Becky Golden-Harrell

From: Carmen Krogh <krogh@email.toast.net>
Sent: Thursday, February 24, 2011 7:26 PM
To: ECOSUB; catulewind@blm.gov
Cc: tisdale.donna@gmail.com
Subject: Tule Wind/Energia Sierra Juarez Gen-Tie Projects
Attachments: Submission Tule Wind_Energia Sierra Juarex Gen-Tie Project March 2011.pdf

To whom it may concern,

Attached is my submission in response to public comment for the Tule Wind/Energia Sierra Juarez Gen-Tie Projects.

Thank you for the opportunity to offer my comments.

I have been working on the risk to health regarding industrial wind turbines for over 2 years and am in touch with many of those experiencing symptoms both in Ontario and in other jurisdictions. Based on the research to date, there is ample evidence adverse health effects are occurring. A major research gap is that there have been no peer reviewed human health studies conducted to determine authoritative guidelines for setbacks and noise levels that will protect families.

I appreciate this opportunity and hope that the attached information will assist with your deliberations.

Respectively submitted,

Carmen Krogh, BScPharm
1183 Cormac Road, RR4
Killaloe, Ontario, Canada, K0J 2A0

Adverse Health Effects

and

Industrial Wind Turbines

March 1, 2011-02-24

Submitted to:
California Public Utilities Commission
United States Department of the Interior, Bureau of Land Management

Public Comment:
East County Substation/Tule Wind/Energia Sierra Juarez Gen-Tie Projects DEIR/DEIS.

Email:
ecosub@dudek.com (CPUC project email)
catulewind@blm.gov (BLM project email)

Extracted from work authored by
Brett Horner BA CMA

NOTICE TO READER

Authoritative references are cited to support the assertions contained within this summary. This summary also contains statements and citations from other individuals and or organizations including that associated with the wind energy industry.

Every reasonable attempt was made to ensure the accuracy of this summary. Any errors or omissions contained within this summary are unintentional.

No financial compensation has been requested nor received for the compilation of this summary.

FORWARD

Dear sirs / madame,

I had the opportunity to make a presentation regarding the risk for adverse health effects if industrial wind turbines are placed in close proximity to family homes.

This presentation took place January 19, 2011, at Boulevard, California.

As background, I am a retired pharmacist with over 40 years experience in health. I am a former Director of Publications and Editor-in-chief of the Compendium of Pharmaceutical and Specialties (CPS), the book used in Canada for prescribing information on medication. Doctors, pharmacists, nurses, and other health care professionals use the book. The CPS is similar to the US Physicians Desk Reference (PDR). I have held senior executive positions at a major teaching hospital, a professional association and Health Canada (PMRA).

I work with a colleague to conduct the WindVOiCe © (Wind Vigilance for Ontario Communities) health survey and am in touch with many victims in Ontario and other areas. I have been researching this issue for over 2 years.

This summary may be used and submitted by other individuals as required.

Due to time and resource constraints this summary does not detail all the references available.

There is, however, ample evidence indicating a risk to health with industrial wind turbines.

Peer reviewed and other authoritative references indicate that wind turbines may have an adverse health effect on humans. [1] These references indicate that adverse health effects occur at sound pressure levels in the ranges expected at participating and non-participating noise receptors. [2]

For example, there are over one hundred Ontario residents who are reporting adverse health from exposure to industrial wind turbines. [3] Some of these victims are currently being or have been billeted by wind energy developers at the developer's expense. [4] Others have had their homes bought out by the wind energy developer and are now silenced by non disclosure clauses. Other victims live in self funded safe houses or have abandoned their homes to protect their health. The balance continues to suffer in their existing homes. This situation is disturbing.

Human health research is urgently required to determine authoritative regulations for safe setbacks and noise levels. [5], [6] Until this research is conducted, no further industrial wind turbine development should occur.

Based on the best available science, decision makers should give serious consideration about the risk to health and not approve any industrial wind turbine facilities in close proximity to family homes until authoritative human health research has been conducted to determine authoritative guidelines for safe setbacks and noise levels.

Respectively submitted,

Carmen Krogh, BScPharm
1183 Cormac Road, RR4
Killaloe, Ontario, Canada, K0J 2A0

CONCLUSIONS

Relevant authoritative references are included in this summary in order to assist decision makers in their assessment of the health impacts of noise, including low frequency noise, annoyance, stress and sleep disturbance.

Based on general observations, it is noted that often a number of points may not be considered by proponents and decision makers. These may include:

- There are peer reviewed human health studies that industrial wind turbines may cause adverse health effects.
- There are no peer reviewed human health studies to determine authoritative setbacks and noise levels.
- Peer reviewed research has shown industrial wind turbine noise levels of 40 dB and lower may cause adverse health effects.
- There typically is no provision to consider low frequency noise and infrasound.
- Peer reviewed research has shown that low frequency noise and infrasound may cause adverse health effects.
- The negative impact of shadow flicker is understated.
- There typically is no complaint protocol for mitigating and / or resolving adverse health effects or other negative impacts.
- There is no vigilance monitoring of those residing near industrial wind facilities.
- There is no long term surveillance of those residing near industrial wind facilities.

- Noise studies are based on predictive computer modelling without a correlation with human responses to noise including dose response.

WIND TURBINES AND ADVERSE HEALTH EFFECTS

Wind turbines emit noise pollution and wind turbine "…noise pollution may be a problem if turbines are situated close to centres of population." [7]

In addition to noise pollution wind turbines have additional burdens of "visual intrusion".[8] (See discussion in Shadow Flicker section of this summary)

Wind turbine induced adverse health effects currently acknowledged include annoyance, stress and sleep disturbance.

The American Wind Energy Association and Canadian Wind Energy Association sponsored report entitled "Wind Turbine Sound and Health Effects" (Colby et al, 2009) acknowledges wind turbine noise, including low frequency noise, may cause annoyance, stress and sleep disturbance and as a result people may experience adverse physiological and psychological symptoms. [9]

The Chief Medical Officer of Health of Ontario and Agency for Health Protection and Promotion concur in that they acknowledge wind turbines may cause annoyance, stress and sleep disturbance. [10], [11]

"Perhaps the main finding is that wind turbine sound is relatively annoying, more so than equally loud sound from aircraft or road traffic. A swishing character is perceived by most respondents, indicating that this is an important characteristic of wind turbine sound. Sound should therefore receive more attention in the planning of wind farms, and (more) sound mitigation measures must be considered." [12]

"The study confirms that wind turbine noise is easily perceived and compared to sounds from other community sources relatively annoying." [13]

"The need for guidelines for maximum exposure to wind turbine noise is urgent:" [14] in order to avoid possible adverse health effects.

