SUMMARY REPORT

LITERATURE SEARCH ON THE POTENTIAL HEALTH IMPACTS ASSOCIATED WITH WIND-TO-ENERGY TURBINE OPERATIONS

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INTRODUCTION

What We Were Asked to Do:
On July 27, 2007, the Health Commissioner of Logan County sent a letter to the Director of the Ohio Department of Health (ODH) requesting the ODH conduct an investigation to determine if there are health effects associated with the operation of wind-to-energy turbines. The request was prompted by a local citizen's organization that expressed concerns about the potential health effects resulting from living adjacent to wind turbine "farms". The development of several of these "farms" is currently being proposed for portions of Logan and Champaign counties.

On August 14, 2007, the Health Assessment Section (HAS) was tasked by the ODH Division of Prevention to conduct a "literature search" and to identify any potential adverse health impacts associated with the operation of the wind turbine farms.

How We Responded:
In response to the August 14th request, the HAS program toxicologist began reviewing the pertinent information, compiling a list of references, and then summarized the main points made with regard to health impacts on nearby residents associated with the operation of mega-turbine wind "farms".

This review included perusal of a number of rapidly proliferating internet web sites on the subject; including both proponents for these wind-to-energy turbines (American Wind Energy Association, Environment Ohio, Green Energy Ohio, Ohio Wind Weekly, Ohio Wind Working Group) as well as opponents of these wind "farms" (locally Save Western Ohio; Save Western New York; and national groups like the National Wind Watch and Stopillwind.org). Links from these sites led to number of papers and articles, including credible papers by governmental agencies including the National Academy of Sciences, the National Research Council, the National Wind Coordinating Committee, the British Wind Energy Association, the Kansas Legislative Research Department, and the French Academy of Medicine. Attached to the body of this summary report is a list of the references reviewed as part of this literature search.

What We Discovered:
<u>Wind Energy in Ohio: Essential Background Information</u>

Hydroelectric power, biomass, and other non-fossil fuel alternatives have been in use in Ohio for decades. In late 2003, the first utility-scale wind turbines (two 1.8 MW turbines) were constructed in Bowling Green, Ohio. In February, 2007, Governor Strickland announced that $5 million in grants would become available for the Ohio Wind Production and Manufacturing Incentive. Eligible projects included large, utility-scale wind projects (generating over 5 megawatts of electricity) and smaller, community wind projects producing between 200 kilowatts up to 5 megawatts. Letters of intent for this project were due into the state by April, 2007. Final applications for this first round of grants were due in July, 2007. Another round of grants will be made available under this program early in 2008. (Ohio Wind Working Group FAQs: 2007).

A wind-to-energy system transforms the kinetic energy of the wind into mechanical or electrical energy that can be harnessed for practical use. The mechanical energy of wind turbines has been used for many years to pump water in many rural areas of the U.S. Wind electric turbines generate electricity for homes and businesses and for sale to utilities. The most commonly utilized design for wind electric turbines are propeller-style "horizontal-axis wind turbines" which constitute nearly all "utility-scale" (100 +kilowatts) turbines currently in use.

The electrical output from a wind turbine depends on the turbine's size and the wind's speed through the rotor. Utility-scale wind turbines for land-based wind farms have rotor diameters of from 150 to 300 ft and sit atop towers of roughly the same size. The largest operating land-based turbines (= 300 ft rotors) would typically have a total height of roughly 425 ft. Off-shore turbine designs can be even larger. Individual wind turbines in this size range can generate 700 kW to 2.5 MW of electrical energy if there is enough wind energy blowing through the turbine's rotor.

Recent wind resource maps generated by the Ohio Department of Development's Office of Energy Efficiency have identified those portions of Ohio where sustained wind velocities are present at high enough speeds to generate commercially significant amounts of electricity. These maps indicate that the best areas for utility-scale wind turbines are Lake Erie off-shore, the Lake Erie shoreline, and topographically - elevated portions of northwest Ohio, in Logan, Champaign, and Hardin counties (maps, Ohio Department of Development website).

