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Trading off human health: Wind turbine noise and government policy

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Summary

Noise is considered a threat to public health that can seriously harm humans. Understanding the health impacts of noise has advanced significantly over past decades. Some jurisdictions responded by implementing policies to reduce the negative health effects of transportation and industrial noise. These gains in health protection from noise are under threat. In Canada government policies to support wind energy development have been adopted, in part, to reduce dependency on fossil fuels. However, wind energy facilities can produce unwanted sound and negative health and socio-economic effects when sited too close to humans. Peer reviewed literature, case reports, and access to information documents are used to evaluate government policies in Canada. Together these sources support the conclusion that human health is being traded off in favour of government policies that support wind energy development. This trade off conflicts with international charters that acknowledge the highest attainable standard of health is a fundamental right of every human being.

1.0 Noise and health

The understanding of noise and health has evolved significantly over past decades.

The World Health Organization (WHO) states: "Members of the United Nations may become members of the WHO by accepting its Constitution." [1] The nations of Australia, the United Kingdom, the United States of America and Canada are among the 194 WHO member states currently listed. [1]

The WHO constitution defines health as follows:

> "Health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity." [2]

The WHO website states: “The Definition has not been amended since 1948.” [3]

The WHO constitution also states:

> “The enjoyment of the highest attainable standard of health is one of the fundamental rights of every human being without distinction of race, religion, political belief, economic or social condition.” [2]

WHO (1999) states:

> “Physically, there is no distinction between sound and noise. Sound is a sensory perception and the complex pattern of sound waves is labeled noise, music, speech etc. Noise is thus defined as unwanted sound.” [4]

Sound, regardless of source, becomes a risk to human health if it is perceived as noise.

According to the WHO:

> “Noise seriously harms human health and interferes with people’s daily activities at school, at work, at home and during leisure time. Traffic noise alone is harming today the health of almost every third European. The main health risks of noise identified by WHO are:
>
> •pain and hearing fatigue;
> •hearing impairment including tinnitus;
> •annoyance;
> •interferences with social behaviour (aggressiveness, protest and helplessness);
> •interference with speech communication;
> •sleep disturbance and all its consequences on a long and short term basis;
> •cardiovascular effects;
> •hormonal responses (stress hormones) and their possible consequences on human metabolism (nutrition) and immune system;
> •performance at work and school.” [5]

The US Environmental Protection Agency states “…“annoyance” can have major consequences, primarily to one’s overall health.” [6]

Based on the findings of the WHO pan-European LARES study Maschke and Niemann (2006) state:

> “The results of the LARES study in relation to severe annoyance by neighbourhood noise demonstrate that neighbourhood noise must be classified as a serious health endangerment for adults.” [7]

Some of the well-accepted scientific principles of noise and health contained in WHO (1999) include: [4]

- Humans should be protected from health effects including interference with communication; noise-induced hearing loss; sleep disturbance effects; cardiovascular and psychophysiological effects; performance reduction effects; annoyance responses; and effects on social behaviour;
- “Prevention”, “Precaution” and “Polluter Pays” are fundamental noise management principles;
- Noise does not have to be considered loud to cause harm to human health;

- The capacity of a noise to induce effects depends upon its physical characteristics, including the sound pressure level, spectral characteristics and variations of these properties with time;
- Low frequency, tonal, modulated, impulsive and night time noise can have more pronounced effects on human health;
- Noise exposures should be based on dose response relationships specific to the individual noise source.

2.0 Wind turbine noise and health impacts

Some individuals living in the environs of industrial wind turbines (IWTs) experience negative health effects. Reported effects include annoyance and/or sleep disturbance and/or stress related health impacts and/or reduced quality of life. [8,9,10,11,12,13,14,15,16,17,18,19]

Unwanted sound (noise), visual impacts (shadow flicker), stray voltage [20] and socio-economic impacts are identified as plausible causes of annoyance and/or other adverse effects.