Currently there is no health based generalized dose-response relationship developed to avoid possible adverse health effects from wind turbine noise exposure. [15]

"Annoyance with wind turbine noise was associated with psychological distress, stress, difficulties to fall asleep and sleep interruption." [16]

World Health Organization recognizes annoyance and sleep disturbance as adverse health effects. [17]

Peer reviewed studies have documented wind turbine annoyance, stress and sleep disturbance may occur at sound pressure levels in the ranges participating and non-participating noise receptors proposed by many proponents will be exposed to. [18], [19], [20], [21]

Geoff Leventhall, a co-author of "Colby et al, 2009" acknowledges the reported symptoms of "Wind Turbine Syndrome" are particular to "low frequency noise" exposure. [22]

The Minnesota Department of Health concludes that: “Most available evidence suggests that reported health effects are related to audible low frequency noise.” [23]

Health Canada states:

“…that there are peer reviewed scientific articles indicating that wind turbines may have an adverse impact on human health.” [24]

Conclusion: Wind Turbines and Adverse Health Effects

Based on the best available science the following conclusions can be made.

- At common residential setbacks wind turbine noise, including low frequency noise, can cause annoyance, stress and sleep disturbance and as a result people may experience adverse physiological and psychological symptoms.

WIND TURBINES AND ANNOYANCE

An August 2009 peer reviewed article states "Wind turbines are a new source of community noise to which relatively few people have been exposed…. No generalized dose-response curves have yet been modeled for wind turbines primarily due the lack of results of published field studies…The need for guidelines for maximum exposure to wind turbine noise is urgent…" [25]

Given it is acknowledged that "Wind turbines are a new source of community noise to which relatively few people have been exposed…" [26] it is incumbent on authorities to assess the impacts of wind turbine noise on human health using established and emerging authoritative references on noise.

Peer reviewed findings of studies of industrial wind turbines conclude "Noise from wind turbines was found to be more annoying than noise from several other sources at comparable Lden sound levels." [27]

This reference determined wind turbine noise is more annoying than equally loud railway, road traffic, and industrial and aircraft noise. [28] These findings are consistent with previous studies of human response to industrial wind turbine noise. [29], [30], [31]

Annoyance is predominately attributed to the unique sound characteristics of wind turbine noise.

"The sound level associated with wind turbines at common residential setbacks …may lead to annoyance and sleep disturbance." [32] and evidence demonstrates

"Annoyance and sleep disruption are common when sound levels are 30 to 45 dBA." [33]

The American Wind Energy Association and Canadian Wind Energy Association sponsored literature review entitled "Wind Turbine Sound and Health Effects" acknowledges wind turbine noise, including low frequency noise, may cause annoyance, stress and sleep disturbance and as a result people may experience adverse physiological and psychological symptoms. [34]

CanWEA President, Robert Hornung, stated regarding The American Wind Energy Association and Canadian Wind Energy Association sponsored report "The study does acknowledge that wind turbines can be annoying, the sound of wind turbines can be annoying for some individuals and that may cause them to feel some stress etcetera,…" [35]

More specifically the wind industry sponsored literature review acknowledges reported symptoms can be caused by wind turbine noise and states "…"wind turbine syndrome" symptoms are not new and have been published previously in the context of "annoyance" to environmental sounds …. The following symptoms are based on the experience of noise sufferers extending over a number of years: distraction, dizziness, eye strain, fatigue, feeling vibration, headache, insomnia, muscle spasm, nausea, nose bleeds, palpitations, pressure in the ears or head, skin burns, stress, and tension.…" [36]

The symptoms listed in the wind industry literature review are consistent with international research and media reports documenting subjects exposed to wind turbines who are reporting adverse health effects. [37], [38], [39], [40], [41]

The health impacts of noise induced annoyance must not be underestimated.

A coauthor of the wind industry sponsored "Wind Turbine Sound and Health Effects", W. David Colby, M.D., reinforced this position regarding wind turbine induced annoyance by stating

"We're not denying that there are people annoyed and that maybe some of them are getting stressed out enough about being annoyed that they're getting sick." [42]

Geoff Leventhall, another coauthor of the wind industry sponsored "Wind Turbine Sound and Health Effects", reportedly elaborated:

"… there was no doubt people living near the turbines suffered a range of symptoms, including abnormal heart beats, sleep disturbance, headaches, tinnitus, nausea, visual blurring, panic attacks and general irritability.…it's ruining their lives – and it's genuine…" [43]

The word annoyance may mean different things to different people; however in clinical terms annoyance is acknowledged to be a risk to human health.

The World Health Organization acknowledges noise induced annoyance to be an adverse health effect. [44], [45]

Regarding noise induced annoyance the US Environmental Protection Agency states "…"annoyance" can have major consequences, primarily to one's overall health." [46]

A World Health Organization study "…confirmed, on an epidemiological level, an increased health risk from chronic noise annoyance." [47]

Noise induced annoyance contributes to stress, [48] sleep disturbance [49] and an increased risk of regulation diseases. [50]

Annoyance may adversely affect physiological health. Research indicates that for "chronically strong annoyance a causal chain exists between the three steps health – strong annoyance – increased morbidity." [51]

The subjective experience of noise stress can, through central nervous processes, lead to an inadequate neuro-endocrine reaction and finally to regulation diseases. [52]

"Adults who indicated chronically severe annoyance by neighbourhood noise were found to have an increased health risk for the cardiovascular system and the movement apparatus, as well as an increased risk of depression and migraine…With children the effects of noise-induced annoyance from traffic, as well as neighbourhood noise, are evident in the respiratory system." [53] Peer reviewed studies have consistently concluded that wind turbine noise is more annoying than equally loud traffic. [54], [55], [56], [57]

To protect against adverse health effects noise level limits "…should be based on annoyance responses to noise." [58]

"Dose-response relations for different types of traffic noise (air, road and railway) clearly demonstrate that these noises can cause different annoyance effects at equal LAeq,24h values." [59] Currently there is no health based generalized dose-

response relationship developed to avoid possible adverse health effects from wind turbine noise exposure. [60]

"The need for guidelines for maximum exposure to wind turbine noise is urgent…" [61]

Wind turbine visual effects such as shadow flicker may also cause visually induced adverse health effects such as annoyance and/or stress. [62], [63], [64], [65], [66], [67], [68], [69]

Conclusions: Wind Turbines and Annoyance

Based on the best available science the following conclusions can be made.

- The main conclusion of peer reviewed scientific studies state noise from wind turbines is more annoying than noise from most other sources at comparable sound levels. This annoyance is predominately attributed to the unique sound characteristics of wind turbine noise.

- Peer reviewed scientific research confirms noise induced annoyance is an adverse health effect which can result in stress, sleep disturbance and an increased risk of regulation diseases.

- Possible symptoms of wind turbine noise induced annoyance include distraction, dizziness, eye strain, fatigue, feeling vibration, headache, insomnia, muscle spasm, nausea, nose bleeds, palpitations, pressure in the ears or head, skin burns, stress, and tension. These symptoms are consistent with international research and media reports documenting

subjects exposed to wind turbines who are reporting adverse health effects.

