Scientific and technical advice

Evidence update – Wind turbines and health

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Introduction

A report was prepared by the Chief Medical Officer of Health (CMOH) in Ontario on the potential health impact of wind turbines in May 2010. Following this report, Public Health Ontario (PHO) provided an update on the scientific research published on this topic from 2010 to October 2012. The CMOH has requested that PHO undertake a second update of the existing report entitled, "Potential Health Impacts of Wind Turbines, May 2010", including conducting a literature review that captures all new literature, including international studies, published since the date of the last citation in the previous update, up to, and including, December 2013 and determining if the recent literature might otherwise change the findings of the original May 2010 study.

This update uses the same study methodology described in the CMOH 2010 report, "...literature search to identify papers and reports on wind turbines and health from scientific bibliographic databases, grey literature, and from structured Internet search..." Where possible, the original search strategies were used.

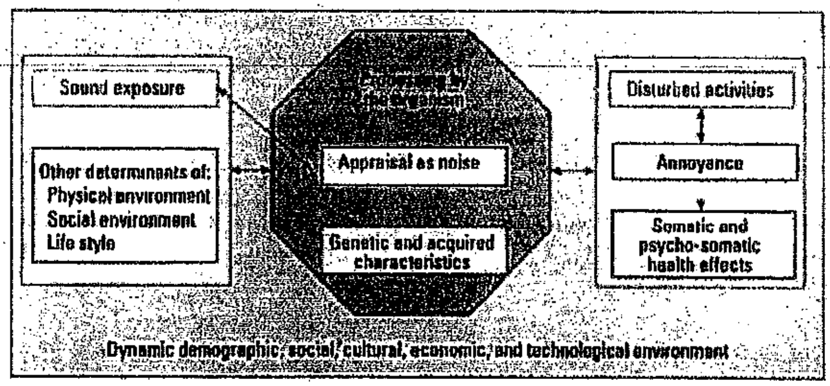
Potential impacts from wind turbines may arise from features of wind turbines, including noise, electromagnetic fields, shadow-flicker from turbine blades and personal injury risk from structural failure and ice throw.(1) Occupational health and safety concerns centre on potential falls from height while servicing.(2) The most controversial aspect of wind turbines is concern over the potential health effects of their associated noise, including low-frequency sound and infrasound (sounds with a frequency less than 20Hz and which are usually inaudible to humans).(3) The relationship between noise and health outcomes is complicated by annoyance, which may mediate indirect health effects.(4)

The WHO Regional Office for Europe developed guidelines for night noise in 2009 which "reviews the health effects of night time noise exposure, examines exposure-effects relations, and presents guideline values of night noise exposure to prevent harmful effects of night noise in Europe."(5) The authors drew upon the World Health Organization definition of health, where "Health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity." These guidelines used biological effects, sleep quality, well- being and medical conditions as endpoints in their development. Relying on the WHO definition of health for considering the adverse health effects of noise can be problematic, as health in this definition is difficult to attain. As Niyi Awofeso writes, "critics argue that the WHO definition of health is utopian, inflexible, and unrealistic, and that including the word "complete" in the definition makes it highly unlikely that anyone would be healthy for any period of time. It also appears that 'a state of complete physical mental and social well-being' corresponds more to happiness than to health. The words 'health' and 'happiness' designate distinct life experiences, whose relationship is neither fixed nor constant. Failure to distinguish happiness from health implies that any disturbance in happiness, however minimal, may come to be perceived as a health problem."(6)

The night noise guideline recommended for protection of public health is a long term average level of 40dB(A) applied to all nights (23:00-7:00) in a year. An interim target of 55dB(A) was also set, which may be a reflection that many cities in Europe may have difficulty meeting 40dB(A) in the short-term.(7) As the scientific and medical research literature on the effects of community noise relates primarily to sources other than wind turbines, the broader community noise literature currently represents the best proxy for quantitative statements about the anticipated presence or absence of any direct human health effects from wind turbines noise.

While health risks from environmental exposure to chemical and biological agents may be determined by investigating an individual's exposure to the agent and the risk of adverse health effects, this model may not apply as easily to a ubiquitous physical stimulus such as sound. Given that everyone is continually exposed to sound (including infrasound and low-frequency noise) to a greater or lesser degree, isolating the risks of adverse health effects resulting from chronic low-level exposure to an environmental source of noise can be difficult. Furthermore, the data about community noise exposure levels can be limited (such as occurs in the United States), reducing the ability of public health to assess its impact on health.(8) Exposure to sound of sufficient intensity and duration can cause end organ damage, as demonstrated by noise induced hearing loss (NIHL). The WHO has concluded there is limited evidence of a link to hypertension and myocardial infarction with exposure to noise at levels below those required to produce NIHL.(5) The subjective experience of sound allows for specific sounds to be perceived as inherently more or less pleasant. The context in which the exposure occurs is a predictor of whether sound will be perceived as pleasant or unpleasant. The importance of the context in which exposure occurs and the influence of a person's reaction as a predictor of annoyance and other effects are reflected in Fig.1 below. Taking into account the complexity of the model, research on the interaction of community noise with human health by necessity is broad-scoping and interdisciplinary.