The National Research Council (2007) reports "…to the extent that 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." [21]

Pierpont (2009) documented symptoms reported by individuals exposed to IWTs to include: 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 when awake or asleep. Pierpont (2009) coined the symptoms "Wind Turbine Syndrome". [13]

The American Wind Energy Association and Canadian Wind Energy Association sponsored a literature review to consider existing literature on wind turbine noise and health. Colby et al. (2009) reported "Wind Turbine Syndrome" symptoms "… are not new and have been published previously in the context of "annoyance"…" and are the "… well-known stress effects of exposure to noise …". [22]

Peer reviewed studies consistently document IWTs produce sound which is perceived by humans to be more annoying than transportation noise or industrial noise at comparable sound pressure levels. [8,12] Annoyance from IWT noise starts at dBA sound pressure levels in the low 30's and rises sharply at 35 dBA.[23,24]

Modern wind turbines produce sound characteristics which are plausible causes for annoyance and/or other health effects. These characteristics include amplitude modulation (swooshing); [22,25,26,27,28] audible low-frequency noise; [29,30,31] infrasound; [32,33] tonal noise, impulse noise; [16] and night time noise. [12]

3.0 Government policy and human health

WHO (2008) states:

"Different government policies, depending on their nature, can either improve or worsen health and health equity." [34]

Governments do not always help individuals maintain or improve their health as policy often trades off human health for competing economic interests or political pressures.

"Health policy" is not synonymous with human "health". WHO (1998) defines "Heath Policy" as:

> "A formal statement or procedure within institutions (notably government) which defines priorities and the parameters for action in response to health needs, available resources and other political pressures." [35]

Health Canada's "*Achieving Health for All*" (1986) identifies three major challenges not adequately addressed by health policies and practices. One of these challenges is that "various forms of preventable diseases and injuries continue to undermine the health and quality of life of many Canadians".[36] Tobacco provides a good example of how government policies can trade off preventable harm for competing economic interests. "*Achieving Health for All*" (1986) acknowledges:

> "It is clear … that existing policies and practices are not sufficiently effective to ensure that Canadian men and women of all ages and backgrounds can have an equitable chance of achieving health … Conflicting interests may exist between sectors. Such conflicts are intrinsic to our society. Take the example of tobacco. We are proponents of a smoke-free environment. On the other hand, there are Canadian farmers who cultivate this product for their livelihood. Changes in tobacco policies have implications for farmers and smokers alike. In this instance the creation of healthy public policy necessitates responding to a situation with serious health as well as economic implications." [36]

Twenty years later in 2006 Canadian tobacco policy had evolved somewhat, although exposure to tobacco products was reported to be "… the primary cause of premature, avoidable death and disease in Ontario." [37] Health Canada (2012) states: "Each year in Canada, second-hand smoke causes the death of at least 800 non-smokers, due to lung cancer and heart disease." [38] This harm is in part due to health policy which continues to trade off harm to human health against conflicting interests.

4.0 Governance in Canada

The Government of Canada web site states:

> "Canada is a democratic constitutional monarchy, with a Sovereign as head of State and an elected Prime Minister as head of Government.
>
> Canada has a federal system of parliamentary government: Government responsibilities and functions are shared between federal, provincial and territorial governments." [39]

According to its web site:

> "Health Canada is the Federal department responsible for helping Canadians maintain and improve their health, while respecting individual choices and circumstances." [40]

Health Canada states "Canada was the Third Member State to ratify the …" WHO constitution. [41] "A Canadian Deputy Minister of Health, Dr. Brock Chisholm, became WHO's first Director General". [41] Dr. Chisholm was also one of the draftees of the WHO definition of health and was instrumental in ensuring mental well-being was included in the definition. [42]

In a July 11, 2012 letter David Butler-Jones of The Public Health Agency of Canada reaffirmed Canada's support for the WHO definition of health stating:

> "Canada, including both Health Canada and the Public Health Agency of Canada, continues to support the definition of health established by the WHO's constitution in

> 1948: Health is “a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity.” [43]

Health Canada (2005) [44],and other references acknowledge annoyance to be an adverse health effect.[10,45,46]