- Peer reviewed scientific research confirms the audible sound from wind turbines, at the levels experienced at typical receptor distances is expected to result in an unacceptable percentage of persons being highly annoyed.

- Peer reviewed scientific research confirms dose-response relations for different types of noise (air, road and railway) clearly demonstrate that these noises can cause different annoyance effects at equal sound pressure levels.

- Peer reviewed scientific research confirms no generalized dose-response curves have yet been modeled for wind turbines, primarily due to the lack of results of published field studies.

- Peer reviewed scientific research confirms the need for guidelines for maximum exposure to wind turbine noise is urgent.

- Exposure to wind turbines may also visually induce adverse health effects. It is acknowledged wind turbine shadow flicker may cause annoyance and/or stress.

- Wind turbines must be sited to protect humans from the adverse health effect of visually induced annoyance as well as noise induced annoyance.

WIND TURBINES AND STRESS

Noise is an environmental stressor [70] which can cause stress related adverse health effects. [71]

A coauthor of the wind industry sponsored "Wind Turbine Sound and Health Effects", [72] W. David Colby, M.D., reinforced this position regarding wind turbine induced annoyance by stating

"We're not denying that there are people annoyed and that maybe some of them are getting stressed out enough about being annoyed that they're getting sick." [73]

CanWEA President, Robert Hornung, stated regarding The American Wind Energy Association and Canadian Wind Energy Association sponsored report "The study does acknowledge that wind turbines can be annoying, the sound of wind turbines can be annoying for some individuals and that may cause them to feel some stress etcetera,…" [74]

"The subjective experience of noise stress can, through central nervous processes, lead to an inadequate neuro-endocrine reaction and finally lead to regulatory diseases." [75]

Peer reviewed scientific research reveals "With children the effects of noise-induced annoyance from traffic, as well as neighbourhood noise, are evident in the respiratory system. The increased risk of illness in the respiratory system in children does not seem to be caused primarily by air pollutants, but rather, as the results for neighbourhood noise demonstrate, by emotional stress." [76]

It is acknowledged that wind turbine noise may cause annoyance, stress and sleep disturbance. [77], [78], [79], [80], [81]
"Also, recent epidemiological studies have shown a connection between disturbed sleep and later occurrence of stress-related disorders such as cardiovascular diseases…and diabetes type II…" [82]

Regarding stress Health Canada states [83]

> "…stress is considered to be a risk factor in a great many diseases, including: heart disease, some types of bowel disease, herpes, mental illness.
>
> …Stress also makes it hard for people with diabetes to control their blood sugar.
>
> …Stress is also a risk factor in alcohol and substance abuse, as well as weight loss and gain. Stress has even been identified as a possible risk factor in Alzheimer's Disease.
>
> …Severe stress can cause biochemical changes in the body, affecting the immune system, leaving your body vulnerable to disease."

Other health effects associated with stress include becoming increasingly distressed, and irritable, unable to relax or concentrate, have difficulty thinking logically, and making decisions, depression, anxiety, sleep disorders, disorders of the digestive system, increases in blood pressure, headaches and musculo-skeletal disorders. [84], [85]

Conclusions: Wind Turbines and Stress

Based on the best available science the following conclusions can be made.

- Noise is an environmental stressor which can cause stress related adverse health effects.

- It is acknowledged that wind turbine noise can cause annoyance, stress and sleep disturbance at common residential setbacks.

- Research has shown that annoyance associated with sound and shadow flicker from wind can be expected to contribute to stress related health impacts.

- Some of adverse health effects associated with stress include becoming increasingly distressed, and irritable, unable to relax or concentrate, have difficulty thinking logically, and making decisions, depression, anxiety, sleep disorders, disorders of the digestive system, increases in blood pressure, headaches and musculo-skeletal disorders.

WIND TURBINES AND SLEEP DISTURBANCE

It is acknowledged that wind turbine noise may cause annoyance, stress and sleep disturbance. [86], [87], [88], [89], [90]

"Some people with wind turbines located close to their homes have reported a variety of clinical symptoms that in rare cases are severe enough to force them to move away. These symptoms include sleep disturbance…" [91]

Wind turbines noise will cause annoyance and sleep disturbance with noise limits of 40dBA. [92]

The American Wind Energy Association and Canadian Wind Energy Association sponsored literature review entitled "Wind Turbine Sound and Health Effects" acknowledges wind turbine noise, including low frequency noise, may cause annoyance, stress and sleep disturbance and as a result people may experience adverse physiological and psychological symptoms. [93]

Wind turbine induced sleep disturbance is consistently reported by those experiencing adverse health effects from exposure to wind turbines. [94], [95], [96], [97]

"Wind turbine noise was more annoying than transportation noise or industrial noise at comparable levels, possibly due to specific sound properties such as a "swishing" quality, temporal variability, and lack of nighttime abatement." [98]

A 2008 study of wind turbines in the Netherlands concludes:

"Perhaps the main finding is that wind turbine sound is relatively annoying, more so than equally loud sound from aircraft or road traffic.…With respect to other health effects associated with wind turbines:

- The risk for sleep interruption by noise was higher at levels of wind turbine sound above 45 dBA than at levels below 30 dBA.
- Annoyance with wind turbine noise was associated with psychological distress, stress, difficulties to fall asleep and sleep interruption." [99]

Sleep specialist Dr Christopher Hanning reviewed the findings of this reference and other peer reviewed studies of European wind turbine facilities and concluded:

"The recent analyses of the WINDFARMPerception and earlier Swedish studies by Pedersen and her colleagues gives, for the first time, robust evidence that wind turbines cause sleep disturbance and impair health and that this occurs at set-back distances previously regarded as adequate…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 dismisses the subjective symptoms. Because most of the sleep disturbance is not recalled, this approach seriously underestimates the effects of wind turbine noise on sleep." [100]

Difficulty falling asleep constitutes sleep disturbance which can have serious consequences. [101]

A UK report documented sleep disturbance caused by wind turbine amplitude modulation and recommended a penalty adjustment to noise guidelines to protect the local population. [102] Other researchers believe a penalty should be considered for wind turbine noise. [103], [104]

"Harry (2007) … subsequently investigated 42 people in various locations in the U.K. living between 300 meters and 2 kilometers (1000 feet to 1.2 miles) from the nearest wind turbine. The most frequent complaint (39 of 42 people) was that their quality of life was affected. Headaches were reported by 27 people and sleep disturbance by 28 people. Some people complained of palpitations, migraines, tinnitus, anxiety and depression.…Pierpont does report that her study subjects maintain that their problems are caused by noise and vibration, and the most common symptoms reported are sleep disturbances and headache." [105]

"In Ontario "WindVOiCe recently published the updated results of a self-reporting survey of communities affected by wind turbine noise. As of March 2010, 141 responses had been received of which 115 reported one or more health effects. 83 of the 115 (72%) reported sleep disturbance." [106] The next update of WindVOiCe will be available mid-March, 2011. The results have increased in numbers.