Fig. 1 Conceptual model of the interaction of sound with the organism and the occurrence of effects on health and quality of life



Passchier-Vermeer W, Passchier W. Noise exposure and public health. Environmental Health Perspectives, 108(Supp1):123-31 (2000).(9)

Much of the recent research on wind turbine developments has examined the social and policy context of wind turbine projects, including how this contributes to the reporting of adverse health effects or annoyance resulting from exposure to wind turbines. Understanding how wind turbine projects were planned and implemented in specific communities, including the extent to which local residents economically benefit from wind turbines or participated in the development process, can help researchers examining the health effects of wind turbines incorporate the social and economic context of wind turbine development into their model of how sound can impact health and quality of life. While some of this type of research is out of the scope of reviews on the potential health effects of wind turbine exposure, it can provide important insight into why communities express concern and opposition to wind turbine development projects. Similarly, gaining an appreciation of how aesthetic aspects of wind turbine developments impact the perception of sound and annoyance can help research into the potential health effects of wind turbine exposure determine the extent to which disturbances to the visual landscape modulate perceived adverse health effects.

Objective

The objective is to identify and review literature on wind turbines and health published between October 2012 and up to December 2013.

Methodology

CRITERIA FOR CONSIDERING STUDIES FOR THIS REVIEW

This review focused on primary peer-reviewed literature and reviews. Published peer-reviewed literature was supplemented by relevant grey literature reviews or studies from government and other public sector organizations.

STUDY INCLUSION CRITERIA

All peer-reviewed studies related to the potential effect of wind turbines on human health published in the scientific literature were included. Articles published in English between October 2012 and December 2013 were selected for further examination based on relevance to the topic of interest from a scan of their title and abstracts. Relevant grey literature, such as literature reviews from governmental organizations or academic institutions, was included. Reviews were included as a means of ascertaining current approaches to the subject area. Qualitative research studies of wind turbines development and opposition were included if they provided insight into the impact of wind turbines on perceived health outcomes or annoyance.

STUDY EXCLUSION CRITERIA

Articles regarding offshore wind developments were excluded. Articles that focused on the environmental impact of wind turbines without substantial analysis of their impact on human health were excluded. Articles that focused on the economic, political, or social aspects of wind turbine development projects were excluded if they did not include substantial relevance to adverse health effects or annoyance from wind turbines. Technical articles on engineering aspects of wind turbines were excluded if they did not examine potential adverse health effects or annoyance from wind turbines. Items either sponsored or published by advocacy or industry groups were not included in the review of grey literature. Case-series, commentary or opinion pieces and conference papers were excluded from the final list. Studies that discussed noise or infrasound in general but not specifically wind turbine noise were excluded.

TYPES OF PARTICIPANTS

The review included all types of participants, including urban and rural populations, and studies from different countries. Individuals with specific morbidities were not excluded.

SEARCH METHODS FOR IDENTIFICATION OF STUDIES

The original search methodology from the CMOH report was replicated as closely as possible, and was in keeping with the previous update to the CMOH report. As occurred with the previous update, while the search strategy was replicated based on the original search terms list (see Appendix A), it was modified to account for the differences in the databases searched. This adjustment is attributed to different availability of sources (databases) at the time of writing the CMOH report and PHO's own resources.

ELECTRONIC SEARCHES

Relevant databases were searched using a tailored and sensitive (combination of MeSH and keywords) search strategy previously developed by the MOHLTC PHD library team and slightly broadened, while retaining its integrity, for the purpose of this review. The primary search strategy developed for MEDLINE (Appendix B) was used as the template for search strategies in other databases.

The following bibliographic databases were searched:
MEDLINE (PubMed and Ovid platforms)
Embase
BIOSIS

Environment Complete
Academic Search Premier
Web of Science
Academic literature was supplemented by searching Google Scholar.

Search terms were selected to represent the concepts of wind turbines (including wind energy), annoyance, noise, and health effects.