In the 2005 article *Noise annoyance in Canada*, Health Canada’s Dr. David Michaud states

> “According to the World Health Organization (WHO), health should be regarded as "a state of complete physical, mental and social wellbeing and not merely the absence of disease or infirmity" (World Health Organization 2001). Under this broad definition, noise induced annoyance is an adverse health effect.” [47]

Health Canada (2010) is “Published by authority of the Minister of Health.” [48] and states:

> “Health Canada considers the following noise-induced endpoints as health effects: noise-induced hearing loss, sleep disturbance, interference with speech comprehension, complaints, and change in percent highly annoyed (%HA).” [48]

WHO (2009) provides the following definition of sleep disturbance.

> “Disturbance of sleep by night-time noise, as perceived by a subject and described in a questionnaire response or journal entry” [49]

Preventing and reducing noise induced health effects is a widely accepted health promotion strategy. [4] Preventing or reducing annoyance and sleep disturbance is a health strategy which helps Canadians maintain and improve their health while respecting individual choices and circumstances.

Health Canada (2004) [50] and Michaud et al (2005) [47] acknowledge human health benefits from a reduction in noise annoyance.

According to the findings of a Health Canada commissioned study noise annoyance in rural Canada is demonstrated to be extremely low. [47,51,52] It was found that for Canadian communities with populations less than 5000, approximately 70.1 % of the sample indicated they were they “not at all annoyed” by noise outside their home.

5.0 IWT development in Canada

The Canadian Wind Energy Association (CanWEA) is an industry trade association and a registered federal lobby organization. CanWEA represents Canada’s “… wind energy owners, operators, manufacturers, project developers, consultants, and service providers, and other organizations and individuals interested in supporting Canada’s wind energy industry.” [53]

According to their website CanWEA develops “…policies, provide advocacy work and engage with all levels of government.” [54]

In recent years Canadian federal and provincial governments have developed policies which support IWT development. Canadian federal and provincial governments provide, or have provided, financial and other assistance to members of the wind energy industry. Examples of government assistance include, but are not limited to, financial subsidies to IWT developers for energy production, [55] sponsoring of CanWEA’s annual industry trade shows [56] and altering of environmental protection requirements for IWT projects.

Some governments in Canada have adopted wind energy targets similar to those of CanWEA.

In its 2008 "*Windvision 2025*" document CanWEA states "… we believe Canada should set a goal of producing 20 percent or more of our electricity from wind by 2025." [57]

In a 2010 document, "*Proposal to Develop National Guideline on Wind Turbine Noise*", Health Canada reports on federal and provincial wind energy targets stating:

> " Federal targets - - 20% of Canada's electricity generation by 2025"
> " Provincial targets - - vary however on average 20-25% by 2025" [58]

In a 2012 document "*Health Canada Policy and Research Approach for Wind Turbine Noise*" Health Canada reports:

> "National targets - - 20% of Canada's electricity generation by wind power by 2025"
> "June 2011 Speech from the Throne reaffirmed Canada's commitment to green energy" [59]

5.1 Removing barriers

IWTs are being sited in close proximity to family homes in order to have access to transmission infrastructure. [60] This close proximity to humans is occurring despite Canada's low population density. Based on 2006 data, Natural Resources Canada reports: "With 3.5 persons per square kilometre, Canada is one of the countries with the lowest population densities in the world." [61]

CanWEA's website states:

> "CanWEA caucuses and committees examine policy issues, and develop and advocate for key proposals to remove barriers to wind energy development across the country." [54]

In 2009 the Ontario Government passed the Green Energy and Economy Act which, in part, removes "…barriers to and promoting opportunities for renewable energy projects and to promoting a green economy." [62]

In a 2009 reported statement former Minister of Energy and Infrastructure, George Smitherman discussed the Green Energy and Economy Act stating: "We passed a law, and the law does not create an opportunity for municipalities to resist these projects just because they may have a concern." [63]

Noise regulations can be a major barrier to IWT development. IWT noise limits have an impact on wind turbine spacing, and therefore the cost of wind generated electricity. [64]

Members of Canada's wind energy industry have lobbied regulators to: increase permitted noise levels for wind turbines, remove requirements to address low frequency noise, and avoid penalties for amplitude modulation.

