Exhibit 27

Health Sciences

Exponent®

Evaluation of the Scientific Literature on the Health Effects Associated with Wind Turbines and Low Frequency Sound

Exponent®

Evaluation of the Scientific Literature on the Health Effects Associated with Wind Turbines and Low Frequency Sound

Prepared for

Wisconsin Public Service Commission
Docket No. 6630-CE-302

Prepared by

Mark Roberts, M.D., Ph.D.
Jennifer Roberts, Dr.PH, MPH
Exponent
185 Hansen Court
Suite 100
Wood Dale, Illinois 60191

October 20, 2009

0903940.000 F0T0 0809 JR03

Contents

List of Figures

List of Tables

Executive Summary

This white paper presents a review of the human health effects associated with infrasound and low frequency sound, preceded by an introduction to the basic concepts of epidemiology, causation, the peer review process, the science of public health, and the precautionary principle.

The goal of this white paper was to highlight key points regarding the health concerns of those involved with the positioning of wind turbines, rather than an in-depth review of the science of sound. The research involving sound is massive in its depth and breadth and is expanding daily. Research on health effects associated with human exposure to sound has evolved from the study of physical damage to the study of psychological and other effects, from ringing in the ears to non-specific physical symptoms. Early research in low frequency noise exposures is difficult to evaluate due to the diversity of the exposure and non-specific nature of the reported health effects. As of this review, there has not been a specific health condition documented in the peer reviewed published literature to be classified as a disease caused by exposure to sound levels and frequencies generated by the operation of wind turbines. That does not mean that there cannot be an effect. Numerous scientific papers document physiological responses to low frequency sound, but the majority of these effects are consistent with human response to environmental stimuli of varied nature and at higher decibel levels than produced by wind turbines. One of the most prominent non-physiological effects noted across the gamut of scientific as well as lay press literature is the annoying qualities of sound as was so vividly pointed out in one of the discussions when it was said that "one man's music is another man's unbearable noise." Annoyance is a normal response and is not predictable based on the sound level below the painful level. It is clear that some people respond negatively to the noise qualities generated by the operation of wind turbines, but there is no peer-reviewed, scientific data to support a claim that wind turbines are causing disease or specific health conditions. Annoyance regarding the wind turbines is an elusive factor that could underlie a majority of the health complaints being attributed to wind turbine operations.

Overview of Epidemiology

Epidemiology is the study of the distribution and determinants of health events in populations (Last JM. 2001). The key elements of epidemiology are comparisons of health outcomes and exposures between populations (which allows for the calculation of relative risk estimates) and the careful evaluation of underlying determinants that may affect the outcome of comparisons of the study populations (bias and confounding). The study of health claims related to wind turbines is an excellent example of the potential influence of both bias (voluntary and involuntary exposures) and confounding (health outcome potentially related to direct and indirect exposure).

The scientific body of knowledge relative to a particular disease often starts with observations by clinicians (case reports and case series). These reports are not analytical studies because they have no comparison group or other means to test for associations. Case reports and reports of series of cases help generate scientific hypotheses; however, they cannot be used in testing for association or causation (Checkoway H. 2004). Surveys of only those persons claiming an effect give only one part of the total equation needed to assess the magnitude of risk associated with living near wind turbines. A collection of observations, no matter how well documented, are not sufficient to prove an increased risk, but instead are a first step in the scientific process. One must rely upon peer reviewed, published studies that are designed to reduce bias and confounding as much as possible.

The two most common types of analytical epidemiologic studies used to evaluate potential disease causation are cohort studies and case-control studies. In cohort studies, the researcher identifies two groups of individuals: individuals who have been exposed to a substance considered a possible cause of disease (“exposed” group) and individuals who have not been exposed (“unexposed” or “comparison” group). The researcher then follows both groups for a length of time and compares the rate of disease among the exposed individuals with the rate of disease among the unexposed individuals. The researchers determine whether there is an association between the exposure and the disease by calculating a relative risk (RR), which divides the rate of disease among the exposed by the rate of disease among the unexposed, with a value statistically greater than 1.0 indicating a positive association. One type of cohort study is a standardized mortality (incidence) ratio study (SMR/SIR). In SMR/SIR studies of occupational groups, the number of observed cases for a particular occupational group is compared to the number one would expect for that group based on rates in the general population. These studies divide the observed number of cases by the expected number of cases, with a value statistically greater than 1.0 indicating a positive association.

In case-control studies, the researcher begins with a group of individuals who have the disease (cases) and then selects a group of individuals who do not have the disease (controls). The researcher then compares the case and control groups looking for differences in past exposures. An association is measured by dividing the odds of exposure among the diseased by the odds of exposure among the non-diseased, with a value statistically greater than 1.0 indicating a positive association.

Another type of epidemiologic study is a proportionate mortality (incidence) ratio study (PMR/PIR). PMR/PIR studies compare the proportions of selected causes of death or disease incidence in the exposed study group to the proportion in the unexposed study population, with a value statistically greater than 1.0 indicating a positive association.

No matter the study design, the researcher applying epidemiological principles and the reader of the studies must have a clear understanding of what constitutes the "disease" being studied. The description of the disease has to be sufficiently specific and described such that the comparisons are truly comparing "like to like." In the case of health complaints related to wind turbines, there is a lack of specificity as to the health complaints. A disease or group of symptoms classified as "Wind Turbine Syndrome" has not been adopted by the medical community. The underlying complaint of annoyance is in and of itself not a disease or a specific manifestation of a specific exposure but instead a universal human response to a condition or situation that is not positively appreciated by the human receptor. Annoyances are highly variable in type (noise, smell, temperature, taste, vision) and vary from person to person. One can be annoyed by the action of others, as well as their own individual actions. Thus, "annoyance" is not a disease but a universal human response that is highly non-specific. In conclusion, it has been found that there is a lack of epidemiologic research studies showing an association between health effects and exposure to noise at low frequency in combination with low sound pressure (dBA) generated by wind turbines.

Epidemiology, Association, and Causation

Historically, there have been careful clinical observations (case reports and series) that have stimulated a number of now-classic epidemiology research efforts that have identified important associations and ultimately the determinants of causal relationships. There have also been case reports identifying associations that did not hold up under epidemiological scrutiny, for example, those associating blunt force trauma and cancer. For this reason, case studies cannot be used to determine causation. A causal association can only be established by the evaluation of well designed and executed epidemiologic studies.

A landmark discussion of the process of moving from a disease being associated with a risk factor to a point where the scientific community is comfortable attributing causation to a risk factor was put forth by Sir Austin Bradford Hill in 1965. It was during this time that a number of papers, including the Surgeon General Report issued in 1964, began to more formally delineate the scientific reasoning process that justifies a conclusion that observed associations between an exposure and a disease are the result of a causal relationship between the exposure and the disease. Key statements from scientists during that time include the following:

> "Disregarding then any such problem in semantics we have this situation. Our observations reveal *an association between two variables, perfectly clear-cut* and beyond what we would care to attribute to chance. What aspects of that association should we especially consider before deciding that the most likely interpretation of it is causation?" [italics added] (Hill AB. 1965). Hill's nine criteria for causation have been described in a number of ways. They are commonly referred to as strength, consistency, specificity, temporality, biological gradient, plausibility, coherence, experiment, and analogy (Hill AB. 1965).
>
> *"If it be shown that an association exists*, then the question is asked, 'Does the association have a causal significance?' … To judge or evaluate the causal significance of the association between the attribute or agent and the disease, or effect on health, a number of criteria must be utilized…" [italics added] (Bayne-Jones S et al. 1964).

Finally, it should be noted that greater weight can be provided to the strength of an association when several epidemiologic studies performed by different researchers arrive at the same conclusions. And as a final step, researchers often submit their work for publication which then typically undergoes a peer review process for completeness and scientific soundness.

Figure 1. The Scientific Process

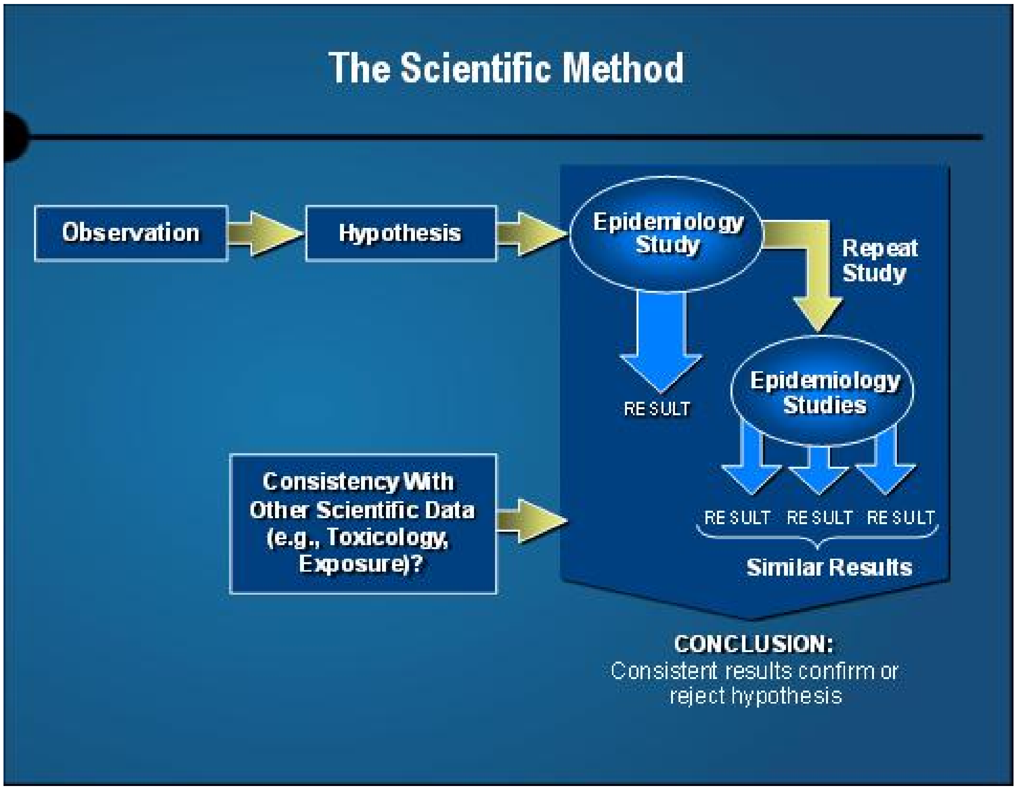

Figure 2. The Scientific Method

Peer Review Process

According to the Centers of Disease Control and Prevention (CDC), the peer review process is an "independent assessment of the scientific merit of research by panels of experts who provide written assurance that their reviews are free of real or perceived conflicts of interest. Results of the peer review process should therefore be without inherent bias and can be viewed as fair and just…" (CDC 2009).