Describing the preliminary results of his pilot study Dr Michael Nissenbaum states:

"In my investigation of Mars Hill, Maine, 22 out of about 30 adults ('exposed') who live within 3500 feet of a ridgeline arrangement of 28 1.5 MW wind turbines were evaluated to date, and compared with 27 people of otherwise similar age and occupation living about 3 miles away (Not Exposed).

Here is what was found:

82% (18/22) of exposed subjects reported new or worsened chronic sleep deprivation, versus 4% (1 person) in the non-exposed group. 41% of exposed people reported new chronic headaches vs 4% in the control group.

59% (13/22) of the exposed reported 'stress' versus none in the control group, and 77% (17/22) persistent anger versus none in the people living 3 miles away. More than a third of the study subjects had new or worsened depression, with none in the control group. 95% (21/22) of the exposed subjects perceived reduced quality of life, versus 0% in the control group.

Underlining these findings, there were 26 new prescription medications offered to the exposed subjects, of which 15 were accepted, compared to 4 new or increased prescriptions in the control group. The prescriptions ranged from anti-hypertensives and antidepressants to anti migraine medications among the exposed. The new medications for the non exposed group were anti-hypertensives and anti-arthritics.

The Mars Hill study will soon be completed and is being prepared for publication." [107]

"The sound level associated with wind turbines at common residential setbacks …may lead to annoyance and sleep disturbance." [108] and evidence demonstrates

"Annoyance and sleep disruption are common when sound levels are 30 to 45 dBA." [109]

Sleep disturbance is acknowledged to be an adverse health effect. [110], [111]

The consequences of sleep disturbance can be serious.

In 2009 World Health Organization released a 184 page peer reviewed summary of research regarding the risks to human health from noise induced sleep disturbance. Some of the adverse health effect documented in the report include poor performance at work, fatigue, memory difficulties, concentration problems, motor vehicle accidents, mood disorders (depression, anxiety), alcohol and other substance abuse, cardiovascular, respiratory, renal, gastrointestinal, musculoskeletal disorders, obesity, impaired immune system function and a reported increased risk of mortality. [112]

A 2009 court decision mandated that a wind turbine facility in France shut down operations at night in order to prevent the sleep disturbance that the local population had been enduring. [113]

Conclusions: Wind Turbines and Sleep Disturbance

Based on the best available science the following conclusions can be made

- Wind turbine noise, including low frequency noise, may cause annoyance, stress and sleep disturbance.

- Wind turbine induced sleep disturbance occurs at common residential setbacks and when sound levels are higher than 30 dBA.

- The consequences of sleep disturbance can be serious. Acknowledged symptoms include poor performance at work, fatigue, memory difficulties, concentration problems, motor vehicle accidents, mood disorders (depression, anxiety), alcohol and other substance abuse, cardiovascular, respiratory, renal, gastrointestinal, musculoskeletal disorders, obesity, impaired immune system function and a reported increased risk of mortality.

WIND TURBINE LOW FREQUENCY NOISE AND INFRASOUND

Wind turbines generate a broad spectrum of noise including low frequency noise and infrasound which may be audible or inaudible. [114], [115], [116]

Audible wind turbine LFN is routinely perceptible to people.

Health Canada states:

"…turbine noise is likely to be audible to the nearest receptors in the form of continuous low-level or intermittent swooshing, as well as low frequencies at approximately 50 Hertz. As such, Health Canada advises the following…

- Please ensure that nearby residents are informed that turbine noises may be audible in terms of a low-level continuous or intermittent swooshing, as well as at low frequencies around 50 Hertz." [117]

It is important decision makers consider that turbine noises may be audible in terms of a low-level continuous or intermittent swooshing, as well as at low frequencies around 50 Hertz.

It is widely affirmed that exposure to audible low frequency noise can cause adverse health effects in humans. [118], [119], [120], [121]

Low frequency noise can cause "…immense suffering to those who are unfortunate to be sensitive to low frequency noise and who plead for recognition of their circumstances." [122]

"Wind turbines are generally located in areas devoid of trees and other large vegetation. Instead, ground cover usually consists of grass, sagebrush, plants, and low shrubs, which are minor impediments to noise propagation except at very high frequencies. At frequencies below about 1000 Hz, the ground attenuation is essentially zero." [123]

The farther away from the wind turbine the greater is the low frequency content due to a relatively larger atmospheric absorption of high frequencies. Considering the A-weighted sound level outdoors in relevant distances to neighbours, the lower frequencies constitute a substantial part of the noise. [124]

"Under 'adverse' wind conditions the sound of wind turbines are clearly audible at distances to approximately 5000 metres turbines-to-receiver to the extent that the sound can be recorded inside and outside a residence at these distances" [125]

There is no doubt that as wind turbines get larger and more densely sited the lower frequency part of the noise spectrum is of importance to the neighbours' perception of noise from large wind turbines. Noise from wind turbines is under certain atmospheric conditions more annoying and - especially the low frequency part - spread much farther than generally accepted. Wind turbines may cause low frequency noise induced annoyance both inside and outside a building. [126]

Annoyance is an acknowledged adverse health effect. [127], [128]

"Regulatory authorities must accept that annoyance by low frequency noise presents a real problem which is not addressed by the commonly used assessment methods." [129]

Literature reviews and peer reviewed scientific articles confirm the symptoms associated with low frequency noise exposure include annoyance, stress, sleep disturbance, headaches, difficulty concentrating, irritability, fatigue, dizziness or vertigo, tinnitus, heart ailments anxiety, stitch and beating palpitation. [130], [131], [132]

International research and media reports document people exposed over time, to too-close wind turbines, are experiencing adverse health effects. "These symptoms include sleep disturbance, headaches, difficulty concentrating, irritability and fatigue, but also include a number of otologic symptoms including dizziness or vertigo, tinnitus and the sensation of aural pain or pressure." [133]

The American Wind Energy Association and Canadian Wind Energy Association sponsored literature review entitled "Wind Turbine Sound and Health Effects" (Colby et al., 2009) acknowledges wind turbine noise may cause annoyance, stress and sleep disturbance and as a result people may experience adverse physiological and psychological symptoms. The literature review specifically acknowledges that wind turbines may cause low frequency noise induced annoyance. [134]

Colby et al., 2009 does not deny that the symptoms documented in Dr. Pierpont's case studies may be caused by wind turbine noise. This wind industry sponsored report disputes the mechanism of action proposed by Dr. Pierpont and concludes

""wind turbine syndrome" symptoms are not new and have been published previously in the context of "annoyance" to environmental sounds …. The following symptoms are based on the experience of noise sufferers extending over a number of years: distraction, dizziness, eye strain, fatigue, feeling vibration, headache, insomnia, muscle spasm, nausea, nose bleeds, palpitations, pressure in the ears or head, skin burns, stress, and tension…." [135]

Colby et al., 2009 states the symptoms documented by Dr. Pierpont are "The collective symptoms in some people exposed to wind turbines are more likely associated with annoyance to low sound levels." [136]

Colby et al., 2009's use of the phrase "**low sound levels**" is misleading. The references cited by Colby et al., 2009 are specifically related to human response to "**low frequency noise and infrasound**" (Nagai et al., 1989 [137]; Møller and Lydolf, 2002 [138]; Mirowska and Mroz, 2000 [139]; Leventhall, 2002 [140]).