6.0 Not applicable to any human being on the planet

In some cases governments, CanWEA and members of the wind energy industry have retained and/or relied on the same consultants to inform policy.

For example Chatham-Kent's (former) Acting Medical Officer has consulted for members of the wind industry, CanWEA and various governments in Canada. Chatham-Kent's (former) Acting Medical Officer has also participated in references which discuss IWT health effects. [22,65,66,67]

Canada, including both Health Canada and the Public Health Agency of Canada, support the definition of health established by the WHO's constitution in 1948.

In 2011 Chatham-Kent's (former) Acting Medical Officer was retained by the Ontario Ministry of Environment to testify at an Environmental Review Tribunal which considered IWT health effects. When questioned about the WHO definition of health Chatham-Kent's (former) Acting Medical Officer testified under oath:

> "… the World Health Organization came up with that platonic definition of "health" in the post-World War II feel-good hubris of general exaltation, and it – that particular definition of "health" is not applicable to any human being on the planet." [68]

Health Canada (2006) states:

> "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." [69]

In 2009 the "Principal" of HGC Engineering discussed IWT noise and health and advised elected members of a municipal government:

> "… it is almost a disservice to dwell on the negative aspects. It clearly does create health problems in certain individuals but primarily through the psychological influence and anxiety …" [70]

Others who consultant for members of the wind energy industry have suggested that cognitive behaviour therapy could be used to treat those suffering adverse effects of wind turbine noise annoyance.[22,28,71,72]

Some consultants for members of the wind energy industry have gone so far as to suggest the "mental and social well-being" of some individuals exposed to wind turbines be traded off "… against the larger demand for energy and its source." [71]

7.0 Health effects expected: Canada

Subsequent to the release of Colby et al. (2009),[22] the President of the Canadian Wind Energy Association stated:

> "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,…" [60]

A current Director of the Ontario Agency for Health Protection and Promotion acknowledged in a 2010 literature review that wind turbine noise annoyance and sleep disturbance are common between 30 and 45 dBA. [73]

Ontario wind turbine noise guideline limits permit, [74] and projects are being approved for, [75] noise levels of up to 51 dBA (formerly 53 dBA) at a defined noise receptor (family home).

Other references acknowledge health effects are expected to result from human exposure to IWTs in Ontario.

For example internal Ontario Ministry of Environment correspondence, obtained through a Freedom of Information Request, states "It appears compliance with the minimum setbacks and

the noise study approach currently being used to approve the siting of WTGs will result or likely result in adverse effects …". [76]

In December 2011 the Ontario Ministry of Environment released a report prepared by then Canadian Wind Energy Association member, [77] HGC Engineering.

HGC (2010) states in the conclusions:

> "The audible sound from wind turbines, at the levels experienced at typical receptor distances in Ontario, is nonetheless expected to result in a nontrivial percentage of persons being highly annoyed. As with sounds from many sources, research has shown that annoyance associated with sound from wind turbines can be expected to contribute to stress related health impacts in some persons." [78]

7.1 IWT health effects reported and "conclusively demonstrated": Canada

Some Canadian residents living in the environs of IWTs experience negative health effects. [13,14] In some cases the effects were so severe that families have effectively abandoned their homes; been billeted by wind energy developers; or negotiated financial agreements with wind energy developers. [79]

These events (i.e. health effects, home abandonment, financial agreements with wind developers) have occurred at some wind energy projects listed eligible to receive government subsidies[80] and have undergone federal and/or provincial environmental assessments.

In June 30, 2009 correspondence from a federal Member of Parliament, the Honourable Rona Ambrose, provided the following statement:

> "Health Canada provides advice on the health effect of noise and low-frequency electric and magnetic fields from proposed wind turbine projects, particularly for environmental assessments done under the Canadian Environmental Assessment Act. To date, their examination of the scientific literature on wind turbine noise is that the only health effect conclusively demonstrated from exposure to wind turbine noise is an increase of self-reported general annoyance and complaints (i.e., headaches, nausea, tinnitus, vertigo)." [81]

Conclusively demonstrated health effects from exposure to wind turbine noise can be avoided if IWTs sound limits are designed to protect human health.