Publication in a peer-reviewed journal remains the standard means of disseminating scientific results and has been since 1665, when the first recorded peer review process was performed at The Royal Society by the founding editor, Henry Oldenburg (UK Parliament and House of Commons 2004). Consequently, publications that have not undergone a peer review are likely to be regarded with skepticism and doubt by scholars and professionals.

Generally, the peer review process uses anonymity and employs a double-blind process whereby the authors and peer reviewers remain unknown or blinded to each other. Reviewers are often required to disclose conflicts of interest. The use of anonymity preserves the integrity of the peer review process and discourages favoritism shown by colleagues, friends, or relatives. Although not fool-proof, the peer review process can also maintain and enhance the quality of work by detecting flaws, plagiarism, fraud, unsound science, or personal views. Hence, the peer review process fosters scholarship and encourages authors to meet the accepted standards of their discipline.

The typical peer review process for scientific journals begins with the author submitting a manuscript. The editor of the journal reviews the article and determines whether or not the article is appropriate for the journal. If the article is determined to be appropriate, the editor assigns peer reviewers to read and critique the work. The reviewers then submit their comments to the editor and a decision is made with respect to the publication status of the article: (1) accept for publication; (2) accept for publication with modifications; (3) reject for publication (Figure 3). An average acceptance rate for publication in peer reviewed journals has been reported to be between 25% and 50%, although journals such as New England Journal of Medicine and the British Medical Journal have been known to be much lower (Elsevier 2009).

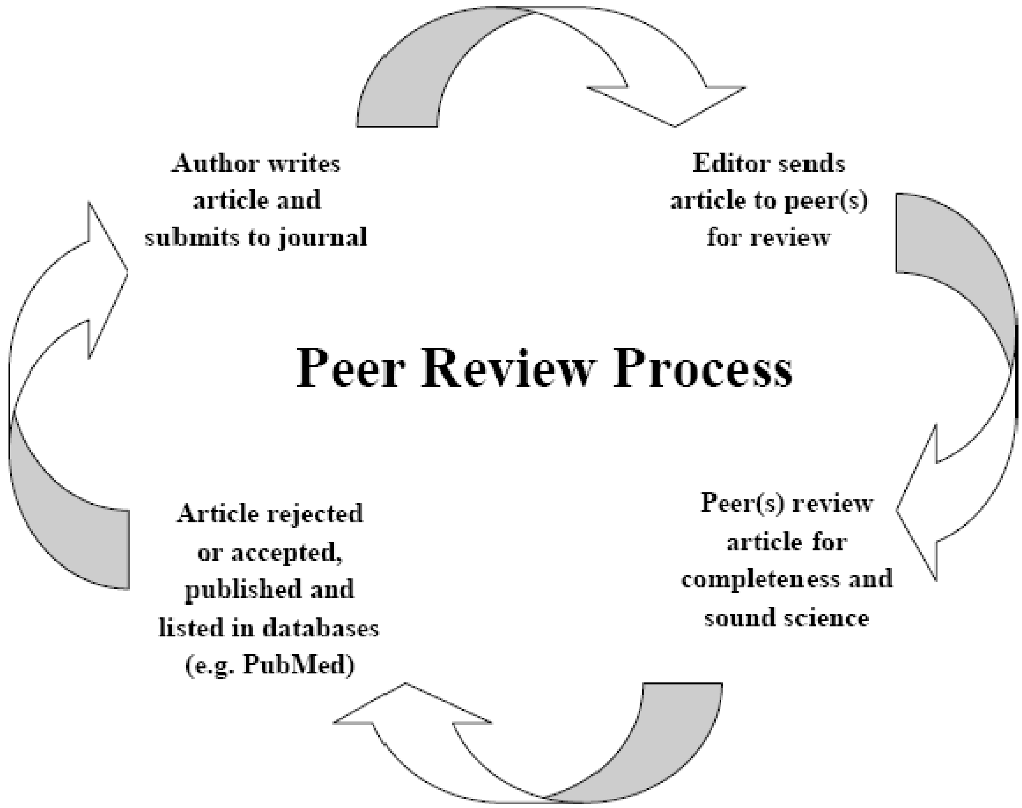

Figure 3. Peer Review Process

A thorough and complete peer review gives the reader some confidence that the article meets appropriate scientific rigor. Seldom does an article submitted for publication get accepted without addressing issues brought to light in the peer review process. At one point in time, "publication" of a scientific work in a peer-reviewed journal was a stamp of quality; however, in today's world, opinions, ideas, and hypothesis can be "published" by a number of methods (websites, blogs, and media articles), without the scientific rigor of critical peer review.

The key aspect of the peer review is a critical appraisal of the research, a continuous challenge of the scientific hypothesis and comparison with the body of scientific knowledge relevant to that research. While the process can never be totally free of bias (we all have opinions that influence our thinking), a clear effort to seek out those who are not directly connected to the researcher(s) is an important first step. The second part of the review process and assessment of the scientific merit of the research is the publication of the research so that others interested in the topic can benefit from the knowledge, apply it in their research efforts, or learn from the mistakes of other researchers. Opinion pieces, media interviews, court testimony, and testimony before legislative bodies, while informative, do not have the weight, standing, or status of peer-reviewed published scientific work. Unfortunately, because of their high visibility, emotional nature, and understandability, these sources outside of the peer-reviewed journals are often perceived as being of high reliability without having the benefit of careful scrutiny and response from those most knowledgeable in the research field being discussed. For example, Dr. Nina Pierpont has received a considerable amount of attention regarding the upcoming publication of her book, Wind Turbine Syndrome: A Report on a Natural Experiment, which uses non-traditional references such as newspaper articles and television interviews. In addition, this book is apparently being published by a publishing company which will have only one published book (this one) and that consists of an editorial board of which Dr. Pierpont and her husband make up two of the members.

Public Health Issues

"Public Health" refers to the overall wellbeing of a group of people. The description of Public Health incorporates the science of identifying major effectors of health status of a population and taking measures to prevent disease, prolong life, and promote health through private, academic, governmental, and corporate efforts. A physician treats a patient and considers the family, whereas a public health professional "examines" populations and takes broader actions to improve the health of the individuals that make up the population. Public health efforts primarily focus on prevention rather than treatment of disease. The United Nations' World Health Organization defines health as "a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity." This is a lofty goal to strive for, but if public health history is any indication of things to come, as we conquer the leading causes of disease, new diseases become more prominent.

There have been major successes in Public Health (e.g., smallpox eradication, control of malaria, nationwide immunization programs to prevent vaccine-preventable diseases, chlorination of municipal water supplies). However, for every public health accomplishment, there have been new health challenges related to lifestyle issues and changing health expectations. According to the U.S. Census Bureau, the final data for 2003 indicated that life expectancy at birth for the total population in America has reached an all-time high level of 77.5 years. This is up from 49.2 years at the turn of the 20th century. Record-high life expectancies were found for white females (80.5 years) and black females (76.1 years), as well as for white males (75.3 years) and black males (69.0 years). With this increase in life expectancy, there has also been an expectation of a life as free of health concerns as possible. Unfortunately, this public health progress has brought the realization of the health effects of the very activities that helped extend our lives (e.g. chlorination of drinking water, mercury-based preservatives in some vaccines).

Along with these advances has come the development of a very expansive information system called the internet, a growing environmental awareness, and a growing expectation of a long and healthy life. The advances that have been made to support a growing and aging population have brought risks with them such as automobiles, massive highway systems, and large-city problems such as crime and pollution. These more familiar risks have been generally been accepted or forgotten, but new risks are less tolerated. Herein lays the difficulty of public health today. Population growth and societal demands have pressured public health professionals to provide guidance in the assessment of risks of new technological advancements and to reduce or eliminate risk.

While assessing a level of risk may be done in a sterile, scientific fashion, assessing the acceptability of that risk level risk becomes a preference choice. A community may choose to accept a level of risk that an individual finds unacceptable. That discrepancy between community and individual acceptability moves the decision from a public health issue to a political and social decision. Public health can bring science to the discussion, but in the end, a decision that weighs all the factors must be made for the larger group as a matter of policy.

In addition to the debate over what levels of risk are acceptable or tolerable, there is also the pressure of clearly delineating between actual risks and perceived risks. Once the analysis of the risk assessment is completed, the responsibility of the risk manager is to explain to the public and all involved stakeholders. A common perception among risk assessors and managers is that individuals who have a lack of information or information that is distorted about a risk are often subjected to unreasonable fears (Vertinsky I. And Wehrung D. 1989). These fears typically are not calmed even when accurate information is provided and unfortunately many expect a level of certainty from science that is almost always impossible to achieve. Several identified risk perception factors have been found to dictate the acceptability of risk regardless of the presentation of science which quantifies and qualifies the actual risk (Table 1).