Currently, there is only one operational wind-to-energy "farm" in Ohio; located west of Bowling Green at the Wood County Landfill. The four turbines at the site have a maximum capacity of 7.2 MW (enough electricity to power 1,600 homes). There are plans to expand the current "farm" at the landfill site to be able to produce up to 50 MW by the end of 2009. To date, ODH has not received any complaints or concerns from nearby residents regarding this operation.

Based on archived news releases (Green Energy Ohio website), several area farmers in the Bellefontaine area in Logan County began discussions with wind-to-energy developers to install and operate 25-30 wind turbines in the area as early as March, 2005 (*Columbus Dispatch,* 3/13/05). Evidently these proposed land-based wind farms are the Ohio sites furthest down the road towards siting, installation, and operation. Current concerns from residents regarding potential adverse health impacts from wind turbine "farm" developments have come entirely from a small number of residents in the vicinity Zanesfield, just east of Bellefontaine, in Logan County.

The state of Ohio does not have jurisdiction over the location and operation of wind-to-energy projects until the project meets or exceeds electrical energy production levels of 50 MW. For sites producing less than 50 MW of energy, jurisdiction over wind turbine operations falls to local governments, typically a zoning board or commission. However, in recent newspaper articles (*Columbus Dispatch,* 6/03/07), local planning commissions in Champaign and Logan counties were reportedly recommending that local township zoning boards not adopt regulations for wind turbine operations. This appears to create a local abdication of responsibility for the oversight of the siting and operation of these smaller wind turbine operations in these counties.

The Ohio Power Siting Board (OPSB) has jurisdiction for those wind-turbine projects that produce electricity at or in excess of 50 MW. The OPSB has 11 members, including a representative from ODH, as well as the Chair of the Public Utilities Commission of Ohio (PUCO), and the directors of the Ohio EPA, the Department of Agriculture, the Department of Natural Resources, and the Department of Development. A certificate of environmental compatibility and public need must be obtained from the OPSB prior to siting, installation, and operation of a utility-scale wind turbine system. There are a number of proposed wind projects in Ohio currently under consideration that would be larger than 50 MW.

Wind Turbine Processes and Phenomena Linked to Health Effects

Our review of the literature with regard to potential health impacts on nearby residents from the operation of wind-to-energy turbines identified three main areas that could result in adverse health impacts. These included:

- ***Audio Impacts*** associated with the noise generated by the operation of the wind turbines;
- ***Visual Impacts*** associated with the phenomena of “shadow flickering” and “strobing”; and
- ***Physical Impacts*** primarily linked to the phenomena of “Ice Throws” and “Ice Shed”.

These processes or phenomena will be briefly discussed below, followed by more in-depth discussions of the health effects linked in the literature to these processes.

Audio Impacts:

Most of the identified human health impacts associated with the operation of wind turbines mentioned in the literature are linked to the noise generated by the operations of the turbine (National Academy of Sciences, 2007). As with any machine with moving parts, wind turbines generate noise during operation. Noise from wind turbines come from two major sources: 1) mechanical noise caused by the gearbox and the generator; and 2) aerodynamic noise caused by the interaction of the turbine blades and the wind. Noise from wind turbines is typically expressed in terms of sound pressure on the ear, measured in decibels [db(A)]. A single utility-scale turbine typically generates sound pressures between 50-60 db(A) at a distance of 120 ft. Noise levels from on-land wind turbines today typically fall in the 35-45 db(A) range at a distance of 900-1,000 ft. This represents sound levels less than the noise in a busy office [roughly 60 db(A)] but slightly higher than night-time ambient background noise levels in the countryside [20-40 db(A)] (Table 1).