8.0 Proposing IWT health effects: Health Canada

For several years Health Canada provided advice on noise impacts from IWTs.

Health Canada (2010) states:

> "Health Canada does not have noise guidelines or enforceable noise thresholds or standards." [48]

However since at least 2007 Health Canada has proposed IWT noise criteria. Health Canada employees, Dr Stephen Keith, Dr. David Michaud, and Dr. Stephen Bly developed a justification for a 45 dBA sound level criterion in three separate references: Keith et al. (n.d.) [82] Keith et al. (2007) [83] and Keith et al. (2008). [84]

Keith et al. (2008) reports that other jurisdictions in Canada and internationally have sound limits for wind turbines that are less than 45 dBA. [84]

Despite other jurisdictions having lower IWT noise limits and despite Canada's low population density Health Canada (2009) states 45dBA is an acceptable limit for IWTs. [85]

Health Canada employees developed "a justification for using a 45 dBA sound level criterion for wind turbine projects" [82] and predict an increase in the percentage highly annoyed. [83,84]

45dBA is above the level at which sleep disturbance can occur. [49,86]

Since at least 2007 wind energy developers and consultants have been in the position to cite Health Canada's "justification" for a 45 dBA sound level criterion.

In 2012, after years of Health Canada providing advice, Dr. David Michaud, Dr Stephen Keith and other Health Canada employees acknowledged: "Health Canada's ability to provide advice on noise impacts from WTs has been challenged…" [87]

8.1 Failure to employ well-accepted principles of noise & health

A review of the Health Canada "justification" for 45 dBA supports the conclusion the authors did not employ a number of well-accepted principles of noise and health.

Prevention of noise induced health effects, including annoyance, is a fundamental principle of modern health promotion and protection.

Health Canada "justification" for 45 dBA calculates the percentage highly annoyed to be 7.6 percent.

Based on dose response data for wind turbines Health Canada Wind Turbine Noise Study Team Member, Sabine Janssen, reports with a highest allowed immission level of 45 dB(A) it could be expected that "… less than 14% of the exposed population to be highly annoyed indoors by wind turbines and less than 29% to be highly annoyed outdoors." [88]

8.2 The wrong dose response relationship

WHO (1999) states:

> "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." [4]

Keith et al. (2007) state:

> "Preferably the proposed criteria would be based on a dose response relationship that was specific to wind turbines" [83]

Despite this stated preference the Health Canada authors chose not to use a dose response relationship specific to IWTs. Instead the Health Canada authors employ a dose-response function based on road traffic noise. Peer reviewed studies conclude IWT noise is perceived to be more annoying than transportation noise including road traffic. [8,12]

8.3 Partial adjustments only

Keith et al. (n.d.) acknowledge that wind turbines are usually sited in quiet rural communities and provides a +10dB adjustment. [82] However Keith et al. (n.d.) does not adjust the noise criterion to reflect that IWTs usually are newly created situations. [82]

Under their proposal the Health Canada authors calculate the percentage highly annoyed to be 7.6 percent. However, if the authors had included a recommended 5 dB adjustment for "newly created situations" [89] the predicted percentage highly annoyed would be higher based on a dose response for road traffic.