Table 1. Risk Perception Factors For the Acceptability of Risk

"Acceptable" Risk	**"Unacceptable" Risk**
Controllable	Uncontrollable
Voluntary	Involuntary
Not Dread	Dread
Natural	Man-made
Beneficial	Of Little or No Benefit
Immediate Effects	Delayed Effects
Not Global Catastrophic	Global Catastrophic
Consequences Not Fatal	Fatal Consequences
Equitable	Inequitable
Affects Adults	Affects Children
Low Risk to Future Generations	High Risk to Future Generations
Easily Reduced	Not Easily Reduced
Risk Decreasing	Risk Increasing
Doesn't Affect Me	Affects Me

Reference: (Slovic P. et al. 1982)

There are many examples in public health where the assessed risk of an event or environmental conditions is perceived differently than an interested segment of the population. In these situations, the public health officials must make the best decision they can using the scientific method. There comes a point where a decision must be made for the good of the largest segment of the population. The ramifications and effectiveness of these decisions are not always seen as positive from a historical perspective. Take for example the "Swine Flu" immunization program of 1976 under the Ford Administration. That program resulted in a segment of the immunized population developing Guillain-Barre Syndrome. The same sort of decision process is being carried out now as public health officials embark on a campaign to protect the population for an H1N1 Pandemic. Part of the analysis included an estimation of how many persons can be expected to develop Guillain-Barre Syndrome from the new vaccine.

Societal decisions, like Public Health decisions, must be made with the benefit of the best, most sound information. Few historical efforts to advance health or societal development have come without concerns from many segments of the population and a few that may be affected.

Precautionary Principle

Some groups and organizations have addressed the acceptability of risk by adopting a position or philosophy that when risk may exist, but the level of risk is in doubt, actions should be taken to avoid the risk much in tune with the idea that "if in doubt, don't." Similarly, a process potentially producing risk is "guilty until proven innocent." This view is commonly referred to as the "precautionary principle." While seemingly attractive, the precautionary principle fails to acknowledge that in reality, every human activity has risk, and the balance between the potential risk and the value of that activity depends on the individual.

The precautionary principle is an attempt to set a goal for environmental planning and response to perceived health threats based less on science and more on the social basis of the issue being examined. While the principle was developed during the discussion of environmental issues, it can be applied to any function of mankind and all our activities. It is a high standard to compare activities of the earth's inhabitants based on social values and less on science. There are few arguments when a solid body of science has been amassed showing an association and meeting the criteria for "causation." The difficulty arises when new discoveries and applications are evaluated on what effect they "could have" rather than on the scientific data obtained during they development and regulatory review. The philosophy of "new is not necessarily good" and the "fear of the unknown" result in an almost instant increased level of concern in a segment of most populations. This is partially due to the easy access to information provided by media and the internet, the risk aversion that has become prevalent in our society, and the pressures of our evolving societies. The precautionary principle should be applied in the light of the science of the day and with the understanding that no scientific study of a sample of the population can "prove" there is no association between a technology and a perceived health threat.

The precautionary principle has evolved in both the legal and social context to the point of being prominent in national and international treaty and agreements. While the principle incorporates an extremely cautious approach, it embodies concepts that we have embraced in our daily lives e.g. “an ounce of prevention is worth a pound of cure,” “look before you leap,’ and “better safe than sorry.” On an individual basis, the precautionary principle is relatively easy to apply, and the risk and benefit directly applies to the individual. Application of the precautionary principle at a community or national level involves societal decisions that may include legal, economic, and political aspects. The application of the scientific process and sharing of knowledge gained through scientific investigation can provide objective information to assist in these decisions. Science will reduce the uncertainty, but not eliminate it entirely. Society must decide what is an acceptable level of risk (e.g. allowing passengers to fly in airplanes without parachutes, allowing people to ride ferryboats without wearing lifejackets). Delineation and comparison of risk is a scientific process, but determination of acceptable risk is beyond the realm of science.

Background on Infrasound and Low Frequency Sound

Sound is an energy generated by a source (e.g., bell), transmitted through a medium (e.g., air), and received by a receiver (e.g., human ear). Sound travels from the source in the form of waves or fluctuations of pressure within the medium. As the human ear detects these vibrating waves, they are translated into electrical signals that are transmitted to the brain for decoding.

Sound is perceived and recognized by its loudness (pressure) and pitch (frequency). The indicator of loudness is the decibel (dB), which is a logarithmic ratio of sound pressure level to a reference level.[1] With a logarithmic scale, sound levels from two or more different sources cannot be arithmetically added together to determine a combined sound level. Specifically, the dB is a logarithmic unit of measurement that expresses the magnitude of a physical quantity such as power or intensity relative to a specified reference level. Human hearing of sound loudness ranges between 0 dB (threshold of sound for humans) and 140 dB (very loud and painful sound for most humans) (NMCPHC 2009; NASD 1993) (Table 2). Not all sound pressures are perceived as being equally loud by the human ear due to the fact that the human ear does not respond equally to all frequencies. The frequency range of human hearing has been found to be between 20 Hz and 20,000 Hz for young individuals with a declining upper frequency range correlating with increasing age (Berglund B. et al. 1996). The frequency of sound is expressed in Hertz (Hz)[2] which is equal to 1 cycle per second. The sound perception, "hearing," for humans is less sensitive to lower frequency (low pitch) and higher frequency (high pitch) sounds. As a result, the human ear can most easily recognize sounds in the middle of the audible spectrum, which is ideally between 1 kHz to 4 kHz (1,000 to 4,000 vibrations per second) (UNSW 2005). As a result, devices used to measure sound (sound meters[3]) are

[1] Reference Level - A special value of a quantity expressing the degree of modulation of a recording medium, in terms of which other degrees of modulation are expressed, usually in decibels (IEC).

[2] Hertz (Hz) - A unit of frequency defined as the number of cycles per second (1 Hz equals 1 cycle per second). Hertz can be used to measure any periodic event within a sinusoidal context, such as radio and audio frequencies (IEC).

[3] Sound Level Meter – Instrument used for the measurement of sound level with a standard frequency weighting and a standard exponential time weighting (IEC).

designed with filters that have a response to frequency similar to human. The A scale is the most commonly used sound level filter and the sound pressure level is given in units of dB(A) or dBA. With the A weighting filter, the sound level meter is less sensitive to very high and very low frequencies. Sound measurements made on the C scale, which are linear over several octaves and suitable for subjective measurements of very high frequency sound levels, are expressed as dB(C) or dBC. Another weighting filter, the B scale, is a rarely used intermediate between the A and C scales (UNSW 2005).

Table 2. Human Sound Intensity Levels

Decibel Level (dB)	Source
140	Threshold of pain: gunshot, siren at 100 feet
135	Jet take off, amplified music
120	Chain saw, jack hammer, snowmobile
100	Tractor, farm equipment, power saw
90	OSHA limit - hearing damage if excessive exposure to noise levels above 90 dB
85	Inside acoustically insulated tractor cab
75	Average radio, vacuum cleaner
60	Normal conversation
45	Rustling leaves, soft music
30	Whisper
15	Threshold of hearing
0	Acute threshold of hearing

Reference: (NASD 1993)

In the 1930s, researchers Fletcher and Munson conducted experiments on the response of the human ear and the relationship between sound frequency and pressure (Fletcher H. and Munson WA. 1933). Fletcher and Munson developed curves to approximate this relationship which were then revised by the International Organization for Standardization (ISO) and are now referred to as Normal Equal-Loudness Level Contours. Hence, an equal-loudness contour is a measure of the sound pressure (dB) level required to cause a given loudness for a listener as a function of frequency (Hz) (Figure 2).

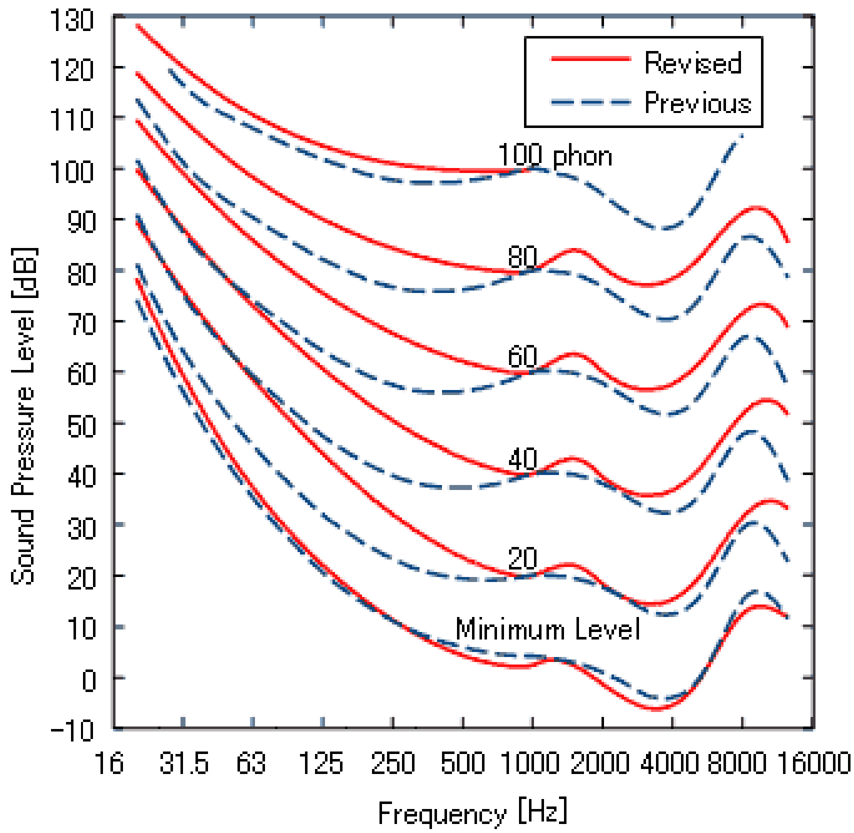

Figure 4. Normal Equal-Loudness Level Contours

Infrasound

Infrasound is generally accepted to be sound between 0 Hz and 20 Hz (Leventhall G. 2007) (Table 3). Infrasound occurs when the frequency of acoustic oscillations (Hz) is lower than the low frequency limit of audible sound, which is approximately 16 Hz according to the International Electrotechnical Commission (IEC) (Leventhall 2007). Although the human hearing threshold has been found to be as low as 4 Hz in an acoustic chamber, a level of 20 Hz, arises from the lower frequency limit of the Normal Equal-Loudness Level Contours. At 1,000 Hz, the contour ranges a span of 100 dB, but at lower frequencies the contours are grouped more closely together. Thus, the change of grouping at 20 Hz or below leads to a greater rate of growth in loudness with increasing level for frequencies in the infrasound region (Leventhall G. 2007).

