened health effects experienced indoors. They write:*

> "The dB(G)-weighted level appeared to be controlled by in-flow turbulence and exceeded physiological thresholds for response to low-frequency and infrasonic acoustic energy as theorised by Salt. The wind turbine tone at 22.9 Hz was not audible yet the modulated amplitudes regularly exceeded vestibular detection thresholds. The 22.9 Hz tone lies in the brain's "high Beta" wave range (15 – 40 cycles per second) and is associated with our alert state, anxiety, and "fight or flight" stress reactions. The brain's frequency following response (FFR) could be involved in maintaining an alert state during sleeping hours, which could lead to health effects. Sleep was disturbed during the study when the wind turbine operated with hub height wind speeds above 10 m/s."

Professor A.N. Salt from the Department of Otolaryngology at Washington University School of Medicine[15] poses several physiological pathways whereby the effects of infrasound are likely to manifest within the human body via the sensory cells of the ear (as discussed elsewhere in this document). Several of the possible mechanisms are not speculation but are based on published data. He concludes:

> "…the effects of wind turbine noise on humans are largely unexplored and more research is needed. We believe that the infrasound levels generated by some large wind turbines are unusual in the environment and that there have been no systematic long-term studies of prolonged exposure to such sounds on humans or other animals".

This reinforces the Australian experience where those suffering the attendant consequences of IWT, are calling for proper and appropriate research as well as a moratorium on IWT construction. Until there are adequate answers to the many questions being raised any population residing close to IWTs is simply being used as unwitting "laboratory guinea pigs". There is great scope for further research to tease out the details of the very real effects of infrasound on noise recipients. This is a great opportunity for Government instrumentalities (Health and Planning) to be proactive in this field. There is considerable cause for concern that they are slow to take up the challenge. Further they are abrogating their responsibility to safeguard their citizens and their duty of care.

Interestingly, and as a portent of action by other institutions internationally, in Massachussetts (as a result of studies such as that of Ambrose & Rand which took place in that state, and because of the continuing complaints by residents close to IWTs) The Massachusetts Clean Energy Center in partnership with the Massachusetts Department of Environmental Protection is currently seeking proposals from qualified acoustic consultants that can assist these departments in conducting a Research Study on Wind Turbine Acoustics.

Through the Research Study on Wind Turbine Acoustics, they seek to measure the level and quality of sound emissions from a variety of operating wind turbines in Massachusetts. The Study will help inform state agencies, local decision-makers, project developers, researchers, and the public about acoustic characteristics of wind turbines.

It seems that it is possible for some governments, or instrumentalities, to finally respond to the plea for urgent research to attempt to elucidate the problems associated with IWT noise and recognised adverse health effects. While the current Wind Farm Audit in NSW, measuring the noise output of three operating wind farm, is seen by some as an attempt to settle the noise issue once and for all, the fact that there is no attempt to measure infrasound because the measurements will only be in units of dB(A) render this audit almost useless. NSW Department of Planning and Infrastructure has again missed a real opportunity to take part in a meaningful debate and one has to wonder why. The possibility of finding uncomfortable results has the potential to put in question the whole IWT development process.

Any diminution of the roll out of wind farms would jeopardise the perceived possibility of the government (both Federal and State) achieving 20% renewable energy by 2020, and of reducing carbon dioxide emissions by 20% over the 1990 level. This would be politically unacceptable and therefore it is apparent that people living in proximity to IWTs will indeed be the "sacrificial lambs" to ill-informed energy policy.

WORLD HEALTH ORGANIZATION

The World Health Organization (WHO) is the international organisation of standing when considering health issues. Australia, like many nations, uses United Nations and WHO standards when formulating its own regulations. It is worth noting that the WHO states in its *Guidelines for Community Noise*[37]:

> *"The goal of noise management is to* <u>*maintain low noise exposures*</u>*, such that human health and well-being are protected. The specific objectives of noise management are to develop criteria for the maximum safe noise exposure levels, and to promote noise assessment and control as part of environmental health programmes. This is not always achieved."*

Further:

> *"….a large proportion of low-frequency components in noise may increase the adverse effects on health…. It should be noted that the low frequency noise, for example, from ventilation systems, can disturb rest and sleep even at low sound pressure level…* ***Special attention should be given to: noise sources in an environment with low background sound levels; combinations of noise and vibrations; and to noise sources with low-frequency components****."*

And further:

> "**The evidence on low frequency noise is sufficiently strong to warrant immediate concern…Health effects due to low frequency components in noise is estimated to be more severe than for community noises in general**".

The WHO recommends that in order to achieve noise management and noise management policies the following should be supported:

> *"a.* ***The precautionary principle****. In all cases, noise should be reduced to the lowest level achievable in a particular situation. Where there is a reasonable possibility that public health will be damaged, action should be taken to protect public health* <u>***without awaiting full scientific proof***</u>*.*
>
> *b.* ***The polluter pays principle****. The full costs associated with noise pollution (including monitoring, management, lowering levels and supervision)* <u>***should be met by those responsible for the source of noise.***</u>
>
> *c.* ***The prevention principle****. Action should be taken where possible to reduce noise* <u>***at the source***</u>*. Land-use planning should be guided by an* ***environmental health impact assessment that considers noise as well as other pollutants."***

It is the public experience that these principles are not followed rigorously by regulatory authorities in Australia.

Therefore it is our contention that the Senate Standing Committees on the Environment and Communications should keep these principles at the forefront and afford those most likely to be affected the ***full protection of their health, safety, and civil and human rights***.

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