8.4 No adjustment for IWT amplitude modulation

IWT amplitude modulation has been identified as a cause of annoyance and/or other reported health effects. [12,22,25,26,27,28]

Modern IWTs routinely produce an audible frequency modulation (swooshing). Health Canada (2009) states "…turbine noise is likely to be audible to the nearest receptors in the form of continuous low-level or intermittent swooshing…" [85]

"From various studies it follows that this modulation is equivalent in annoyance to the un-modulated sound at an approximately 5 dB higher level." [90]

Leventhall (2006) discusses IWT amplitude modulation and states:

> "Attention should be focused on the audio frequency fluctuating swish, which some people may well find to be very disturbing and stressful, depending on its level … A time varying sound is more annoying than a steady sound of the same average level and this is accounted for by reducing the permitted level of wind turbine noise." [25]

Ontario Noise pollution control publication NPC-104 states: "If a sound has an audible cyclic variation in sound level such as beating or other amplitude modulation then the observed value shall be increased by 5." [91] However in 2008 the Ontario Ministry of Environment elected to exclude IWT noise from this adjustment. [74]

An April 9 2010 internal Ontario Ministry of Environment memorandum obtained from a Freedom of information request states:

> "… it is reasonable to suggest the setback calculations should have included a 5dB addition to the sound level emissions from the WTGs to account for the amplitude modulation or blade swooshing sound of the WTGs. A 5 dB addition would address the Ministry observations and the Ministry 2007 Acoustic Consulting Report finding that the sound contamination from WTGs has a blade swoosh or amplitude modulation characteristic. A 5 dB addition for this cyclic variation of the quality of the sound discharged into the natural environment form WTGS would also be consistent with the Ministry's Publication Noise Pollution Control 104. …" [92]

The Health Canada authors also choose not to apply an adjustment for amplitude modulation to their "justification" for 45 dBA. [82,83,84]

8.5 IWTs routinely produce audible low frequency noise

In 2007 and 2008 the Health Canada authors acknowledge that research shows annoyance is greater when low frequency noise is present but state that "… modern turbine designs are not normally associated with audible levels of low frequency or infrasound …". [83,84]

However Health Canada (2009) states "…turbine noise is likely to be audible to the nearest receptors in the form … low frequencies at approximately 50 Hertz." [85]

HGC (2010) states:

> "In the low frequency range, it should be expected that low frequency sound due to aerodynamic sources will routinely be an audible component of the acoustic impact. … Since it is evident that complaints related to low frequency noise from wind turbines often arise from the characteristics of the sound impact indoors, and since the indoor low frequency sound levels and frequency spectra can differ markedly from those outdoors, it is recommended that the MOE consider adopting or developing a protocol to provide guidance for addressing such complaints." [78]

The Health Canada authors state: "… a 45 dBA limit in quiet rural areas should adequately protect against low frequency noise impacts from wind turbines." [84]

However, Møller& Pedersen (2011) state:

> "If the noise from the investigated large turbines has an outdoor A-weighted sound pressure level of 44 dB (the maximum of the Danish regulation for wind turbines), there is a risk that a substantial part of the residents will be annoyed by low-frequency noise even indoors. … Problems are much reduced with an outdoor limit of 35 dB." [93]

Minnesota Department of Health (2009) concluded:

> "The most common complaint in various studies of wind turbine effects on people is annoyance or an impact on quality of life. Sleeplessness and headache are the most common health complaints and are highly correlated (but not perfectly correlated) with annoyance complaints. Complaints are more likely when turbines are visible or when shadow flicker occurs. Most available evidence suggests that reported health effects are related to audible low frequency noise. Complaints appear to rise with increasing outside noise levels above 35 dB(A)." [30]

WHO (1999) reports that annoyance from audible low-frequency noise is acknowledged to be more severe in general than higher frequencies. [4]

Leventhall (2003) states low frequency noises can cause "… immense suffering to those who are unfortunate to be sensitive to low frequency noise and who plead for recognition of their circumstances." [94]

Leventhall (2004) states "… chronic psychophysiological damage may result from long-term exposure to low-level low frequency noise." [95]

DeGagne and Lapka (2008) report low-frequency noise does not need to be considered loud for it to cause annoyance and irritation. [96]

Symptoms associated with low frequency noise annoyance include stress, sleep disturbance, headaches, difficulty concentrating, irritability, fatigue, dizziness or vertigo, tinnitus, anxiety, heart ailments, and palpitation. [94,95,97]

8.6 Using the wrong metric

Michaud et al. (2012) states wind turbine noise may be "… problematic for rural residents as it may be more noticeable and they may experience large changes in sound levels with unpredictable operating times and variable wind conditions." [87]

IWTs routinely produce cyclical amplitude modulation, impulse and low frequency noise.