Although it has been believed that infrasound is inaudible, that belief has been determined to be a misconception (Berglund B. et al. 1996; Leventhall G. 2007; Maschke C. 2004). Infrasound at frequencies lower than 20 Hz are audible at very high levels and these sounds may occur from many natural sources, such as meteors or volcanic eruptions. Anthropogenic (i.e., human-caused) sources, which often are the predominant type of source, can also generate infrasonic noise and include machinery, ventilation, or large combustion processes (Berglund B. et al. 1996; Leventhall G. 2007; Sienkiewicz Z. 2007). In addition, the human body has multiple sources of sound. For example, heart sounds are in the range of 27 to 35 dB at 20-40 Hz (Sakai A. et al. 1971) and lung sounds are reported in the range of 5-35 dB at 150-600 Hz (Fiz JA. Et al. 2008).

The threshold of human hearing has been found to be well in the range of infrasound, but it has been suggested that detection does not occur through hearing in the normal sense. Infrasound detection has been theorized to result from nonlinearities of conduction in the middle and inner ear which produces a harmonic distortion in the higher frequency range (Berglund B. et al. 1996). Also, the definition of infrasound detection has not only considered direct hearing, but also subjective reactions such as annoyance as well as detection occurring through the resonance of other body organs (Berglund B. et al. 1996).

Table 3. Sound Frequency Spectrum

Frequency (Hz)				
0	**10**	**20**	**100/250**	**20,000**
Infrasound (With Body Resonance)	Infrasound	Low Frequency Sound	Non-Low Frequency Audible Sound	Ultrasound

Low Frequency Sound[4]

The low frequency sound range is approximately between 10 or 20 Hz and 100 or 250 Hz (Berglund B. et al. 1996). The setting of a lower and upper limit of a continuum has been

[4] The word "sound" and "noise" are terms that can be used interchangeably. "Noise" often implies an unwanted sound. The use of "noise" also depends on the intensity of the sound or the complex temporal pattern. The classification of a "sound" or "noise" may also depend of cultural factors, the individual, or the time and circumstance (Berglund B. et al. 1996).

problematic due to the arbitrary nature of setting those limits. However, it has generally been accepted that low frequency sound is below 100 Hz (Takahashi Y. et al. 2005) or 200 Hz (Maschke C. 2004). Due to the long wavelengths of low frequency noise, it has been known to travel long distances and pass through walls and windows with little attenuation (Waye K. 2004).

With respect to reception, the hearing sensitivity of the human ear declines at low frequencies (Takahashi Y. et al. 2005). Occupational and residential activities have been found to be a common source of low frequency sound (Berglund B. et al. 1996). Many sources of low frequency noise are transportation vehicles such as buses, trains, and some aircraft. Other stationary sources of low frequency noise include heating, cooling, or ventilation of buildings (Waye K. 2004). Low frequency sound possesses features that are not commonly shared by higher pitch noises.

A review of the literature related to sound indicates that there are uncertainties associated with the measurement and characterization of low frequency sound. As mentioned previously, the A scale is the most commonly used sound level filter (Sienkiewicz Z. 2007; Takahashi Y. et al. 2005; Takahashi Y. et al. 2001; Takahashi Y. et al. 1999). Furthermore, it was recommended that either a scale with a more appropriate response be developed and used for characterizing low frequency sound or that the details of the acoustic environment be provided for each exposure scenario (Sienkiewicz Z. 2007).

As mentioned previously, human hearing becomes less sensitive for decreasing frequency. In addition to the sensitivity of sound, the perceived character of that sound also changes at lower frequencies. The threshold[5] for hearing is standardized by ISO for frequencies down to 20 Hz, but there has been research and some agreement among investigators regarding a possible threshold for frequencies below this level (Moller H. and Pedersen CS. 2004). Men and women have the same hearing threshold with the standard deviation between individuals being

[5] Threshold - For a specified signal and method of presentation, amount in decibels by which the threshold of hearing for a listener, for either one or two ears, exceeds a specified standard threshold of hearing (IEC).

approximately 5dB. Furthermore, low frequency sound may be inaudible to some, but that same sound may be loud to others.

Background on Wind Turbines and Noise

There are two types of noise generated from wind turbines. One is a mechanical noise originating from the gearbox, generator, and yaw motors. The other type of noise, aerodynamic noise, originates from the flow of air around the components of the wind turbine (blades and tower) produces a “whooshing” sound in the range of 500 to 1000 Hz (Hau E. 2006). This type of noise is typically the dominant component of wind turbine noise because manufacturers have been able to reduce the mechanical noise to a level that is below the aerodynamic noise (Pedersen E. and Waye KP. 2004). However, the whooshing sound is highly variable and dependent upon mechanical as well as atmospheric conditions. Hence, the sound power levels reached by wind turbines are determined by the mechanical and aerodynamic specifications.

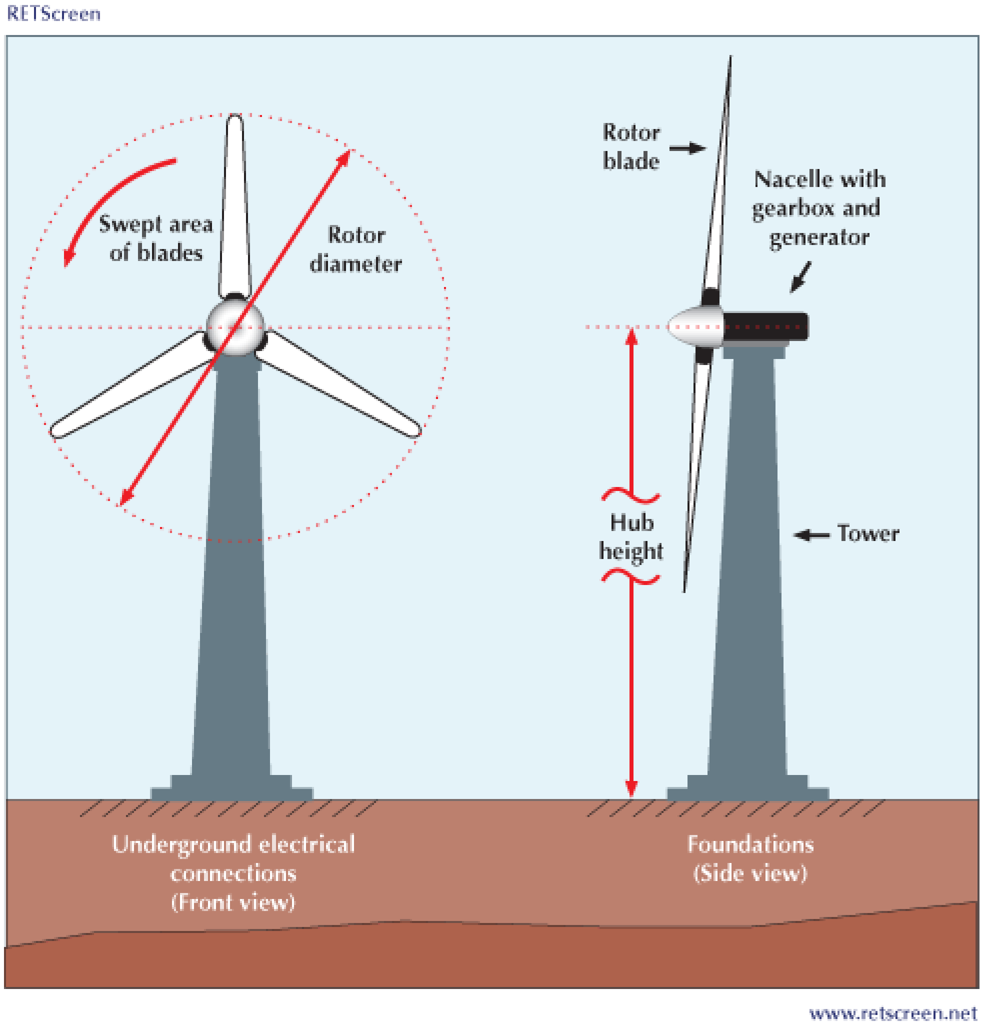

Figure 5. Horizontal Axis Wind Turbine

Evaluation of Scientific Literature on Health Effects

A thorough search was performed of the peer-reviewed scientific literature using the PubMed[6] search engine which is maintained by the United States National Library of Medicine. The purpose of the search was to identify literature that has addressed the known or unknown health effects associated with infrasound and low frequency sound. The following search criteria terms were used for each search query with some overlapping results.

Table 4. Literature Search Queries

Search Query	Number of Articles Found
Infrasound AND Health Effects	16
Low-Frequency Noise AND Health Effects	59
Low-Frequency Sound AND Health Effects	40
Wind Power AND Noise	18
Wind Turbines	20
Wind Turbines AND Noise	3
Total	**156**

In 2003, the U.S. Environmental Protection Agency (EPA) published a document entitled "A Summary of General Assessment Factors for Evaluating the Quality of Scientific and Technical Information" which outlined general assessment factors to evaluate the quality and relevance of scientific and technical information (U.S. EPA 2003). The assessment factors include (1) soundness; (2) applicability and utility; (3) clarity and completeness; (4) uncertainty and variability; and (5) evaluation and review. These factors use a weight-of-evidence approach that considers the information provided in an integrative assessment. These factors also take into account the quality and quantity as well as the strengths and weaknesses of the information. These EPA guidelines were used to evaluate the articles identified in this literature search.

[6] Pub Med is a searchable database that comprises more than 19 million citations for biomedical articles from MEDLINE and life science journals.

Applicability and Utility

The extent to which the information is relevant for the intended use, or how relevant the study is to current conditions of interest (U.S. EPA 2003).