Besides the amplitude of the noise from turbines, the frequency of the sound is also important and human perception of sound can be different at different frequencies. Wind-turbines have been found to generate broadband, tonal, and low-frequency noise. "*Broadband noise*" from a wind-turbine is the "swishing" or "whooshing" sound resulting from the continuous rotations of the turbine blade (frequencies greater than 100 Hertz). "*Tonal" noise* consists of a "hum" or "pitch" occurring at distinct frequencies (NAS, 2007). "*Low-frequency noise*" is noise in the range of 10 to 200 Hz. This range includes "*infrasound*" which consists of vibrations that are inaudible or barely audible (levels at or below 20 Hz) and have been associated with aerodynamic noise generated by wind turbines (University of Salford, 2007; HGC Engineering, 2006). Another noise phenomena is what has been termed *amplitude modulation* (AM); wind turbine noise with a greater than normal degree of regular fluctuations (University of Salford, 2007).

Mechanical sounds from a turbine are emitted at "tonal" frequencies associated with the rotating machinery in the nacelle, including the generator and the gearbox. Aerodynamic noise, produced by the flow of air over the rotating turbine blades, generates broadband noise. Both mechanical and aerodynamic noise is often loud enough to be heard by people. Older "downwind" turbines emitted some low-frequency "infrasound' vibrations each time the rotor blade interacted with the disturbed wind behind the tower. Wind-energy developers in Oregon, Germany, and other European countries are required to meet local standards for acceptable sound levels (NWCC, 2006). In Germany and across much of Europe, this level is 35 db(A) for rural night-time environments (NAS, 2007).

Audio Impacts and Health Concerns: Gathered from Literature

Most of the literature with regard to human health effects from noise generated by wind turbine developments is based on **anecdotal testimony** from residents living in proximity to operational wind turbines. Testimony reported on anti-wind turbine websites (*National Wind Watch; Save Western New York*) from residents in Illinois and Maine in the U.S. and a physician near a turbine site in Great Britain reported the constant noise as creating a chronic source of irritation resulting in disruptions in sleep (insomnia), headaches, dizziness, exhaustion, irritability, lack of concentration, high levels of stress and anxiety, depression, nausea and other stomach disorders, and tinnitus. Dr. Nina Pierpont, formerly with the College of Physicians and Surgeons at Columbia University, has referred to this collection of ailments as “Wind Turbine Noise Syndrome” (Pierpont, 2006). The French National Academy of Medicine (Chouard, 2006) referred to potential neuro-biological reactions, including hypertension and cardiovascular illness, from exposures to chronic noise as “chronic sound trauma”. It is important to note that these health impacts were based, however, on studies of communities living around airports which have sound levels of 120 decibels at 200 feet, compared to communities living next to wind turbine farms with sound levels of 50 and 60 decibels at a closer distance of 120 feet.

The Kansas Legislative Research Department report on potential health impacts from wind turbine farms (2007) stated that the “negative impacts of wind farms on public health appear to be based on the assumption that a link exists between Low-Frequency Noise (LFN) and a vibro-acoustic disease that can lead to epilepsy and cancer”. This link has been suggested in a series of papers by Portugese researcher Mariana Alves-Pereira (2004; 2007). Abstracts of this research are found on the *National Wind Watch* website. Dr. Alves-Pereira and her co-authors suggest that excessive exposure to LFN can impact the body, causing irreversible organ damage referred to as Vibro-acoustic Disease (VAD). Symptoms associated with this disease included thickening of cardiovascular structures and mutagenic changes in cell structure, potentially leading to tumor formation (cancers?). They found evidence of VAD in a variety of occupations associated with aircraft and airports (aircraft mechanics, pilots, crew members), as well as ship machinist and disk jockeys. As indicated above, sound levels associated with airport operations and these other occupations are significantly greater than those associated with wind turbine operations (Table 1). They are currently expanding their research to include residents living near wind turbines.

<u>Audio Impacts and Health Effects: Evaluation of Literature</u>

As indicated above, many of the health impacts linked to noise from wind turbine operations are of an anecdotal nature and difficult to qualify or quantify. Data with regard to the nature of these health impacts does seem to be consistent for all of these communities. More scientific, epidemiological studies need to be undertaken in these communities to try and better establish the reality of the link between these health problems and wind turbine operations in the neighborhood.