In August 2009 Geoff Leventhall, a coauthor of Colby et al., 2009, critiqued Dr. Pierpont's research and confirmed that people may suffer from the symptoms described as Wind Turbine Syndrome. In a critique Geoff Leventhall states

"The symptoms of…Wind Turbine Syndrome...sleep disturbance, headache, tinnitus, ear pressure, dizziness, vertigo, nausea, visual blurring, tachycardia, irritability, problems with concentration and memory, and panic attack episodes associated with sensations of internal pulsation or quivering when awake or asleep…I am happy to accept these symptoms, as they have been known to me for many years as the symptoms of extreme psychological stress from environmental noise, particularly low frequency noise." [141]

Geoff Leventhall's acknowledgement that the symptoms described as "Wind Turbine Syndrome" are particular to "low frequency noise" exposure confirms that wind turbine low frequency noise may cause serious adverse health effects.

Another document attributed to Geoff Leventhall lists symptoms associated with wind turbine syndrome (WTSyndrome): [142]

"…sleep disturbance, headache, tinnitus, ear pressure, dizziness, vertigo, nausea, visual blurring, tachycardia, irritability, problems with concentration and memory, and panic episodes associated with sensations of internal pulsation or quivering which arise while awake or asleep" [143]

The same document also lists symptoms associated with noise annoyance:

"…insomnia; headache; pressure in the ears or head; Dizziness; nausea; eye strain; fatigue; distraction; nose bleeds; feeling vibration; muscle spasms; palpitations; skin burning; stress; tension etc" [144]

The same document states "Wind Turbine Syndrome Symptoms…same as those of noise annoyance. Psychological, not physiological" [145]

While there is a consensus on the symptoms caused by low frequency noise exposure the mechanism of action is not fully understood.

"Today we know that most illnesses, mental and physical, are influenced by a combination of biological, psychological and social factors." [146]

"In an integrated and evidence-based model of health, mental health (including emotions and thought patterns) emerges as a key determinant of overall health. Anxious and depressed moods, for example, initiate a cascade of adverse changes in endocrine and immune functioning, and create increased susceptibility to a range of physical illnesses." [147]

"Mental health is as important as physical health. In fact, the two are intertwined. Our mental health directly affects our physical health and vice versa…mental health factors can increase the risk of developing physical problems such as, diabetes, heart disease, weight gain or loss, gastrointestinal problems, reductions in immune system, efficiency, and blood biochemical imbalances." [148]

World Health Organization advises that "Health effects due to low-frequency components in noise are estimated to be more severe than for community noises in general…The evidence on low-frequency noise is sufficiently strong to warrant immediate concern." and consequently "Noise with low-frequency components require lower guideline values." [149]

The effects of low frequency noise induced annoyance and stress are acknowledged to be serious as evidenced by "The claim that their "lives have been ruined" by the noise is not an exaggeration…" [150]

"…LFN *(low frequency noise)* does not need to be considered "loud" for it to cause such forms of annoyance and irritation." [151]

"The effects of infrasound or low frequency noise are of particular concern because of its pervasiveness due to numerous sources, efficient propagation,

and reduced efficiency of many structures (dwellings, walls, and hearing protection) in attenuating low frequency noise compared with other noise." [152]

"Unlike higher frequency noise issues, LFN is very difficult to suppress. Closing doors and windows in an attempt to diminish the effects sometimes makes it worse because of the propagation characteristics and the low-pass filtering effect of structures. Individuals often become irrational and anxious as attempts to control LFN fail, serving only to increase the individual's awareness of the noise, accelerating the above symptoms" [153]

"Those exposed may adopt protective strategies, such as sleeping in their garage if the noise is less disturbing there. Or they may sleep elsewhere, returning to their own homes only during the day." [154]

Ontario victims have resorted to sleeping in a tent [155] , been billeted by the wind energy proponent, [156], [157] or have abandoned their homes [158], [159] to escape the wind turbine noise that has invaded their home.

Wind turbines may produce infrasound which may be inaudible or audible.

A spectral analysis of sounds emitted at a Michigan site revealed that unweighted peak levels at frequencies under 5 Hz exceeded 90 dB SPL (Wade Bray, pers. comm., 2009). [160]

"There is no doubt that some humans exposed to infrasound experience abnormal ear, CNS, and resonance induced symptoms that are real and stressful." [161]

There is no scientific consensus that infrasonic noise below the threshold of hearing will have no effect on health. There is scientific uncertainty regarding the understanding of human response to infrasound.

"There is no consensus whether sensitivity below 20 Hz is by a similar or different mechanism than sensitivity and hearing above 20 Hz…" [162]

The National Research Council states "Low-frequency vibration and its effects on humans are not well understood. Sensitivity to such vibration resulting from wind-turbine noise is highly variable among humans…. studies on human sensitivity to very low frequencies are recommended." [163]

The conclusions of a 2010 peer reviewed scientific article states

> "1) Hearing perception, mediated by the inner hair cells of the cochlea, is remarkably insensitive to infrasound.
>
> 2) Other sensory cells or structures in the inner ear, such as the outer hair cells, are more sensitive to infrasound than the inner hair cells and can be stimulated by low frequency sounds at levels below those that are heard. The concept that an infrasonic sound that cannot be heard can have no influence on inner ear physiology is incorrect.
>
> 3) Under some clinical conditions, such as Meniere's disease, superior canal dehiscence, or even asymptomatic cases of endolymphatic hydrops, individuals may be hypersensitive to infrasound.

4) A-weighting wind turbine sounds underestimates the likely influence of the sound on the ear. A greater effort should be made to document the infrasound component of wind turbine sounds under different conditions.

5) Based on our understanding of how low frequency sound is processed in the ear, and on reports indicating that wind turbine noise causes greater annoyance than other sounds of similar level and affects the quality of life in sensitive individuals, there is an urgent need for more research directly addressing the physiologic consequences of long-term, low level infrasound exposures on humans." [164]

Recent research on the issue of infrasound below the hearing threshold states:

"For years, people have been told that infrasound you cannot hear cannot affect you. This is completely WRONG.