The Health Canada authors propose an "A"-weighted base limit for their "justification" for 45 dBA.

Averaged noise metrics are unsatisfactory for sources which produce cyclical amplitude modulation or impulse noise.

It is well-accepted that an "A"-weighted base limit is unsatisfactory for a noise source that contains low frequencies. [4,95,96]

Health Canada Study Team member Werner Richarz states in Richarz et al. (2011):

> "Sound emissions from operating wind farms frequently give rise to noise complaints. Most compliance-based noise audits measure hourly "A"-weighted Leq, thereby removing the low-frequency contents of the wind turbine sound. The metric is also insensitive to amplitude modulation and is unsatisfactory when sensitive receptor are annoyed by the low frequency sound and amplitude modulation. [98]

8.7 Omit statements about noise masking as they can be misleading: Health Canada

Peer reviewed studies demonstrate wind turbine noise is very easily perceived[99] and difficult to mask.[8,12]

A CanWEA fact sheet, funded in part by Natural Resources Canada, states: "…much of the sound from the blade is masked by the sound of the wind itself and of the accompanying sound of rustling leaves in nearby trees and shrubs."[100]

The Health Canada authors of the "justification" for 45 dBA suggest their noise criterion can be exceeded stating: "The noise level criteria proposed here should not be considered as strictly applied limits. It is possible that the noise from the wind turbine could be masked by wind noise." [84]

WHO (2009) states:

> "Masking, … is a complex process. The human auditory system is uncannily good at separating signals from "background". … The rule of thumb that a noise can be considered masked if the signal is 10 dB below the background is only valid if the noises have the same frequency composition and if they actually occur at the same time."[49]

IWTs in Canada are typically installed in quiet Canadian rural communities. Ambient sound levels in rural Canada can be below 30 dBA. [92]

Furthermore: "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 …". [101] Canada is a northern climate with a relatively short growing season consequently much of the surrounding plant life is without foliage for a large percentage of the year.

A 2009 IWT consultant report stated "…it has generally been considered that the increased background wind noise will cause some masking of the sound levels from the turbines"[102]. In response to this statement Health Canada (2009) states: "Please omit statements about noise masking as they can be misleading …" [85]

8.8 Not a worst case prediction

DeGagne & Lewis (2006) state: "The genuine difficulty that developers face is that noise levels are difficult to predict fully in advance…"[103]

Møller& Pedersen (2011) state:

> "A safety margin must be incorporated at the planning stage in order to guarantee that the actual erected turbines will comply with noise limits. An international technical specification exists for this, but it is often not used." [93]

The Keith et al. (2008) section "*Justification for use of the predicted worst case*" discusses ISO 9613-2, uncertainty in predicted noise modelling, with a standard uncertainty of +/- 3 dB, and note it may be larger in some cases.

HGC (2007) states ISO 9613-2 "… does not purport to consider the absolute worst case environmental situation, and consequently, there may be times when the actual impact exceeds that predicted…" [104]

HGC (2009) states: "… there remains in practice variations of at least +/- 5 dB between the predicted impacts and sound levels measured in the field." [105]

2009 Health Canada correspondence states: "…predicted sound levels, even under assumed worst-case conditions, may underestimate measured levels by 5 dBA or greater." [85]

Based on IWT dose response relationships, a 5 dBA underestimation of IWT would result in a significant increase in percentage annoyed.

9.0 Discussion

Canada accepts the WHO Constitution and thereby acknowledges the highest attainable standard of health is one of the fundamental rights of every human being.

Since the inception of the WHO Constitution, there has been significant advancement of our understanding of physical health mental and social well-being. We now understand "Mental health is as important as physical health to the overall well-being of individuals, societies and countries." [106] "The goal of improving the quality of life, alongside preventing avoidable ill-health, has become of increased importance in health promotion." [35]

It is accepted that that noise can seriously harm human health including risks of annoyance, sleep disturbance, stress and other health effects.