With each identified article, the research and research subjects were ranked as a whole based on the applicability to the overall purpose of the literature search. The following ranking system was employed, and then we eliminated articles with a rank of one or two from further review (Table 6). These ratings and those used in later tables were also used in the appendix. Although it has been found in animal experiments, during the last 50 years, that high levels of low frequency noise and vibration can influence the respiratory rate, cardiac, digestive and central nervous systems, (Maschke C. 2004) animal studies were not reviewed in this white paper. At this time only human studies were reviewed and evaluated, which also eliminated articles with a rank of three. It was assumed that animal studies would not provide the necessarily applicability to effects of wind turbines on humans, thus resulting in an extrapolation layered with assumptions. Articles that were not written in the English language were also eliminated. Background research consisted of articles that reviewed infrasound and low frequency sound in general.

Table 5. Applicability and Utility Ranking System

Rank	Rank Description
1	No applicability at all
2	Limited applicability (e.g. *in vitro* studies)
3	Some applicability (e.g. animal studies)
4	Applicable (e.g. human studies)
5	Very applicable (e.g. human studies and wind turbines)
**	Background research

Soundness

The extent to which the scientific and technical procedures, measures, methods or models employed to generate the information are reasonable for, and consistent with, the intended application (U.S. EPA 2003).

The articles were evaluated based on whether or not the study purpose was reasonable and consistent with its design. If articles did not employ sound scientific theory or accepted approaches, such as the use of an adequate sample size or the validation of a survey instrument, they were graded accordingly.

Table 6. Soundness

Rank	Rank Description
1	Not sound (e.g. study instrument not validated)
2	Sound with limitations (e.g. useful research but not consistent with design)
3	Very sound (e.g. study reasonable and consistent with design)
**	Background research

Clarity and Completeness

The degree of clarity and completeness with which the data, assumptions, methods, quality assurance, sponsoring organizations and analyses employed to generate the information are documented (U.S. EPA 2003).

Articles were assessed for clarity and completeness and whether or not the results were clearly described and comparable to other study results. The description of the study design and methods was also assessed to determine if the description was clear enough for reproducibility.

Table 7. Clarity and Completeness

Rank	Rank Description
1	Several limitations
2	Complete with some limitations
3	Very complete (e.g. clear enough to be reproduced)
**	Background research

Uncertainty and Variability

The extent to which the variability and uncertainty (quantitative and qualitative) in the information or in the procedures, measures, methods or models are evaluated and characterized (U.S. EPA 2003).

The level of uncertainty and variability of the study methodology and results and how these uncertainties were handled were also evaluated. Potential sources of error and study bias were considered as well.

Table 8. Uncertainty and Variability

Rank	Rank Description
1	High uncertainty and variability
2	Medium uncertainty and variability
3	Low uncertainty and variability
**	Background research

Evaluation and Review

The extent of independent verification, validation and peer review of the information or of the procedures, measures, methods or models (U.S. EPA 2003).

Independent verification was measured by whether or not the methodology used and survey instruments were used on other similar, peer-reviewed studies. The consistency of the results with other relevant studies performed by the same or different authors was also accounted for in this analysis.

Table 9. Evaluation and Review

Rank	Rank Description
1	Low validation (e.g. no independent verification or similar results)
2	Medium validation (e.g. result consistent with same author)
3	High validation (e.g. results consistent in peer-review literature)
**	Background research

Final Included Literature

Of the original 156 articles identified, 21 were included for the literature review (Appendix A). Based on the previously outlined five assessment factors, the most relevant and scientifically appropriate articles were selected for this review. Many articles were excluded from this review due to the fact that the research focused in animal responses as opposed to human. Furthermore, with the exception of articles dealing with annoyance, articles were excluded if the sound studied was above the established range of low frequency sound.

Health Effects of Infrasound and Low Frequency Sound

Human Effects

It has been demonstrated that high levels of low frequency sound can excite body vibrations, such as a chest resonance vibration that can occur at a frequency of 50 Hz to 80 Hz (Leventhall G. 2007). These chest wall and body hair vibrations have also been shown to occur at the infrasonic range (Mohr GC. et al. 1965; Schust M. 2004). It is of interest to note that various body organs and physical activities of the human body produce low frequency, low amplitude sounds, some of which are key diagnostic tools for physicians (e.g., heart, lung, and gastrointestinal).

Vibroacoustic disease, a thickening of cardiovascular structures, such as cardiac muscle and blood vessels, was first described and documented by Castelo Branco *et al.* among airplane technicians, commercial and military pilots, mechanical engineers, restaurant workers, and disc jockeys for exposure to large pressure amplitude and low frequency (LPALF) sound (> or = 90 dB SPL, < or = 500 Hz) (Maschke C. 2004; Castelo Branco NA. and Rodriguez E. 1999). Castelo Branco *et al.* concluded that workers who were exposed to high level low frequency noise for more than 10 years exhibited extra-aural[7] symptoms such as thickening of heart valve issue (Castelo Branco NA. and Rodriguez E. 1999; Takahashi Y. et al. 2001; Maschke C. 2004). However, this association was not determined to be causally related and a dose response relationship was not established.

Takahashi *et al.* has explored the effects of acoustic excitation by measuring the resulting vibration (Takahashi Y. et al. 1999; Takahashi Y et al. 2001; Takahashi Y. et al 2005). In 1999, six male subjects were exposed to pure tones in the 20 Hz to 50 Hz frequency range, and vibration was measured on the subjects' chest and abdomen. There were 15 kinds of the low frequency noise stimuli (5 frequencies x 3 sound pressure levels) reproduced by loud speakers.

[7] Aural - Of or relating to the ear or to the sense of hearing

All of them were pure tones frequencies of 20, 25, 30.5, 40 and 50 Hz with each of the corresponding sound pressure levels of 100,105 and 110 dB (SPL).

It was found that measured noise induced vibration negatively correlated with the subject's body mass index and the researchers concluded that the health effects of low frequency noise depended on the physical constitution of the human body (Takahashi Y. et al. 1999). However, it was also concluded by the researchers that it was still unknown if or how vibrations measured on the body surface related to vibrations in the body's internal organs, and that no conclusions could be determined as to the possible chronic health effects caused by long term exposure to low frequency noise (Takahashi Y. et al. 1999). Similarly, in a later article, Takahashi *et al.* reported that low frequency noise (same frequency and sound pressure levels as previously reported) induced vibration measured on the chest was higher than the vibration measured on other parts of the body (Takahashi Y. et al. 2001). By taking this research a step further; Takahashi *et al.* examined the level of unpleasantness of human body vibration and low frequency sound (same frequency and sound pressure levels as previously reported). It was found through the use of a rough rating scale for subjective unpleasantness that there was a significant correlation between the measured body surface vibration induced by the low frequency noise and the rating of unpleasantness (Takahashi Y. et al. 2005). This finding was similar to research conducted by Inukai *et al*., who discovered that the slopes of the equal-unpleasantness level contours are very similar to those of the equal-loudness level contours. This similarity supported the fact that hearing sensation was an influential component in the perception of unpleasantness or annoyance among those exposed to low frequency noise (Inukai Y. et al. 2000; Takahashi Y. et al. 2005). This perception of unpleasantness was also determined to be independent of the audibility of the noise (Takahashi Y. et al. 2005). Inukai *et al*. also recognized the fact that the human psychological responses to low frequency noise, such as unpleasantness or annoyance, were based not only on hearing sensation, but also on three other factors: sound pressure, vibration, and loudness (Inukai Y. et al. 1986; Takahashi Y. et al. 2005).

In a general review of the effects of low frequency noise up to 100 Hz, Schust stated that the use of frequency weighting with an attenuation of low frequencies, such as G-weighting, was not appropriate for evaluating the health risk caused by low frequency noise (Schust M. 2004). Karprova *et al* (1970) ((5, 10 Hz / 100, 135 dB) for 15 minutes) and Slarve *et al*. (1975) (144 dB / 1 Hz - 20 Hz for 8 minutes) also indicated that study subjects reported aural complains after exposure to high level industrial infrasound in the range of 1 Hz to 20 Hz (Karpova NI. et al. 1970; Schust M. 2004; Slarve RN. and Johnson DL. 2009). Non-aural effects, such as a significantly increased diastolic blood pressure and decreased systolic blood pressure, were also mentioned after exposure to high levels of low frequency noise (125 dB, 16 Hz for 1 hour) (Danielsson A. and Landstroem U. 1985; Schust M. 2004). Karprova *et al* also reported complaints of fatigue, feelings of apathy, loss of concentration, somnolence, and depression following exposure to high levels of low frequency noise (5 Hz and 10 Hz (100 dB and 135 dB) for 15 minutes) (Karprova NI. et al. 1970; Schust M. 2004). Furthermore, the effects of low frequency noise among 439 employees working in offices, laboratories, and industries were also evaluated in another study. It was shown that there was a relationship between fatigue and tiredness after work and increasing low frequency noise. There were no employees that were exposed to low frequency noise with C-A differences greater than 20 dB (Schust M. 2004; Tesarz M. et al. 1997).

Ising *et al.* conducted a study that examined the effect of low frequency nighttime traffic noise by measuring saliva cortisol concentrations in children. Based on a previous study, the authors stated that the full spectrum of truck noise in the children's bedroom was at a maximum of 100 Hz (Ising H. et al. 2004; Ising H. and Kruppa B. 2004). It was found that the children under high noise exposure (8h = 54-70dB(A)) had a significantly increased morning saliva cortisol concentration compared to a control population, which indicated an activation of the hypothalamus-pituitary-adrenal (HPA) axis (Ising H. et al. 2004). This endocrine change was found to be an indication of restless sleep and a further aggravation of bronchitis in the children.

Finally, in 2000, a multidisciplinary group of clinicians and researchers called the Study Group on Neonatal Intensive Care Unit (NICU) Sound and the Expert Panel gathered and reviewed over 50 studies on the effects of sound on the fetus, newborn, and preterm infants. Upon the completion of review, the panel recommended that women should avoid prolonged exposure to low frequency sound levels (< 250 Hz) above 65 dB(A) during pregnancy (Graven SN. 2000). This recommendation was based on research that was conducted on sheep fetuses, which determined that after sustained periods of intense low frequency sound, the fetuses experienced injury to the hair cells of cochlea (Graven SN. 2000).