As the inner ear DOES respond to infrasound at levels that are not heard, people living near wind turbines are being put at risk by infrasound effects on the body that no-one presently understands.

Until a scientific understanding of this issue is established we should not be dismissing these effects, but need to be erring on the side of caution." [165]

It is incorrect to assume that inaudible low frequency noise cannot cause adverse health effects as "…non-aural physiological and psychological effects may be caused by levels of low frequency noise below the individual hearing threshold." [166]

“Low-frequency noise may also produce vibrations and rattles as secondary effects.” [167]

“Although infrasound levels from large turbines at frequencies below 20 Hz are too low to be audible, they may cause structural elements of buildings to vibrate.” [168]

“Jung and colleagues (2008), in a Korean study, concluded that low-frequency noise in the frequency range above 30 Hz can lead to psychological complaints and that infrasound in the frequency range of 5–8 Hz can cause complaints due to rattling doors and windows in homes.” [169]

Field studies and “…research has shown that the acoustic energy from wind turbines is capable of resonating houses, effectively turning them into three-dimensional loud speakers in which the affected residents are now expected to live. The phenomenon of natural resonance combines to produce a cocktail of annoying sounds which not only disturb the peace and tranquility once-enjoyed by the residents, but also stimulate a number of disturbing physiological effects which manifest in the physical symptoms...” [170]

A NASA technical paper on wind turbine noise states

“People who are exposed to wind turbine noise inside buildings experience a much different acoustic environment than do those outside.…They may actually be more disturbed by the noise inside their homes than they would be outside.…One of the common ways that a person might sense the noise-induced excitation of a house is though structural vibrations. This mode of observation is

particularly significant at low frequencies, below the threshold of normal hearing." [171]

Living conditions are acknowledged to be a key determinate of health. [172]

A World Health Organization epidemiology study confirms disturbed living conditions caused by noise increases the risk of ill health. [173]

Peer reviewed scientific research confirms "Pollution and degradation of the indoor environment cause illness, increased mortality, loss of productivity, and have major economic and social implications.…The health effects of indoor noise include an increase in the rates of diseases and disturbances… these illnesses, and the related reduction in human productivity, can result in substantial economic losses." [174]

Wind turbine low frequency noise and infrasound is unique.

Modern upwind industrial wind turbines produce a characteristic audible modulation of aerodynamic noise. [175] This is commonly referred to as amplitude modulation and is acknowledged to contribute to higher levels of wind turbine induced annoyance and/or sleep disturbance in the exposed population. [176], [177], [178]

Wind turbine low frequency noise and infrasound is also modulated.

"Low frequency sound and infrasound are normal characteristics of a wind farm as they are the normal characteristics of wind, as such. The difference is that

"normal" wind is laminar or smooth in effect whereas wind farm sound is non-laminar and presents a pulsing nature." [179]

"A limitation of much work on assessment of low frequency noise has been that long term averaged measurements were used and, consequently, information on fluctuations was lost. Many complaints of low frequency noise refer to its throbbing or pulsing nature." [180]

Research related to low frequency noise "…confirms the importance of fluctuations as a contributor to annoyance and the limitation of those assessment methods, which do not include fluctuations in the assessment." [181]

Adverse health effects associated with low frequency noise and infrasound can be avoided with authoritative regulations that ensure protection is engineered into the design of wind turbine projects.

Low Frequency Noise is an issue that must be resolved quickly and accurately to improve the sound environment and quality of life for the residents. For this reason, it remains the duty of industry and authorities to implement regulations that will account for low frequency noise. [182]

It is widely affirmed that A-weighting underestimates the sound pressure level of noise with low-frequency components. [183], [184], [185], [186], [187] "A-weighted level is very inadequate…" [188] when assessing low frequency noise and infrasound.

C-weighting and Z-weighting are more appropriate to assess noise with low frequency components.

The proposed noise level proposed by proponents are usually based on the A-weighted level metric.

The adoption of low frequency noise and infrasound regulations is hampered by wind energy industry resistance. The Canadian Wind Energy Association (a registered lobby group for the wind industry) lobbies against having to address the impacts of wind turbine low frequency noise and infrasound "…CanWEA submits that the proposed requirement for infrasound or low frequency noise monitoring as a condition of the REA be removed." [189]

It is acknowledged that wind turbine noise, including low frequency noise, may cause annoyance, stress and sleep disturbance. [190], [191], [192], [193], [194] These adverse health effects occur at sound pressure levels in the ranges expected at participating and non-participating noise receptors. [195]

Conclusions: Wind Turbine Low Frequency Noise and Infrasound

Based on the best available science the following conclusions can be made.

- Wind turbine noise is likely to be audible to receptors in the form of continuous low-level or intermittent swooshing, as well as low frequencies at approximately 50 Hertz.

- Exposure to audible low frequency noise can cause adverse health effects in humans.

- The symptoms associated with low frequency noise exposure include annoyance, stress, sleep disturbance, headaches, difficulty concentrating, irritability, fatigue, dizziness or vertigo, tinnitus, heart ailments anxiety, stitch and beating palpitation.

- Humans must be protected from the adverse health effects caused by low frequency noise exposure.

- Wind turbine low frequency noise may induce annoyance, stress and sleep disturbance which may have other health consequences.

- International research and media reports document people exposed to wind turbines reporting adverse health effects. Reported symptoms include annoyance, stress, sleep disturbance, headaches, difficulty concentrating, irritability, fatigue, dizziness or vertigo, tinnitus and the sensation of aural pain or pressure.

- Wind turbines emit infrasound which may be audible or inaudible. There is scientific uncertainty regarding infrasound; however, it is plausible wind turbine infrasound could adversely affect human health.

- It is acknowledged infrasound can induce annoyance, stress and sleep disturbance by disturbing people inside their homes through structural vibrations.

- Based on current understanding of how low frequency sound is processed in the ear, and on reports indicating that wind turbine noise causes greater annoyance than other sounds of similar level and

affects the quality of life in sensitive individuals, there is an urgent need for more research directly addressing the physiologic consequences of long-term, low level infrasound exposures on humans.

- Adverse health effects associated with low frequency noise and infrasound can be avoided with authoritative regulations that ensure protection is engineered into the design of wind turbine projects.

- Members of the wind energy industry oppose addressing wind turbine low frequency noise and infrasound. For example the Canadian Wind Energy Association has lobbied against the introduction of protective guidance designed to address wind turbine low frequency noise and infrasound.