Health advancement is at risk of being reversed if governments accept consultant suggestions that individual "mental and social well-being" be traded off for the greater demand for IWT

energy; or that the WHO definition of health "is not applicable to any human being on the planet".

Government policies can either improve or worsen human health. In recent years both federal and provincial governments in Canada have adopted policies and programs to support the development of the wind energy industry. At the same time it appears some governments have lost sight of their responsibility to help individuals maintain and improve their health.

A 2011 Ontario Environmental Review Tribunal (ERT) considered evidence and testimony under oath and found that wind turbines can harm humans if they are placed too close to residents.

> "This case has successfully shown that the debate should not be simplified to one about whether wind turbines can cause harm to humans. The evidence presented to the Tribunal demonstrates that they can, if facilities are placed too close to residents. The debate has now evolved to one of degree." [107]

Unwanted sound from IWTs can cause annoyance, stress, and sleep disturbance which can have other health consequences. This harm to human health is avoidable, as Canada has one of the lowest population densities in the world. However IWTs are being sited too close to humans for economic reasons.

IWT development in Canada provides a contemporary example of government policy trading off "human health" for competing economic interests.

Governments have been exposed to lobbying efforts from the wind energy industry to: increase permitted noise levels for wind turbines, remove requirements to address low frequency noise, and avoid penalties for amplitude modulation.

Some governments in Canada have developed IWT noise guidance which is expected to result in adverse health effects.

At the provincial government level the Ontario Ministry of Environment has developed IWT noise guidelines which:

- permit higher levels of IWT noise (up to 51 dBA) than other sources of industrial noise;
- do not address IWT low frequency noise;
- exempt IWTs from existing Ontario adjustments for amplitude modulation;
- use an average A-weighted metric;
- do not account for uncertainty in the noise modelling predictions;
- are expected to result in a non-trivial percentage of persons being highly annoyed; and
- can be expected to contribute to stress related health impacts.

The situation is similar at the federal government level. Health Canada is the federal department responsible for helping Canadians maintain and improve their health, while respecting individual choices and circumstances. However, instead of helping Canadians maintain and improve their health, the department has developed a "justification" for causing health effects from exposure to IWTs. Health Canada's "justification" for a 45 dBA IWT noise criterion fails to employ critical accepted noise principles. Specifically the Health Canada authors propose a noise criterion which:

- is not based on a dose response relationship specific to IWTs;
- does not adjust (+5dB) to reflect IWT are usually a newly created source of noise;
- does not apply adjustments for audible amplitude modulation;
- does not apply adjustments for audible low frequency noise;

- uses an A-weighted metric;
- is not to be considered a strictly applied limit; and
- is predicted to result in adverse health effects (i.e. an increase in percentage highly annoyed).

To summarize, government policy to support IWT development in Canada has resulted in harm to human health.

Specifically Health Canada and The Ontario Ministry of Environment developed IWT noise criteria which are expected to result in a non-trivial percentage of persons being adversely affected. These two government agencies are now funding research intent on studying the effects of exposing humans to IWT noise with the objective of informing government policy.[87,108]

10.0 Conclusions

Wind energy facilities can produce unwanted sound and negative health and socio-economic effects when sited too close to humans. In some cases the effects are so severe Canadian families have effectively abandoned their homes; been billeted by wind energy developers; or negotiated financial agreements with wind energy developers. Canada has one of the lowest population densities in the world. Harm to human health can be avoided by situating IWTs a protective distance from residents.

Government has a responsibility to help individuals maintain and improve their health. However some governments in Canada have developed IWT noise criteria which are expected to result in a non-trivial percentage of the exposed population experiencing harm to human health. This avoidable harm is in conflict with the WHO constitution which accepts the enjoyment of the highest attainable standard of physical, mental and social well-being as one of the fundamental rights of every human being.

The references cited in this paper support the conclusion that human health is being traded off in favour of government policies that support IWT development in Canada.

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