Noise produced by wind turbines has diminished markedly over the last decade as the technology has matured (NWCC, 2002). Orienting rotors on the “upwind side” of the turbine tower avoids the production of Low-Frequency Noise (LFN) associated with the passage of the blades through the tower’s wind shadow, as occurs on “down-wind” machines. The U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, conducted studies of LFN associated with wind turbines and found significant differences in the amounts of LFN produced by downwind versus upwind turbines. For more than 10 years, the

U.S. has been using upwind turbines that do not generate the noise impulses that cause LFN as there is nothing blocking the flow of the upwind rotor (NWCC, 2002; KLRD, 2007). Significantly reducing or eliminating the production of LFN should minimize concerns about potential for the development of vibro-acoustic disease, if indeed this syndrome can be linked to wind turbine operations.

Studies in Canada and elsewhere (HGC Engineering, 2006) have indicated that modern wind turbines created levels of "infrasound" comparable to ambient levels in the natural environment due to wind. Infrasound is problematic to humans only if decibel levels are high (>115 dB). Infrasound levels associated with the operation of modern wind turbines generates levels typically below 70 dB (NWCC, 2005; KLRD, 2007) No evidence was found to indicate adverse health impacts in humans caused by infrasound levels generated by modern wind turbines (HGC Engineering, 2006).

Recent studies in the United Kingdom (University of Salford, 2007) have indicated that the noise phenomena termed aerodynamic modulation (AM) is not an issue, at least for the UK's wind farm fleet. Studies of the 133 operational wind projects in Britain indicated that occurrence of AM from operational turbines is low (4 out of 133). Complaints in three of these cases subsided following remediation of the turbine systems. The British study emphasized the need for these energy projects to be located and designed in such a way to minimize the production of AM.

Newer generations of wind turbines have been intensively re-engineered to reduce noise at all levels (NWCC, 2002). These include increasing the distance between the tower and rotor; developing more streamlined tubular towers and rotor nacelles that produce little or no sound with the passage of the wind; more heavily sound-proofing the nacelles, resulting in dampening down of the tonal noise associated with the mechanical operation of the turbine; modifying the blade airfoils to make them more efficient, converting more of the wind energy to rotational torque rather than acoustic noise. Under most conditions, modern turbines should be comparatively quiet, generating primarily broadband sound at levels slightly above those of a quiet room at distances of 750-1,000 ft [45 db(A) vs 30-35 db(A)]. Variable-speed turbines create less noise at lower wind speeds when ambient noise is also low, compared to constant speed turbines. Direct-drive machines, which have no gearbox or high-speed mechanical components, also operate more quietly (NAS, 2007). These various measures to reduce the noise from wind energy turbines suggest that the noise produced by wind turbines usually should not be a major concern for residents at distances a half-mile or more away from the turbine (NAS, 2007).

Recent studies by G.P. van den Berg (2003; 2006) have indicated that the sound from a wind turbine or a wind farm likely becomes louder and exhibits stronger fluctuations at night and thus can be more annoying after sunset. This research suggested that additional studies into noise impacts from turbine operations, especially at night versus those during the day, need to be undertaken to better establish the full extent of the noise levels people are exposed over the course of a 24-hour period.

Visual Impacts:

A peculiar phenomenon, identified in the literature with the operation of wind turbines, is what is termed *Shadow Flicker*. Shadow flicker occurs when the blades of the turbine rotate in sunny conditions, casting moving shadows on the ground resulting in alternating changes in light intensity (NAS, 2007). Shadow flicker intensity is defined as the difference or variation in brightness at a given location in the presence and absence of shadow. Shadow flickering is a function of 1) the location of people relative to the turbine; 2) the wind speed and direction; 3) the daily variation in sunlight; 4) the geographic location of the location; 5) local topography; and 6) presence of any obstructions in the line of sight.

Shadow flicker is most pronounced at distances from the turbine of less than 1,000 ft and during sunrise and sunset when the sun's angle is lower and the resulting shadows are longer. Shadow flicker is typically problematic for short periods each day – rarely more than a half-hour at sunrise and at sunset. The phenomenon is more a problem in the winter than the summer due to the sun's lower position on the horizon in winter months in North America (NAS, 2007).