WIND TURBINES AND SHADOW FLICKER

World Health Organization acknowledges that in addition to noise pollution wind turbines also have visual burdens. [196]

The health impact of visual burdens cannot be underestimated. An epidemiology study conducted by World Health Organization determined a “bad view out of window” increased the risk for depression by 40%. The same study also demonstrated disturbance by noise and sleep disturbance by noise increased the risk of depression 40%, and 100% respectively. [197] In addition to visual burdens wind turbines create noise pollution [198] which is acknowledged to cause annoyance, stress and sleep disturbance. [199], [200], [201], [202], [203] In light of these statistics it is expected that people may suffer adverse health effects from visual and noise impacts of wind turbines.

The National Research Council states “…wind-energy projects create negative impacts on human health and well-being, the impacts are experienced mainly by people living near wind turbines who are affected by noise and shadow flicker.” [204]

Rotating wind turbine blades interrupt the sunlight producing unavoidable flicker bright enough to pass through closed eyelids, and moving shadows cast by the blades on windows can affect illumination inside buildings. [205] This effect is commonly known as shadow flicker.

Wind turbine shadow flicker has the potential to induce photosensitive epilepsy seizures however the risk is low with large modern models and if proper planning

is adhered to. [206], [207] Planning should ensure the flash frequency does not exceed three per second, and the shadows cast by one turbine on another should not have a cumulative flash rate exceeding three per second. [208]

Wind turbine shadow flicker induced adverse human health effects include annoyance and/or stress. [209], [210], [211], [212], [213]

Wind turbine noise including low frequency noise may also contribute to the overall annoyance.

"Wind turbine noise is easily perceived and annoying even at low A-weighted SPLs….Wind turbines are furthermore prominent objects whose rotational movement attracts the eye. Multimodal sensory effects or negative aesthetic response could enhance the risk of annoyance. Adverse reactions could possibly lead to stress-related symptoms due to prolonged physiological arousal and hindrance to psychophysiological restoration." [214]

No generalized dose-response curves have yet been modeled for wind turbine shadow flicker primarily due to the lack of results of published field studies.

Further investigation into the effects of wind turbine stressors including shadow flicker is required to assist in the development authoritative guidelines designed mitigate potential adverse health effects. [215]

Shadow flicker is also a safety concern. For example it can cause vehicle driver distraction. [216]

Most jurisdictions do not have explicit regulations to protect people from the adverse health effects of shadow flicker. [217]

To mitigate risk to human health wind turbines should be sited to ensure people will not be adversely affected. For example in the northern hemisphere people located East-NE or WNW from the turbine must be protected from shadow flicker. [218]

Recommended shadow flicker setbacks for current wind turbine designs are 10 rotational diameters which would typically translate to approximately 1000 m. [219]

Greater setback distances may be required when wind turbines are sited on elevated ridges as the shadows can be cast over distances of several kilometres.

It is acknowledged that "…shadow flicker can be an issue both indoors and outdoors when the sun is low in the sky. Therefore, shadow flicker may be an issue in locations other than the home." [220] Shadow flicker modelling must consider human exposure to shadow flicker outside a building.

Protection from wind turbine shadow flicker exposure must be engineered into the design of the wind turbine facility during the planning stage. [221], [222]

Furthermore the assumption that 30 hours a year of shadow flicker is protective of human health is not based on science. No generalized dose-response curves have been modeled for wind turbine shadow flicker primarily due to the lack of results of published field studies.

To ensure protection from adverse human health effects a revised shadow flicker study must be conducted during the planning stage of a wind turbine facility. The shadow flicker study must:

- Calculate shadow flicker based on the actual location of the wind turbines.

- Calculate shadow flicker exposure on the entire neighbouring properties and not just the “receptor (house)”.

- Calculate shadow flicker for both sun and moon induced flicker using conservative assumptions to ensure maximum protection against adverse human health effects and safety risks.

- Protect against photosensitive epilepsy by ensuring the flash frequency does not exceed three per second, and the shadows cast by one turbine on another do not have a cumulative flash rate exceeding three per second.

Conclusions: Wind Turbines and Shadow Flicker

Based on the best available science the following conclusions can be made.

- Wind turbines produce noise and visual burdens.

- Scientific research confirms visuals impacts can adversely affect human health.

- Wind turbine shadow flicker has the potential to induce photosensitive epilepsy seizures; however the risk is low with large modern models and if proper planning is adhered to.

- Wind turbine shadow flicker induced adverse human health effects include annoyance and/or stress.

- No generalized dose-response curves have yet been modeled for wind turbine shadow flicker primarily due to the lack of results of published field studies.

- Protection from wind turbine shadow flicker exposure must be engineered into the design of the wind turbine facility during the planning stage.

WIND TURBINE NOISE CHARACTERISTICS

"Noise is multidimensional. A one dimensional view of noise is the A - weighting, which considers only levels and neglects frequencies. Another one-dimensional view is to consider only frequencies and neglect levels. Developing the dimensions further, two dimensions include both frequency and level (the spectrum), three dimensions adds in the time variations of the noise, whilst higher dimensions include subjective response." [223]

Peer reviewed scientific research confirms "The capacity of a noise to induce annoyance depends upon many of its physical characteristics, including its sound pressure level and spectral characteristics, as well as the variations of these properties over time. [224]

"Noise measures based solely on LAeq values do not adequately characterize most noise environments and do not adequately assess the health impacts of noise on human well-being. It is also important to measure the maximum noise level and the number of noise events when deriving guideline values. If the noise includes a large proportion of low-frequency components, values even lower than the guideline values will be needed, because low-frequency components in noise may increase the adverse effects considerably. When prominent low-frequency components are present, measures based on A-weighting are inappropriate. However, the difference between dBC (or dBlin) and dBA will give crude information about the presence of low-frequency components in noise. If the difference is more than 10 dB, it is recommended that a frequency analysis of the noise be performed." [225]

The sound energy produced by wind turbine noise is complex. Wind turbine noise is comprised of a number of characteristics including broad band noise, low frequency noise, infrasound, amplitude modulation, tonal noise, impulse noise. [226], [227], [228], [229] It is widely affirmed that modulated broad band noise, low frequency noise, infrasound, tonal noise, and impulse noise have a particularly pronounced effect on people exposed to them. [230], [231], [232], [233] Another problematic special characteristic of wind turbine noise is that unlike other forms of noise it does not abate at night. [234]

A-weighted guidelines have proven ineffective at protecting individuals from the adverse health effects associated with wind turbine noise. [235]

"The probability of being annoyed by wind turbine sound increased with increasing levels of wind turbine sound." [236]

Peer reviewed scientific research confirms "…that wind turbine noise is easily perceived…" [237] and difficult to mask. [238]

Regarding representations pertaining to industrial wind turbine noise masking Health Canada advises…" omit statements about noise masking as they can be misleading;" [239]

"The sound of the turbines is not masked by wind or by wind through vegetation or leaf rustle in trees" [240]

Peer reviewed scientific research confirms noise masking may only be successful if the "…noises have the same frequency composition and if they actually occur at the same time." [241]