There have been some studies that have looked at the effect of low frequency noise on nighttime sleep (Maschke C. 2004). Unfortunately, for many of these studies, it was difficult to determine what percentage of the nightly noise was actually low frequency noise. Case studies have reported that low frequency noise (low-frequency noise reaching levels between 72 and 85 dB(A)) affects sleep quality and results in insomnia and concentration problems (Berglund B. et al. 1996; Waye K. 2004). A cross-sectional study of 279 individuals, it was determined that there were no significant differences detected in reported sleep among those exposed to flat frequency noise (>100 Hz; 24 to 33 dBA and 41 to 49 dBC) in their homes as compared to low frequency noise (50 Hz – 200 Hz; 26 to 36 dBA and 49 to 60 dBC) from ventilation and heat pumps (Persson Waye K. and Rylander R. 2001; Waye K. 2004). However, it was determined that fatigue, difficulty falling asleep, feeling tense and irritable were reported significantly more often among those individuals who were annoyed by low frequency noise than those who were exposed to the same noise but did not report being annoyed. Additionally, a dose-response relationship was identified between reported annoyance/disturbed rest and degree of low frequency noise before and after correction for differences in A-weighted sound pressure levels (Persson Waye K. and Rylander R. 2001; Waye K. 2004). In another study, six individuals were exposed to sinusoidal tones as 10, 20, 40, and 63 Hz with sound pressure levels ranging from 75 to 105 dB for 10 Hz and 20 Hz and 50 to 100 dB for 40 Hz and 63 Hz. No significant difference was found between the exposure and control nights in sleep efficiency index, number of changes in sleep state, or changes in the proportion of each sleep stage evaluated by electroencephalogram recordings (Inaba R. and Okada A. 1988; Waye K. 2004).

Annoyance

The World Health Organization (WHO) definition of the adverse effects of noise is as follows:

> *Change in the morphology and physiology of an organism that results in impairment of functional capacity to compensate for additional stress, or increases in the susceptibility of an organism to the harmful effects of other environmental influences. Includes any temporary or long-term lowering of the physical, psychological or social functioning of humans or human organs* (WHO 2001).

An earlier definition of annoyance was "a feeling of displeasure associated with any agent or condition, known or believed by an individual or group to adversely affect them" (Koelega HS.(ed.) 1987; Lindvall T. and Radford EP.(eds.) 1973; WHO 1999). The WHO considers annoyance an adverse health effect of noise in addition to sleep disturbance, performance effects, and psychological effects such as irritability (WHO 2001). Annoyance was also defined as a feeling of displeasure with varying tolerance levels. WHO also characterized annoyance as a feeling that increases with noise impulses as opposed to a steady noise (WHO 2001).

As specifically related to low frequency noise generated from wind turbines, Pedersen *et al.* noted a dose response relationship between calculated A-weighted sound pressure levels from wind turbines and noise annoyance in a cross-sectional study that was conducted in five dwelling areas in Sweden. It was determined that the study respondents were annoyed by the wind turbines at a higher level than other community noises, such as road traffic (Pedersen E. and Waye KP. 2004). It was also found the noise annoyance was related to visual or aesthetic interference, and attitude or sensitivity toward to wind turbine (Pedersen E. and Waye KP. 2004). Importantly, it should be noted that the Swedish wind turbines were all upwind devices which had a blade passage frequency of 1.4 Hz, but unlike earlier downwind turbines with contained low frequency noise, these turbines had upwind rotor blades and the noise was much more broadband (Pedersen E. and Waye KP. 2004).

In addition to annoyance, the relationship between wind turbine noise and self-reported health and well-being factors was also researched by Pedersen *et al.* It was confirmed that there was no correlation between A-weighted sound pressure levels from wind turbines and any health or well-being factors, such as the respondent's status of chronic disease, diabetes, or cardiovascular disease (Pedersen E. and Persson, Waye K. 2007). However, among the 31 respondents who stated that they were annoyed by the wind turbine noise, out of 754 respondents, 36% reported that their sleep was disturbed and 19% reported being tired (Pedersen E. and Persson, Waye K. 2007). Both of these findings were statistically significantly higher in comparison to those respondents who were not annoyed. Recall bias is likely to occur among annoyed individuals, and it is not apparent that this bias was considered in this study. Furthermore, Pedersen *et al.* also identified that living in a rural area, as opposed to an urban area, increased the risk of perceiving wind turbine noise and being annoyed by it (Pedersen E. and Persson, Waye K. 2007).

The underlying complaint of annoyance is, in and of itself, not a disease or a specific manifestation of a specific exposure, but instead a universal human response to a condition or situation that is not positively appreciated by the human receptor. The variability of annoyance and its link to undesirable factors makes it a prime indicator for the possibility of recall bias. Annoyances are highly variable in types (noise, smell, temperature, taste, vision) and vary from person to person. One can be annoyed by the action of others as well as their own individual actions. Thus "annoyance" is not a disease but a human response that is highly non-specific.

Disease vs. DIS-ease

The state of being in which individuals are uneasy, agitated or without ("dis") freedom from labor, pain, anxiety or physical annoyance ("ease") can often be undistinguishable from the state of disease as related to morbidity. Both states of being can be assessed objectively and subjectively. However, with physical illnesses, objective measureable indicators can be obtained through instrumentation testing that is typically absent of human error or influence. Subjective responses to stimuli are much harder to prove or disprove which is why it is very important to supplement a subjective response with an objective assessment.

Limitations of Scientific Literature

The research and scientific literature on the human health effects of low frequency noise exposure are limited. Most researchers have agreed that there are some uncertainties associated with the measurement and characterization of low frequency sound. The most important limitation of the current research involves the use of the A-weight scale. The WHO and other researchers have stated that the conventional method of using an A-weighted equivalent sound level may be inadequate for low frequency noise. There are other researchers who advocate that the current research using various weighted measures is sufficiently robust to be depended upon for the evaluation of the potential for sound related health effects. As a result of these diverse opinions, biased or conflicting conclusions may have been made about the level of low frequency sound and its human health effects.

Another significant limitation of the current research is the use of a small number of subjects or those with prejudicial views of wind turbines. Although it was noted in some studies that the questionnaires used were masked, it was quite possible the participants still had negative or unfavorable attitudes about the wind turbines and the low frequency noise that was generated. The presence of wind turbines has instigated heightened levels of annoyance and NIMBY (*Not In My Back Yard)* attitudes by the nearby residents. With such levels of annoyance and discontent, it is very plausible that the associated anxiety can engender health effects or amplify already existing health conditions. It would be beneficial to examine the health effects of low frequency noise among residents that did not experience the annoyance of the presence of wind turbines. There are health effects and adverse health effects and it is important to differentiate the between the two types of effects.

A common effect that has been observed with low frequency noise is vibration. Although the effects of low frequency noise and vibration have not been well characterized, objective body vibration results only from very high levels of low frequency noise, greater than those produced by wind turbines. Sleeplessness and insomnia have also been associated with low frequency noise, but this finding has been poorly correlated and lacking in consistency. However, the level of annoyance with low frequency noise was found to be correlated with insomnia.

Conclusions

Noise exposures outside the workplace have not been studied as extensively as those that occur in the workplace. There have been pockets of research centering on population exposures to highway traffic noise, noise exposures associated with living near commercial airports, and a scattering of other community noise sources, but there is not an extensive amount of research specifically on the health effects related to the sound exposure generated by wind turbines. However, wind turbines have been used in the U.S. since the late 1800s that has provided a baseline of knowledge and experience of their usage and presence in American lives. The first windmill for electricity production in the United States was built in Cleveland, Ohio by Charles Brush (Windpower.org 2003). In addition, wind turbines have continued to evolve (e.g. vertical to horizontal designs, downwind to upwind blade positioning and numerous sound reduction design changes with the mechanics of the turbine.) This evolution of design and the use of improved technology have resulted in quieter and more efficient wind turbines. Possibly the biggest change beyond these design changes is the trend to build more wind farms.

The implementation of wind turbines has resulted in a steadily growing population of individuals who live in their geographical and visual proximity. The literature clearly delineates a subset of this population that is annoyed by the nearby presence of wind turbines, but there has not been a specific disease or condition that has been found by the research community to be caused by the wind turbines. However, there have been illnesses, symptom complexes, and other health events attributed to wind turbines. This is to be expected given the circumstances and emotions that often surround the presence of wind turbine farms. This is a common phenomenon that is associated with activities that are perceived as a social disruption or infringement on personal rights or freedom.

The literature, both scientific and lay, clearly indicates the diversity of concerns regarding the presence of wind turbines near residences and communities. The science of sound is robust and has identified a number of health-related links to high level industrial sound in the workplace. This same science has not identified a causal link between any specific health condition and exposure to the sound patterns generated by wind turbines of the type used today, perhaps because they generate far lower decibel levels than most vocational sources. However, the same science has determined that there is a range of sounds (some would say noise) that is clearly described by some as annoying. The process of being annoyed is a universal response that is not specific to wind turbines. The nonspecificity of annoyance leads to confusion and concern that the peer reviewed published scientific literature has not been able to adequately clarify. It appears that the scientific process of research and discussion before acceptance of new principles, or redefinition of previously accepted principles, has to some extent gotten caught up in rush of the lay media. Jumping from observations and speculation to cause and effect has been the result of this rush. This type of short cut has historically led to misdirection of resources and efforts.

The subjective nature of annoyance makes the job of epidemiological investigation difficult due to the biases that this subjectivity brings to any study. One cannot assess the level of effect of an activity by analyzing the experience and perceptions of those who are annoyed, without an appropriate comparison group and study design that reduces or delineates the biases that commonly hamper studies of emotionally-charged activities such as the positioning of wind turbines.

