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Report

Analysis of the Research on the Health Effects from Wind Turbines, including Effects from Noise

Prepared in Response to L.D. 1366, Resolve, to Clarify the Expectation for the 2012 Assessment of Progress on Meeting Wind Energy Development Goals

Sec. 4. Health effects. Resolved: That, to the extent that resources are available, the Department of Health and Human Services, Maine Center for Disease Control and Prevention shall conduct an analysis of the research on health effects from wind turbines, including effects from noise, and provide a report to the Joint Standing Committee on Energy, Utilities and Technology by February 1, 2012. The report must include recommendations for making the information in the report easily accessible to the public.

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Executive Summary

In 2011, the 125th Legislature passed a Resolve, To Clarify the Expectations for the 2012 Assessment of Progress on Meeting Wind Development Goals. Section 4 of the Resolve makes a specific request to the DHHS, Maine CDC.

Sec. 4. Health effects. Resolved: That, to the extent that resources are available, the Department of Health and Human Services, Maine Center for Disease Control and Prevention shall conduct an analysis of the research on health effects from wind turbines, including effects from noise, and provide a report to the Joint Standing Committee on Energy, Utilities and Technology by February 1, 2012. The report must include recommendations for making the information in the report easily accessible to the public.

The Legislature recognized that the Maine CDC had limited resources to meet this request. Given this, the Maine CDC reached out to its state public health agency partners for assistance and learned that two studies on the subject of wind turbines and health were being performed in 2011 in the states of Massachusetts and Oregon.

These two studies, in addition to a 2010 study conducted by the State of Vermont, formed the basis of the Maine CDC's analysis of the current research on health effects from wind turbines.

The Maine CDC emphasizes that this analysis is deliberately limited in scope and biased to state public health agency studies. Selected key findings and conclusions from the reports are included herein. The full reports are located on the Maine CDC's website and the link is included below. The Maine CDC reviewed:

- The Massachusetts Department of Environmental Protection in collaboration with the Massachusetts Department of Public Health convened an independent panel of experts to study the potential health impacts of wind turbines whose report is titled, *Wind Turbine Health Impact Study: Report of the Independent Expert Panel*. The report was issued on January 17, 2012. Public comments on the report will be accepted until March 19, 2012.
- The State of Oregon's draft report titled, *Strategic Health Impact Assessment on Wind Energy Development in Oregon*. The report was issued on January 3, 2012. Public comments on the report will be accepted until March 30, 2012.
- The State of Vermont's Department of Health report titled, *Potential Impact on the Public's Health from Sound Associated with Wind Turbine Facilities*. The report was issued on October 15, 2010.

The Massachusetts's independent expert panel report performed the most comprehensive study of those reviewed. Many of their findings relate to noise from wind turbines. They report that most epidemiologic literature of human response to wind turbines relates to self-reported "annoyance," and this response appears to be a function of some combination of the sound itself, the sight of the turbine, and attitude towards the wind turbine project. They found insufficient evidence that noise from wind turbines is *directly (i.e., independent from an effect on annoyance or sleep)* causing health problems or disease.

The State of Oregon's Health Impact Assessment notes that a small number of epidemiological studies have reported that wind turbine noise is linked to sleep disturbance, annoyance, stress, and decreased cognitive performance, and that annoyance from wind turbine noise was more likely when levels exceeded 35-40 dBA. However, this same study noted that the perception of sound as noise is a subjective response. It concludes that there is insufficient evidence to determine if low frequency sound from wind turbines is associated with increased annoyance, disturbance or other health effects. Furthermore, the review notes there have been no complaints about noise related to operating large wind energy facilities sited through Oregon's review process.

The Oregon study did not find any health impacts from visual effects (shadow flicker, looming, distracted drivers) caused by wind turbines, and concluded that wind turbines that displace fossil-fuel based power plants can indirectly result in positive health impacts due to reduction in air pollution.