"Turbines produce a range of disturbing frequencies out of place in the natural soundscape extending from the audible range down into infra-sound. Residents frequently report that developers have claimed that the gentle sounds of the turbines will be absorbed or masked by the natural sounds of the environment... Residents report this as entirely untrue and an insult to their intelligence. Research undertaken by the author and many others has proved these claims of natural sound masking to be without foundation." [242]

"Wind turbine noise is NOT comparable to the rustling of leaves." [243]

Modern upwind industrial wind turbines produce a characteristic audible modulation of aerodynamic noise. [244] This is commonly referred to as amplitude modulation and is acknowledged to contribute to higher levels of wind turbine induced annoyance and/or sleep disturbance in the exposed population. [245], [246], [247]

"Wind farm noise can be intrusive in the home and is identified as low amplitude modulated sound (modulated in amplitude and frequency)" [248]

A UK report documented sleep disturbance caused by wind turbine amplitude modulation and recommended a penalty adjustment to noise guidelines to protect the local population. [249] The report also recommended addition research into amplitude modulation. [250]

Other researchers believe a penalty should be considered for wind turbine amplitude modulation. [251], [252]

Peer reviewed scientific research confirms noise limits should be based on annoyance scientific dose responses to individual noise sources. [253]

According to a peer reviewed article there is no health based generalized dose-response relationship developed to avoid possible adverse health effects from wind turbine noise exposure. [254]

Peer reviewed research confirms wind turbine noise is more annoying than equally loud noise sources such as traffic noise, airport, rail and industrial noise. [255], [256], [257], [258]

"The need for guidelines for maximum exposure to wind turbine noise is urgent:" [259]

Researchers have concluded that more sound mitigation measures must be considered for wind turbine noise. [260]

Wind turbine noise induced annoyance, stress and sleep disturbance have been documented at sound power levels less than 40 dBA. [261], [262], [263], [264]

Wind turbines produce low frequency noise and infrasound which may be audible or inaudible.

To protect people from the adverse health effect of noise annoyance World Health Organization states "Noise with low-frequency components require lower guideline values." [265]

Peer reviewed research confirms is inadequate as A-weighting underestimates the sound pressure level of noise with low-frequency components. [266], [267], [268]

"A-weighted levels for assessment of environmental noise are normally taken outside a residential property. The complexities of low frequency noise, including uncertainties in the transmission loss of the structure and resonances within rooms, require low frequency noise to be assessed by internal measurements." [269]

Wind turbine noise is modulated. Research related to low frequency noise "…confirms the importance of fluctuations as a contributor to annoyance and the limitation of those assessment methods, which do not include fluctuations in the assessment." [270]

CanWEA lobbies against having to address the impacts of wind turbine low frequency noise and infrasound "…CanWEA submits that the proposed requirement for infrasound or low frequency noise monitoring as a condition of the REA be removed." [271]

Peer reviewed scientific references confirm noise regulations must be enforceable. [272], [273]

"Health Canada advises that noise monitoring be undertaken under varying climatic conditions in order to ensure that noise levels do not exceed the acceptable level, and if exceedences are identified, that appropriate mitigation be implemented to reduce the noise level to an acceptable level." [274] The MOE Noise Guidelines for Wind Farms do not meet this standard.

Proposed industrial facilities including wind turbine facilities must be designed with appropriate noise control considerations so that the likelihood of compliance

is strong. Wind turbine developers should model noise assessments based on worst case conditions and should maximize setback distances. [275]

"The genuine difficulty that developers face is that noise levels are difficult to predict fully in advance…" [276] The NASA Technical paper "Wind Turbine Acoustics" illustrates that noise propagation of a wind turbine is complex and locations closer to a wind turbine such as under the base may be quieter than locations further away due to the wind induced refraction on acoustic rays radiating from an elevated point source. [277]

There is no scientific study to conclusively support that any of the wind turbine noise regulations and/or guidelines are protective of human health and safety. There are reports of individuals reporting noise problems [278] and adverse health effects in other jurisdictions with experience with wind turbines. [279], [280]

Conclusions: Wind Turbine Noise Characteristics

Based on the best available science the following conclusions can be made.

- A-weighted guidelines have proven ineffective at protecting individuals from the adverse health effects associated with wind turbine noise.

- A significant percentage of the exposed population will experience annoyance, stress and sleep disturbance and other related health problems from noise emissions.

- It is widely affirmed that A-weighting underestimates the sound pressure level of noise with low frequency components is not appropriate when managing human exposure to low frequency noise. C-weighting and Z-weighting are more appropriate to assess noise with low frequency components.

- Reliance on wind turbine manufacturers' statements showing the degree of tonality present is unwise as experience indicates that these statements are not reliable. Given this scientific uncertainty tonal penalties must be applied to all wind turbine projects during the engineering and approval stage.

WIND TURBINES AND PUBLIC SAFETY

Ice throw may not apply in warmer climates. However, wind turbine ice throw and structural failure are potentially severe public hazards. Ice throw and structure failure are physical dangers to people or passing vehicles. [281], [282]

"The majority of the available literature reporting on potential risk of ice from wind turbines is qualitative (opinion articles) with little scientific support…there has been only one scientific study conducted to assess the risk of ice throw." [283]

"Small blade parts and tips can fly very far. The maximum distance reported is 500 m. The maximum throw distance of an entire blade found during this analysis is about 150 m. Distances of 400 and 600 meters for entire blades were also reported in publications. Nevertheless, attempts to confirm these numbers through contacting the owner or the publisher were unsuccessful. When a rotor or nacelle falls down, the risk zone is approximately equal to half a rotor

diameter. When an entire tower fails, the risk zone is equal to the height of the tower plus half a rotor diameter." [284]

Studies have identified setback distances of 200–350 m for ice throw and 150 – 500 m for blade failure. [285]

A July 2009 Ontario commissioned report highlighted uncertainty regarding wind turbine ice throw and structural failure setbacks and stated among other things "Determination of the recommended separation distance based on these results may be premature and may not be appropriate." [286]

More research is required into the risk of ice throw in regions where glaze ice is common as most research has focused on rime ice. [287]

Wind turbine "structural failure is potentially fatal" and is a "physical danger to people or passing vehicles" [288]

"Although most turbines are designed to withstand temperatures as low as –20 to –40°C, structural materials can be compromised by extreme cold. Cold stress can cause steel and/or composite components to crack or deform, interfere with electrical equipment, or damage moving parts in the gearbox increasing the risk of turbine failure." [289]

Conclusions: Wind Turbines and Public Safety

Based on the best available science the following conclusions can be made.

- Wind turbine ice throw and structural failure are potentially severe public hazards. Ice throw and structure failure are physical dangers to people or passing vehicles.

- Based the research to date, determination of the recommended separation distance for ice throw and/or structural failure is premature and not appropriate.

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