Believing without question can lead to positions of unnecessary vulnerability. It is often stated that the best advocate for a patient's rights, well-being and infallible medical care is the actual patient. Therefore, second medical opinions are often highly recommended despite who is giving the first opinion or what that opinion may be. Likewise, the rush to accept opinions without an adequate scientific or medical basis (e.g. objective medical tests) may actually lead to adverse health outcomes originating from the perception of health effects. From the positive perspective, there can be a healing effect or belief, as in the "placebo effect", which is often a key part of a medical encounter. Unfortunately, the reverse can also occur in the situation where a person is given "bad health news" that is unfounded or incorrect and person actually becomes physically and/or emotionally ill. It is a delicate balance that must be maintained as health care professionals and public health officials weigh the science in making decisions.

Based on the literature review that was conducted for this white paper, there was not any scientifically peer-reviewed information found demonstrating a link between wind turbines and negative health effects.

References

Agrawal Y., Platz E.A., and Niparko J.K. (2009). Risk Factors for Hearing Loss in U.S. Adults: Data From the National Health and Nutrition Examination Survey, 1999 to 2002. *Otology & Neurotology.* 30.139 -145).

Baerwald, E. F., D'Amours, G. H., Klug, B. J., and Barclay, R. M. (8-26-2008). Barotrauma is a significant cause of bat fatalities at wind turbines. 18(16), (R695 -R696).

Bayne-Jones S., Burdette WJ., Cochran WG., Farber E., Fieser LF., Furth J., Hickam JB., LeMaistre C., Schuman LM., and Seevers MH. (1964). Smoking and Health. Report of the Advisory Committee to the Surgeon General of the Public Health Service. Report No. PublicHealth Services Publication No.1103.Washington, DC: Public Health Service.

Berglund, B., Hassmen, P., and Job, R. F. (1996). Sources and effects of low-frequency noise. *Journal of the Acoustical Society of America.* 99(5), (2985 -3002).

Bernstein, L. R., Trahiotis, C., and Hyde, E. L. (1998). Inter-individual differences in binaural detection of low-frequency or high-frequency tonal signals masked by narrow-band or broadband noise. *Journal of the Acoustical Society of America.* 103(4), (2069 -2078).

Bjor, B., Burstrom, L., Karlsson, M., Nilsson, T., Naslund, U., and Wiklund, U. (2007). Acute effects on heart rate variability when exposed to hand transmitted vibration and noise. 81(2), (193 -199).

Castelo Branco N.A.A. and Rodriguez E. (1999). The Vibroacoustic Disease - An Emerging Pathology. *Aviation Space & Environmental Medicine.* 70(3,Pt2), (A1 -A6).

CDC.Centers for Disease Control and Prevention. Peer Review Process of Research Applications. (4-13-2009), Available at http://www.cdc.gov/od/science/PHResearch/peerreview.htm.

Checkoway, H. (2004). Case-crossover designs in occupational health. *Journal of Occupational and Environmental Medicine.* 61(12), (953 -954).

Danielsson A. and Landstroem U. (1985). Blood Pressure Changes in Man During Infrasonic Exposure. *Acta Medica Scandinavica.* 217.531 -535).

Davies H.W., Teschke K., Kennedy S.M., Hodgson M.R., and Demers P.A. (2009). Occupational Noise Exposure and Hearing Protector Use in Canadian Lumber. *Journal of Occupational and Environmental Hygiene.* 6.32 -41).

Deans, J. K., Powell, A. D., and Jefferys, J. G. (9-1-2007). Sensitivity of coherent oscillations in rat hippocampus to AC electric fields. 583(Pt 2), (555 -565).

Desholm M. and Kaahlert J. (2005). Avian Collision Risk at an Offshore Wind Farm. *Biology Letters.* 1.296 -298).

Dobie, R. A. (2007). Noise-induced permanent threshold shifts in the occupational noise and hearing survey: an explanation for elevated risk estimates. 28(4), (580 -591).

DOE and EIA.U.S.Department of Energy, Energy Information Administration. Wind Energy -- Energy from Moving Air. (2008), Available at http://www.eia.doe.gov/kids/energyfacts/sources/renewable/wind.html.

Elsevier.Elsevier. The Peer Review Process. (2009), Available at http://www.elsevier.com/wps/find/intro.cws_home/review_process.

Findeis, H. and Peters, E. (2004). Disturbing effects of low frequency sound emissions and vibrations in residential buildings. 6(23), (29 -35).

Fiz, J. A., Gnitecki, J., Kraman, S. S., Wodicka, G. R., and Pasterkamp, H. (2008). Effect of body position on lung sounds in healthy young men. 133(3), (729 -736).

Fletcher H. and Munson W.A. (1933). Loudness, its definition, measurement and calculation. *Journal of the Acoustical Society of America.* 5.82 -108).

Graven S.N. (2000). The Full-Term and Premature Newborn. *Journal of Perinatology.* 20.S88 - S93).

Harding, G., Harding, P., and Wilkins, A. (2008). Wind turbines, flicker, and photosensitive epilepsy: characterizing the flashing that may precipitate seizures and optimizing guidelines to prevent them. 49(6), (1095 -1098).

Hau E., W*ind Turbines: Fundamentals,Technologies, Application,Economics*,2nd ed.(Springer, Berlin, 2006).

Hill AB. (1965). The Environment and Disease: Association or Causation? *Proc R Soc Med.* 58295 -300).

Inaba R. and Okada A. (1988). Study on the Effects of Infra- and Low Frequency Sound on the Sleep by EEG Recordings. *Journal of Low Frequency Noise, Vibration and Active Control.* 7.15 -19).

Inukai Y., Taya H., Miyano H., and Kuriyama H. (1986). A Multidimensional Evaluation Method for the Psychological Effects of Pure Tones at Low and Infrasonic Frequencies. *Journal of Low Frequency Noise, Vibration and Active Control.* 5.104 -112).

Inukai Y., Nakamura N., and Taya H. (2000). Unpleasantness and Acceptable Limits of Low Frequency Sound. *Journal of Low Frequency Noise, Vibration and Active Control.* 19.135 -140).

Ising, H., Lange-Asschenfeldt, H., Moriske, H. J., Born, J., and Eilts, M. (2004). Low frequency noise and stress: bronchitis and cortisol in children exposed chronically to traffic noise and exhaust fumes. *Noise and Health.* 6(23), (21 -28).

Ising, H. and Kruppa, B. (2004). Health effects caused by noise: evidence in the literature from the past 25 years. *Noise and Health.* 6(22), (5 -13).

Jauchem, J. R. and Cook, M. C. (2007). High-intensity acoustics for military nonlethal applications: a lack of useful systems. *Journal of Military Medicine.* 172(2), (182 -189).

Karpova N.I., Alekseev S., Erokhin V.N., Kadyskina E.N., and Reutov O.V. (1970). Early Response of the Organism to Low Frequency Acoustical Oscillations. *Noise and Vibration Bulletin.* 11(65), (100 -103).

Kim, J., Morest, D. K., and Bohne, B. A. (1997). Degeneration of axons in the brainstem of the chinchilla after auditory overstimulation. 103(1-2), (169 -191).

Koelega HS.(ed.), *Environmental Annoyance: Characterization, Measurement, and Control*,(Elsevier, Amsterdam, Netherlands, 1987).

Kondoh, Y., Arima, T., Okuma, J., and Hasegawa, Y. (1993). Response dynamics and directional properties of nonspiking local interneurons in the cockroach cercal system. 13(6), (2287 -2305).

Last JM, *A Dictionary of Epidemiology*,Fourth Edition ed.(Oxford University Press, 2001).

Leighton, T. G. (2007). What is ultrasound? 93(1-3), (3 -83).

Leventhall, G. (2007). What is infrasound? 93(1-3), (130 -137).

Leventhall, H. G. (2004). Low frequency noise and annoyance. 6(23), (59 -72).

Lindvall T. and Radford EP (eds.). (1973). Measurement of annoyance due to exposure to environmental factors. *Environmental Research.* 6.1 -36).

Maschke, C. (2004). Introduction to the special issue on low frequency noise. *Noise and Health.* 6(23), (1 -2).

McConnell, S. O., Schilt, M. P., and Dworski, J. G. (1992). Ambient noise measurements from 100 Hz to 80 kHz in an Alaskan fjord. 91(4 Pt 1), (1990 -2003).

MDHEHD.Minnesota Department of Health Environmental Health Division. Public Health Impacts of Wind Turbines. (5-22-2009), Available at http://www.health.state.mn.us/divs/eh/hazardous/topics/windturbines.pdf.

Mohr G.C., Cole J.N., Guild E., and Gierke von, H. E. (1965). Effects of Low Frequency and Infrasonic Noises on Man. 36.817 -827).

Moller, H. and Pedersen, C. S. (2004). Hearing at low and infrasonic frequencies. *Noise and Health.* 6(23), (37 -57).

Muly, S. M., Gross, J. S., Morest, D. K., and Potashner, S. J. (2002). Synaptophysin in the cochlear nucleus following acoustic trauma. *Experimental Neurology.* 177(1), (202 - 221).

Nakashima, A., Abel, S. M., Duncan, M., and Smith, D. (2007). Hearing, communication and cognition in low-frequency noise from armoured vehicles. 9(35), (35 -41).

NASD.National Agricultural Safety Database. Noise: The Invisible Hazard. (1993), Available at http://www.nasdonline.org/docs/d000801-d000900/d000882/d000882.html.

NMCPHC.NMCPHC (Navy and Marine Corps Public Health Center). Physics of Sound. (4-15-2009), Available at http://www-nmcphc.med.navy.mil/downloads/occmed/toolbox/PHYSICSOFSOUND.ppt.

NRC. (2007). Environmental Impacts of Wind-Energy Projects. *National Research Council.* Committee on Environmental Impacts of Wind-Energy Projects, Board on Environmental Studies and Toxicology, Division on Earth and Life Studies140 -179).

Pedersen, E. and Waye, K. P. (2004). Perception and annoyance due to wind turbine noise--a dose-response relationship. *Journal of the Acoustical Society of America.* 116(6), (3460 - 3470).

Pedersen, E. and Persson, Waye K. (2007). Wind turbine noise, annoyance and self-reported health and well-being in different living environments. 64(7), (480 -486).