Also mentioned in association with the operation of wind turbines is the related phenomenon of *"Strobing"*. Strobing can occur when the turbine blades catch the sun and reflect it back towards the viewer. Since the turbine blade can be in a position where this reflection takes place up to 60 times per minute, the effect is like a strobe light. Unlike shadow flickering, strobing evidently can occur any time of the day and happen any where turbines can be seen, especially when viewed from the south, east, and west (*Save Western NY* website; 2007).

Visual Impacts and Health Concerns: Gathered from Literature

The same anti-wind power websites (*National Wind Watch*; *Save Western New York*) report similar anecdotal testimony from residents near wind turbines with regard to visual phenomena associated with the operation of these turbines and health effects. Shadow-Flickering and the Strobing effect of operating wind turbines was linked to blinding effects, headaches, disorientation, confusion, loss of balance, increased levels of stress and anxiety, and seizures. These impairments were noted both by residents living proximal to the wind turbines and drivers on roads passing by the wind turbine farms.

Visual Impacts and Health Effects: Evaluation of Literature

Studies of the visual phenomena associated with turbine operations indicate that shadow flickering is not an issue with increasing distance from the turbine site (greater than 1,000 ft from the turbine) except during the morning and evening when shadows are longer (NAS, 2007). Shadow flicker seems to be more of an issue in Northern Europe because of its higher latitudes and the lower angle of the sun, especially during the winter. Flicker frequency due to a turbine is on the order of the rotor frequency (= 0.6-1.0 Hz) which is harmless to humans. According to the Epilepsy Foundation, only flicker frequencies above 10 Hz are likely to trigger epileptic seizures (NAS, 2007).

Physical Impacts:

If utility-scale wind turbines are operating in icing conditions, ice may collect on the rotor blades and could result in two types of physical phenomena. The first is termed *Ice Throw* and occurs when fragments of accumulating ice are thrown off of an operating turbine due to melting combined with aerodynamic and centrifugal forces with chunks of ice allegedly tossed distances up to 1,700 ft away from the turbine site (*Save Western NY* website, 2007). The other, more passive and common phenomena, termed *Ice Shed,* involves accumulated ice slumping off of rotors and towers as the ice melts from a stationary turbine.

Physical Impacts and Health Concerns: Gathered from Literature

Also cited in these same websites are references to hazards of a more physical nature posed by the operation of these wind turbines. These included primarily the phenomena of “Ice Throw” mentioned above and the potential for the flying or falling ice chunks to physically impact passers-by or people driving on adjacent roadways. Other physical hazards mentioned included the possibility of collapse of these gigantic structures and the potential for these devices to serve lightening rods during electrical storms, possibly leading to increases in lightening hits in the nearby area. These physical hazards are not mentioned or discussed in the lengthy review by the National Academy of Sciences (2007). The report by the National Wind Coordinating Committee (2006) indicated icing issues are likely to be more significant in Northern Europe than in the U.S.. They noted that icing issues pose potential safety issues to service personnel and to local infrastructure within 500 ft. of the turbine.

Physical Impacts and Health Effects: Evaluation of Literature

Review of the various literature with regard to the physical hazards that have been linked to turbine operations indicated that these concerns can be reduced or eliminated by siting the turbines “a safe distance” from human structures, either from homes or roadways. What is a “safe distance” is not well defined, but it appears to be a distance in excess of 500 ft. (NWCC, 2006).