The Vermont Department of Health concludes that there is no direct health effect from sound associated with wind turbine facilities. This study finds that there can be a secondary health effect due to sleep disturbance due to excessive noise at night, and recommends a nighttime noise limit from wind turbines of 40 dbA consistent with the recommendations of the World Health Organization.

Based on its review of these studies, the Maine CDC concludes that there is no evidence that sound from wind generating facilities that are in compliance with Maine's regulations directly cause health problems. As noted throughout this report, there is some evidence that nighttime wind turbine noise can cause sleep disturbance. Generally, sleep disturbance can adversely affect mood, cognitive functioning, and one's overall sense of health and well-being.

All of these reports can be found on the Maine CDC's website at:
<http://www.maine.gov/dhhs/mecdc/environmental-health/wind-turbines.shtml>

Wind Turbine Health Impact Study: Report of Independent Expert Panel
Prepared for:

Massachusetts Department of Environmental Protection
Massachusetts Department of Public Health

Two Massachusetts State Departments, Environmental Protection and Public Health, convened a 7-person expert panel to address the public's concerns about wind turbines and health effects.

Maine's former State Health Officer, Dr. Dora Anne Mills, served on the panel. Dr. Mills had performed research on the subject of wind turbines and health in her role as Maine's former Health Officer.

The panel performed an extensive literature search and expanded the search beyond peer-reviewed scientific studies to other reports, popular media and public comments.

The panel made a number of findings. The Maine CDC has selected some key findings relating primarily to noise which are shown below.

- There is no evidence for a set of health effects from exposure to wind turbines that could be characterized as a "Wind Turbine Syndrome."
- Claims that infrasound from wind turbines directly impacts the vestibular system have not been demonstrated scientifically. Available evidence shows that the infrasound levels near wind turbines cannot impact the vestibular system.
- The weight of the evidence suggests no association between noise from wind turbines and measures of psychological distress or mental health problems.
- None of the limited epidemiological evidence reviewed suggests an association between noise from wind turbines and pain and stiffness, diabetes, high blood pressure, tinnitus, hearing impairment, cardiovascular disease, and headache/migraine.
- There is limited epidemiologic evidence suggesting an association between exposure to wind turbines and annoyance. There is insufficient epidemiologic evidence to determine whether there is an association between noise from wind turbines and annoyance independent from the effects of seeing a wind turbine and vice versa.
- There is limited evidence from epidemiologic studies suggesting an association between noise from wind turbines and sleep disruption. In other words, it is possible that noise from some wind turbines can cause sleep disruption. Whether annoyance from wind turbines leads to sleep issues or stress has not been sufficiently quantified. While not based on evidence from wind turbines, there is evidence that sleep disruption can adversely affect mood, cognitive functioning, and overall sense of health and well-being.
- Scientific evidence suggests that shadow flicker does not pose a risk for eliciting seizures as a result of photic stimulation. There is limited scientific evidence of an association between annoyance from prolonged shadow flicker (exceeding 30 minutes per day) and potential transitory cognitive and physical health effects.

The Massachusetts report included a supplementary report titled, *A Brief Review of Wind Power in Denmark, Germany, Sweden, Vermont, and Maine*, which included a profile of the Fox Islands Wind Project, a 4.5 MW 3-turbine wind power project built in 2009 and operating on the island of Vinalhaven, Maine. In the past month, in anticipation of this report, several residents of

Vinalhaven wrote to the Maine CDC expressing their health concerns resulting from the operation of the Fox Islands Wind Project. According to the Massachusetts report, 12 residences are located within 1,200 to 3,000 feet, with 5 of these within 1,200 to 2,000 feet. The report states that several of these home owners have raised health concerns related to the noise generated by the turbines. The report also states that as a result of the complaints, measurements were made and in 2010 the turbines were found to be in non-compliance with the nighttime noise standard of 45 dBA.

In the Maine CDC's conversations with Maine's Department of Environmental Protection (DEP) staff, it learned that the DEP is working to address the compliance issues on Vinalhaven.