Pedersen, E. and Waye, K. P. (2008). Wind Turbines - Low Level Noise Sources Interfering With Restoration. *Environmental Research Letters.* 3.

Pei, Z., Sang, H., Li, R., Xiao, P., He, J., Zhuang, Z., Zhu, M., Chen, J., and Ma, H. (2007). Infrasound-induced hemodynamics, ultrastructure, and molecular changes in the rat myocardium. 22(2), (169 -175).

Persson Waye K. and Rylander R. (2001). The Extent of Annoyance and Long-Term Effects Among Persons Exposed to LFN in the Home Environment. 240.483 -497).

Sakai, A., Feigen, L. P., and Luisada, A. A. (1971). Frequency distribution of the heart sounds in normal man. *Cardiovascular Research.* 5(3), (358 -363).

Schust, M. (2004). Effects of low frequency noise up to 100 Hz. *Noise and Health.* 6(23), (73 - 85).

Shields, F. D. (2005). Low-frequency wind noise correlation in microphone arrays. *Journal of the Acoustical Society of America.* 117(6), (3489 -3496).

Sienkiewicz, Z. (2007). Rapporteur report: Roundup, discussion and recommendations. *Progress in Biophysics and Molecular Biology.* 93(1-3), (414 -420).

Silva, M. J., Dias, A., Barreta, A., Nogueira, P. J., Castelo-Branco, N. A., and Boavida, M. G. (2002). Low frequency noise and whole-body vibration cause increased levels of sister chromatid exchange in splenocytes of exposed mice. 22(3), (195 -203).

Slarve R.N. and Johnson D.L. (2009). Human Whole - Body Exposure to Infrasound. 46(4), (428 -431).

Slovic P., Fischhoff B., and Lichtenstein S. (1982). Why Study Risk Perception. *Risk Analysis.* 2(2), (83 -93).

Takahashi, Y., Yonekawa, Y., Kanada, K., and Maeda, S. (1999). A pilot study on the human body vibration induced by low frequency noise. *Industrial Health.* 37(1), (28 -35).

Takahashi, Y., Yonekawa, Y., and Kanada, K. (2001). A new approach to assess low frequency noise in the working environment. *Industrial Health.* 39(3), (281 -286).

Takahashi, Y., Kanada, K., Yonekawa, Y., and Harada, N. (2005). A study on the relationship between subjective unpleasantness and body surface vibrations induced by high-level low-frequency pure tones. *Industrial Health.* 43(3), (580 -587).

Tesarz M., Kjellberg A., Landstroem U., and Holmberg K. (1997). Subjective Response Patterns Related to Low Frequency Noise. *Journal of Low Frequency Noise, Vibration and Active Control.* 16(2), (145 -149).

U.S.EPA.U.S.Environmental Protection Agency. A Summary of General Assessment Factors for Evaluating the Quality of Scientific and Technical Information. (2003), Available at http://www.epa.gov/osa/spc/pdfs/assess2.pdf.

UK Parliament and House of Commons.House of Commons, The United Kingdom Parliament. The Origin of the Scientific Journal and the Process of Peer Review. (2004), Available at http://eprints.ecs.soton.ac.uk/13105/1/399we23.htm.

UNSW.The University of New South Wales. dB: What is a decibel? (2005), Available at http://www.phys.unsw.edu.au/jw/dB.html.

Waye K. (2004). Effects of Low-Frequency Noise on Sleep. *Noise and Health.* 6(23), (87 -91).

WHO.World Health Organization. WHO Guidelines for Community Noise - A complete, authoritative guide on the effects of noise pollution on health: 3. Adverse health effects of noise. (1999), Available at http://www.ruidos.org/Noise/Comnoise-3.pdf.

WHO.World Health Organization, Presentation at the TRB Session 391 "Setting an Agenda for Transportation Noise Management Policies in the United States" 10 January 2001, Washington DC, USA. World Health Organization Guidelines on Community Noise. (2001), Available at http://www.adc40.org/docs/schwela.pdf.

Windpower.org.Danish Wind Industry Association. A Wind Energy Pioneer: Charles F. Brush. (7-23-2003), Available at http://www.windpower.org/en/pictures/brush.htm.

Appendix A

Final Literature

List #	Year	Author	Title	Journal	Soundness	Applicability and Utility	Clarity and Completeness	Uncertainty and Variability	Evaluation and Review	Did Not Review
Search Term: Infrasound AND Health Effects										
1	2007	Sienkiewicz Z.	Rapporteur report: Roundup, discussion and recommendations.	Prog Biophys Mol Biol.	**	**	**	**	**	
2	2007	Leventhall G.	What is infrasound?	Prog Biophys Mol Biol.	**	**	**	**	**	
3	2004	Feldmann J. et al.	Effects of low frequency noise on man--a case study.	Noise Health.		4				x
4	1999	Pawlaczyk-Luszczyńska M.	Evaluation of occupational exposure to infrasonic noise in Poland.	Int J Occup Med Environ Health.		4				x
5	1996	Pawlaczyk-Luszczyńska M.	Infrasound in the occupational and general environment: a three-element microphone measuring method for locating distant sources of infrasound.	Int J Occup Med Environ Health.		4				x

List #	Year	Author	Title	Journal	Soundness	Applicability and Utility	Clarity and Completeness	Uncertainty and Variability	Evaluation and Review	Did Not Review
Search Term: Low-Frequency Noise AND Health Effects										
6	2005	Hori K. et al.	Influence of sound and light on heart rate variability	J Hum Ergol (Tokyo).		4				x
7	2005	Takahashi Y et al.	A study on the relationship between subjective unpleasantness and body surface vibrations induced by high-level low-frequency pure tones.	Ind Health.	2	4	2	2	2	
8	2004	Schust M. et al.	Effects of low frequency noise up to 100 Hz	Noise Health.	**	**	**	**	**	
9	2004	Ising H. et al.	Low frequency noise and stress: bronchitis and cortisol in children exposed chronically to traffic noise and exhaust fumes	Noise Health.	1	4	1	1	2	

List #	Year	Author	Title	Journal	Soundness	Applicability and Utility	Clarity and Completeness	Uncertainty and Variability	Evaluation and Review	Did Not Review
10	2002	Silva MJ. et al.	Low frequency noise and whole-body vibration cause increased levels of sister chromatid exchange in splenocytes of exposed mice.	Teratog Carcinog Mutagen.	2	3	2	1	1	
11	2001	Takahashi Y et al.	A new approach to assess low frequency noise in the working environment	Ind Health.	2	4	1	2	1	
12	2000	Graven SN.	Sound and the developing infant in the NICU: conclusions and recommendations for care	J Perinatol.	**	**	**	**	**	
13	1999	Silva MJ. et al.	Sister chromatid exchange analysis in workers exposed to noise and vibration	Aviat Space Environ Med.		4				x
14	1999	Alves-Pereira M.	Noise-induced extra-aural pathology: a review and commentary	Aviat Space Environ Med.		4				x

List #	Year	Author	Title	Journal	Soundness	Applicability and Utility	Clarity and Completeness	Uncertainty and Variability	Evaluation and Review	Did Not Review
15	1999	Takahashi Y et al.	A pilot study on the human body vibration induced by low frequency noise	Ind Health.	2	4	2	2	1	
16	1996	Berglund B. et al.	Sources and effects of low-frequency noise.	J Acoust Soc Am.	**	**	**	**	**	
17	1993	Seidel H.	The problem of a "vibration disease" caused by low-frequency whole-body vibration (wbv) is critically discussed.	Am J Ind Med.	**	**	**	**	**	
Search Term: Low-Frequency Sound AND Health Effects										
18	2008	Carrubba S. et al.	The effects of low-frequency environmental-strength electromagnetic fields on brain electrical activity: a critical review of the literature	Electromagn Biol Med.		4				x

Search Term: Wind Power AND Noise										
List #	**Year**	**Author**	**Title**	**Journal**	**Soundness**	**Applicability and Utility**	**Clarity and Completeness**	**Uncertainty and Variability**	**Evaluation and Review**	**Did Not Review**
19	2005	Shields FD.	Low-frequency wind noise correlation in microphone arrays	J Acoust Soc Am.	**	**	**	**	**	
20	2004	Pedersen E. et al.	Perception and annoyance due to wind turbine noise--a dose-response relationship	J Acoust Soc Am.	3	5	5	2	3	
21	1998	Munro KJ. et al.	Are clinical measurements of uncomfortable loudness levels a valid indicator of real-world auditory discomfort?	Br J Audiol.		4				x
22	1992	McConnell SO. et al.	Ambient noise measurements from 100 Hz to 80 kHz in an Alaskan fjord.	J Acoust Soc Am.	**	**	**	**	**	
Search Term: Wind Turbines										
23	2008	Harding G. et al.	Wind turbines, flicker, and photosensitive epilepsy: characterizing the flashing that may precipitate seizures and optimizing guidelines to prevent them	Epilepsia.	**	**	**	**	**	

List #	Year	Author	Title	Journal	Soundness	Applicability and Utility	Clarity and Completeness	Uncertainty and Variability	Evaluation and Review	Did Not Review
24	2007	Pedersen E. et al.	Wind turbine noise, annoyance and self-reported health and well-being in different living environments.	Occup Environ Med.	3	5	5	2	3	
Search Term: Wind Turbines AND Noise										
ALREADY INCLUDED IN OTHER SEARCHES										
Other articles found in *Noise and Health*										
25	2004	Waye K.	Effects of low frequency noise on sleep.	Noise and Health	**	**	**	**	**	
26	2004	Moller H. et al.	Hearing at low and infrasonic frequencies	Noise and Health	**	**	**	**	**	
27	2004	Maschke C.	Introduction to the special issue on low frequency noise	Noise and Health	**	**	**	**	**	
28	2004	Leventhall H.	Low frequency noise and annoyance	Noise and Health	**	**	**	**	**	
29	2004	Findeis H. et al.	Disturbing effects of low frequency sound emissions and vibrations in residential buildings	Noise and Health	**	**	**	**	**	