A Comparative Risk Example: Coal-burning Electrical Power Plants in SE Ohio

To put the health and environmental impacts of the proposed wind turbine operations in perspective, included here is a description of the health and environmental impacts from a more or less typical coal-burning electrical power plant in Beverly, in Washington County, Ohio. Information about the types and volumes of chemicals released from this power plant was obtained from the U.S. EPA Toxic Release Inventory report for the facility in 2004. Total releases of chemicals to the environment totaled 9,827,164 lbs, including 8,643,990 lbs released to the air, 9,941 lbs released to nearby surface waters, 407,407 lbs land-filled, and another 772,826 lbs in on-site surface impoundments. These chemicals include toxic heavy metals like arsenic, barium, copper, lead, manganese, mercury, nickel, and zinc, plus acidic aerosols including sulfuric acid, hydrochloric acid, and hydrofluoric acid, plus general air quality pollutants like particulates, nitrogen oxide, sulfur dioxide, carbon dioxide, and carbon monoxide. Arsenic is a known human carcinogen. Lead and mercury are highly toxic metals. Mercury is carried in the ambient air to area water bodies where it accumulates and contributes to methyl mercury contamination of the aquatic food chain, including sport fish. Particulates and the various acids are respiratory irritants. The nitrogen oxide and sulfur dioxide contribute to air quality impairment and acid rain in down-gradient areas east of the site. Carbon dioxide contributes to global warning and carbon monoxide is a poison.

In addition to the impacts from the coal-burning power plant operation itself, the mining of the coal burned in the power plant is very destructive to the region's landscape and its natural resources. Coal-mining operations typically disrupt and adversely impact the water quality of local groundwater and surface waters. Land disposal of coal mine wastes provides a source of heavy metals and sulfides to the environment. The sulfides released to the environment cause acidification (acid mine drainage) of local water supplies, rendering them useless as drinking water sources and toxic to aquatic life.

In summary, when compared to the operation of a typical coal-burning power plant in Ohio, the proposed development and operation of wind turbine farms in northern Ohio represents a minimal public health threat with minimal environmental impacts.

Recommended Actions:

The State of Ohio should establish protocols or guidelines for the siting and operation of wind-to-energy turbine developments in the state. There seems to be a lot of confusion and lack of information at the local level with regard to what regulatory authority these local governments have and how these turbines should be sited and what levels of oversight or regulation are needed to be protective of the interests of the community living adjacent to these turbine operations.

Included in these guidelines should be siting requirements to limit adverse impacts, aesthetically and with regard to quality of life issues, to nearby residences. An excellent discussion of these issues can be found in the reports of the National Wind Coordinating Committee (2006) and the National Academies of Science (2007).

Current siting guidelines identified during this literature search, ranged from 1,200 ft from the turbine site (Palm Beach, California) to nearly one mile (French Academy of Science; United Kingdom Noise Association). It is suggested that operational noise levels at these distances should be kept to levels at or below 35 db(A) [=turbine noise standard established by the State of Oregon, Germany, other European countries].

To effectively handle noise and visual concerns that may arise in the community after permitting, a complaint collection and investigation process should be established to minimize future friction between the turbine operators, the governmental regulatory entity, and nearby residents.

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Table 1.
Typical Environmental and Industrial Noise Levels

Source and Distance from Source	**Sound Level in Decibels (dbA)**	**Environmental Noise**	**Impact**
Civil Defense Siren	130-140		Pain Threshold
Jet Take-off (200 ft) (Broadband & Tonal)	120		Pain Threshold
	110	Rock Music Concert	Very Loud
Pile Driver (50 ft) (Impulsive)	100		Very Loud
Ambulance Siren (100 ft) (Tonal)	90	Boiler Room	Very Loud
Freight Cars (50 ft) (Broadband & Tonal)	90		Very Loud
Pneumatic Drill (50 ft) (Broadband)	80	Printing Press Kitchen Garbage Disposal	Loud
Freeway (100 ft) (Broadband)	70		Moderately Loud
Vacuum Cleaner (100ft) (Broadband & Tonal)	60	Data Processing Center; Department Store; Office	Moderately Loud
Light Traffic (100 ft) (Broadband)	50	Private Business Office	Quiet
Large Transformer (200 ft) (Tonal)	40		Quiet
Soft Whisper (5 ft)	30	Quiet Bedroom	Quiet
	20	Recording Studio	Quiet

Source: Table 3.1 National Wind Coordinating Committee (2002)