Oregon Health Authority
Strategic Health Impact Assessment on Wind Energy Development in Oregon

The State of Oregon Health Authority's Office of Environmental Public Health (OEPH) performed a study in response to questions regarding the potential health impacts from wind energy facilities in Oregon. State staff performed the study and was advised by a 12-member steering committee.

To establish the scope of the study, OEPH solicited input in three public listening sessions and through an on-line questionnaire. Based on these data, OEPH identified five areas of study: sound, visual impacts, air pollution, economic effects and community conflict. Oregon's review focused on research and publications in peer-reviewed public health, engineering, social science, and other journals; reports and studies by state, federal and international governmental agencies; and information published by industry groups, community members, and non-profit organizations. OEPH included baseline data on current conditions in Oregon when available and appropriate. Their review was constrained by limited scientific information on some topics, and limited staff time and resources to conduct an exhaustive review on these issues.

For the purposes of this report the Maine CDC has included only selected key findings and conclusions from the sound, visual impacts and air pollution areas of Oregon's report. The following selected findings and conclusions are excerpted from the report.

SOUND

Key Findings – Sound:

- Noise is sound that is perceived as unwanted, annoying, or disturbing [7]. Environmental noise in community settings is linked to sleep disturbance, annoyance, stress, and decreased cognitive performance [7-9]. These effects, undesirable in their own right, can in turn adversely affect physical health. Chronic sleep disturbance and stress from environmental noise exposures can increase risks for cardiovascular disease, decreased immune function, endocrine disorders, mental illness, and other effects [8-12].
- Objective measures of sound do not necessarily correlate with subjective experiences of sound. When comparing similar sounds, a 3 dB increase correlates to a doubling in objective sound energy levels, but is considered the threshold of perceivable difference in sound levels [10, 13]. A 10 dB increase equates to a 10-fold increase in sound energy, but is perceived as a doubling in sound loudness [10].
- The perception of sound as noise is a subjective response that is influenced by factors related to the sound, the person, and the social/environmental setting. These factors result in considerable variability in how people perceive and respond to sound at the individual and community level [7, 14]. Factors that are consistently associated with negative community response are changes in noise exposure (i.e., the introduction of a new sound, or a noticeable change in a sound's loudness or quality), and increases in human-generated sound [14].

- There is some evidence that wind turbine sound is more noticeable, annoying and disturbing than other community or industrial sounds at the same level of loudness [16-20]. This may be because:
 - wind turbines produce environmental sound that fluctuates in loudness and “type” (i.e., swishing vs. pulsing amplitude-modulated sound) [19-21]. Since fluctuating sounds are generally considered more annoying than steady or constant sounds, wind turbine sound may be perceived as more annoying than other community sounds;
 - unlike other community sounds, wind turbine sound levels may not decrease predictably at night, and could be perceived as more noticeable and louder at night than during the day. This could result in sleep disturbance in nearby residences [15, 16, 19].
- A small number of epidemiological studies have linked wind turbine noise to increased annoyance, feelings of stress and irritation, sleep disturbance, and decreased quality of life [16-18, 22]. In studies from Europe, annoyance from wind turbine noise was more likely when levels exceeded 35-40 dBA [16, 17].
- Wind turbine-generated infrasound (frequencies below 20 Hz) is below levels that can be perceived by humans [23-26].
- Some field studies have found that in some locations near wind turbine facilities, low frequency sound (frequencies between 10 and 200 Hz) may be near or at levels that can be heard by humans [24-26]. However, there is insufficient evidence to determine if low frequency sound from wind turbines is associated with increased annoyance, disturbance or other health effects [26].
- People who live near wind turbines are more likely to be impacted by wind turbine sound than those farther away. The extent of that impact depends on many site-specific variables, such as distance from the facility, local topography and water bodies, weather patterns, background sound levels, etc.

Conclusions – Sound:

- 1) Sound from wind energy facilities in Oregon could potentially impact people’s health and well-being if it increases background sound levels by more than 10 dBA, or results in long-term outdoor community sound levels above 35-40 dBA. The potential impacts from wind turbine sound could range from moderate disturbance to serious annoyance, sleep disturbance and decreased quality of life.
- 2) Chronic stress and sleep disturbance could increase risks for cardiovascular disease, decreased immune function, endocrine disorders, mental illness, and other effects [8-12]. Many of the possible long-term health effects may result from or be exacerbated by sleep disturbance from night-time wind turbine sound [16, 18].
- 3) The major source of uncertainty in our assessment is related to the subjective nature of response to sound, and variability in how people perceive, respond to, and cope with sound. Additional uncertainty is due to moderate or limited evidence in the following areas:

- a. Epidemiological studies on wind turbine sound
 - b. Amplitude modulation of wind turbine sound
 - c. Indoor low frequency sound impacts from wind turbines
- 4) The Oregon Department of Energy is responsible for responding to noise complaints related to large energy facilities sited through the EFSC process. To date, there have been no complaints related to operating wind energy facilities sited through the EFSC process [30]. However, there does not appear to be a systematic process for responding to complaints from county-sited facilities. While OEPH has anecdotal evidence of noise complaints and reported health impacts from a few operating facilities in Oregon, we are unable to determine the magnitude of noise-related impacts from existing facilities in the state.

VISUAL IMPACTS

Key Findings – Visual Impacts:

- Shadow flicker refers to the alternating levels of light intensity produced when rotating turbine blades cast shadows on nearby buildings or receptors [31]. Most modern large wind turbines produce shadow flicker at frequencies between 0.3 and 1 Hz [31].
- Wind turbines produce shadow flicker at certain times, locations, and under certain conditions. In the continental U.S., shadow flicker impacts are relatively lower compared to locations at higher latitudes, are more likely to occur at sunrise or sunset, and affect a butterfly-shaped area to the northeast and northwest of a wind turbine [31, 32].
- There is insufficient evidence to determine if the “looming effect” (i.e., psychological reactions from feeling “enclosed” by a tall building or object) could have negative impacts on people’s quality of life and well-being. While urban planning guidelines suggest that a 4:1 distance-to-height ratio can minimize negative psychological reactions from feeling “enclosed” by a tall building or object [33], it is not clear if this guideline is applicable to wind turbines in rural environments.
- Some Oregonians voiced concern that wind turbines could distract drivers and result in traffic crashes. However, the very few research studies on this issue did not find any increase in crash rates after the construction of the wind energy facilities [34].

Conclusions – Visual Impacts:

- 1) Shadow flicker from wind turbines in Oregon is unlikely to cause adverse health impacts in the general population. The low flicker rate from wind turbines is unlikely to trigger seizures in people with photosensitive epilepsy. Further, the available evidence suggests that very few individuals will be annoyed by the low flicker frequencies expected from most modern wind turbines [31, 32, 35].
- 2) While Oregon does not have specific guidelines for shadow flicker, the setback distances (i.e., the distances between turbines and other structures) required to meet Oregon’s noise standard may be sufficient to minimize shadow flicker impacts in most cases.

AIR POLLUTION

Key Findings – Air Pollution:

- Direct exposure to air pollutants is associated with short and long-term health effects that include respiratory irritation, asthma, cardiovascular disease, cancer, and premature death [36, 37]. Greenhouse gas (GHG) emissions indirectly impact public health through their contribution to global climate change [37]. Children, the elderly, and those with pre-existing respiratory problems are particularly vulnerable to the health effects from air pollution.
- The major sources of air pollution in Oregon and the U.S. are the combustion of fossil fuels for electricity, transportation and other uses; industrial processes; agricultural practices; wildfires; and construction sites and equipment.
- Wind energy facilities do not generate air emissions from electricity production, and reduce air pollution when they displace electricity generated from gas, coal, and other fossil fuels [37, 38]. The magnitude of any reductions in air pollutant emissions will depend on the type and amount of fossil fuel units replaced, technological changes, and the effect of policies aimed at reducing air emissions from power plants [37]. The available evidence suggests that the largest air pollution reductions will occur by first replacing energy from coal-fired sources, followed by replacement of oil and natural gas.
- Wind energy could contribute to air pollution through the burning of fossil fuels in vehicles and equipment used for construction and maintenance of wind energy developments. However, the construction-related impacts on local air quality are likely to be short-term and relatively small in magnitude.
- It is unlikely that new or improved access roads will result in substantial increases in vehicular traffic or appreciable changes in local air quality.

Conclusions – Air Pollution:

- 1) Wind energy facilities in Oregon can indirectly result in positive health impacts by reducing regional emissions of GHGs, criteria air pollutants and hazardous air pollutants.
- 2) Communities near fossil-fuel based power plants that are displaced by wind energy could experience reduced risks for respiratory illness, cardiovascular diseases, cancer, and premature death.
- 3) The health benefits from reduced GHG emissions depend on the extent to which these reductions prevent or lessen the severity of future climate change impacts in Oregon.

Vermont Department of Health
**Potential Impact on the Public's Health from Sound Associated with Wind Turbine
Facilities - October 15, 2010**
Summary

The Vermont Department of Health conducted a literature review of the potential human health effects from exposure to sound and vibration from wind-powered electrical generating facilities, as requested by the Vermont Department of Public Service.

To do this, we convened a panel of public health scientist who are experienced in reviewing the quality of the scientific literature on health protection, and in assessing the adequacy of the evidence that an exposure can cause, or contribute to, an adverse health outcome. The Health Department panel drew primarily upon the most recent and most comprehensive literature reviews conducted by other expert panels. These included citations for hundreds of primary research studies on the health effects of exposure to sound generally, and to wind turbine sound specifically.

From this extensive review, the Vermont Department of Health concludes that there is no direct health effect from sound associated with wind turbine facilities. However, there is sufficient evidence of a secondary health effect from sleep disturbance due to excessive sound at night. The potential adverse health effects that can result from sleep disturbance include increased heart rate, sleep state changes and awakening, increased use of medications to aid sleep, increased body movements, insomnia, fatigue, accidents, reduced performance, cardiovascular illness and depression and other mental illness (WHO 1999). The 1999 WHO report also concludes that limiting sound exposure at night to reduce the probability of sleep disturbance can minimize these effects in the exposed population.

To protect public health, the Vermont Department of Health recommends that nighttime sound levels from wind turbines be limited 40 decibels or less, as measured at the exterior façade of the dwelling and averaged over 12 months of exposure. This is consistent with the most recent recommendations of the World Health Organization (WHO 1999).

This review and conclusions are general in nature. No specific wind turbine facility has been assessed.

Summary

Through a stroke of good luck and timing, the Maine CDC was able to meet the Committee's request by capitalizing on the very good and recently completed studies conducted by the State of Massachusetts and their expert panel, the Health Impact Assessment performed by the State of Oregon; and on an earlier study done by the State of Vermont.

The Maine CDC paid particular attention to the Massachusetts Supplemental Report, *A Brief review of Wind Power in Denmark, Germany, Sweden, Vermont and Maine: Possible Lessons for Massachusetts*, because it included a short profile on the Fox Islands Wind Project operating on Vinalhaven, Maine. Recently, the Maine CDC has received a number of adverse health effects complaints from residents living near this operating 3-turbine wind farm. The Maine CDC has learned that the Maine Department of Environmental Protection is working with the project owner to address compliance issues with this project. The Massachusetts Supplemental Report also states that despite concerns from some residents, a 2010 survey of 515 islanders indicated strong support for the project – 99% said they support wind energy, and 95% said they are either more supportive or have unchanged views of the project since it became operational.

Based on the Agency's limited review, the Maine CDC finds that there is no evidence that sound from wind generating facilities that are operating in compliance with Maine's regulations directly cause health problems. As noted throughout this report, there is some evidence that nighttime wind turbine noise can cause sleep disturbance. Generally, sleep disturbance can adversely affect mood, cognitive functioning, and one's overall sense of health and well-being.