The search vocabulary was adjusted for each database searched, based on presence or absence of controlled vocabulary (i.e. MeSH). To increase search sensitivity, proximity operators were used with keyword combinations as well where the functionality of the searched database allowed it. Boolean operators were used to combine the concepts.

Complete search strategies are included in Appendix B.

SEARCHING OTHER RESOURCES

Grey literature was searched using Google Scholar. Search terms used mimicked those used for database searches. The search was discontinued when no new reports were identified with the addition of different search terms.

The reference lists of included studies were scanned to identify other articles that fit the inclusion criteria.

RESULTS MANAGEMENT

Obviously irrelevant results were excluded from further assessment. All articles covering any aspect of human health or well-being (annoyance) were retained for further assessment based on the abstracts. Duplicate results from all searches were removed before the titles and abstracts were scanned for inclusion/exclusion and further appraisal.

Search strategies for each individual database were saved electronically; abstracts of items selected for further examination were kept in RefWorks libraries.

To ensure a comprehensive review of the existing literature, all reviews and primary studies were included.

Results

The literature surrounding wind turbines addresses various outcomes and exposures and includes a variety of study designs. As structured in the previous update, this section separates the identified articles into the following categories:

- Observational and experimental studies (i.e. studies that generated or analyzed data to better understand the relationship between an exposure and an outcome)
- Exposure studies (i.e. studies that focussed on estimating exposures only)
- Reviews

Grey literature

Other peer-reviewed literature (including qualitative research studies)

OBSERVATIONAL AND EXPERIMENTAL STUDIES

The observational studies identified in this review are summarized in Table 1 and Table 2. The majority of the studies identified for the review were observational, and were summarized in tables to allow for easy comparison of the different methodologies used and their subsequent results. The abstraction of the information from the articles was standardized across the studies. Table 1 provides a descriptive summary of the studies that generated or analyzed data. The studies are organized by study type. The columns outline the citation, the years the study was actually conducted (if available), the study design, a brief description of the study with its objectives, the setting in which the study was conducted, and the sample population of the corresponding study. Table 2 provides an analytical summary of the same articles. This table is meant to provide a more in-depth summary with a list of the methods used for the exposure and outcome measurements, and a clear description of the health and non-health outcomes addressed in the corresponding article. The Results column separates the health and non-health related results where applicable. The last column outlines the sample size, whether or not a comparison group was available, the response rate (if available) as well brief descriptions of selection bias, and whether confounders were controlled in the study.

Table 1. Descriptive Table of Observational and Experimental Studies

Citation	Year of Study	Study Design Type	Study Description	Country	Study Participants
(10) Baxter J, Morzaria R, Hirsch R. A case-control study of support/opposition to wind turbines: Perceptions of health risk, economic benefits, and community conflict. Energy Policy (2013);61:931-943.	2010	Cross-sectional	Analysis of the responses of voluntary survey with 35 Likert scale questions in matched case-control communities, where one community had one of the largest and earliest wind energy developments in Ontario (for Melancthon and Amaranth—taken as a single community) vs no active or proposed wind turbines in the control community (West Perth)	Ontario, Canada: (Melancthon, Amaranth and West Perth)	109 respondents from Melancthon and Amaranth (case) and 116 respondents from West Perth (control). The demographic characteristics were roughly similar between case and controls, with slightly more males (59% vs 51%) in the control setting responding.
(11) Bockstael, A., Dekoninck, L., Can, A., Oldoni, D., De Coensel, B., & Botteldooren, D. (2012). Reduction of Wind Turbine Noise Annoyance: An Operational Approach. Acta Acustica united with Acustica, 98(3), 392–401. doi:10.3813/AAA.918524	2012	Cross-sectional	A six–month study at an industrial site near a residential area with regular on-line annoyance reports, continuous 1/3–octave band noise level registrations, periodic sound recordings, data on electricity production per minute and meteorological observations. The authors measured long-term measurements from three wind turbines located 270 m away and tried to assess the annoyance levels associated with different aspects of the noise.	Belgium	Eight families recruited through a door-to-door campaign that live near three wind turbines.
(12) Chapman S, St George A, Waller K, Cakic V. The Pattern of Complaints about Australian Wind Farms Does Not Match the Establishment and Distribution of Turbines: Support for the Psychogenic, 'Communicated Disease' Hypothesis. PLoS One 2013 Oct 16;8(10):e76584.) (2013)	2012-3	Cross-sectional	Secondary data analysis of records of complaints about noise or health from residents living near 51 Australian wind farms that were obtained from all wind farm companies, and corroborated with complaints in submissions to 3 government public enquiries and news media records and court affidavits.	Australia	All Australian wind farms (51 wind farms with 1634 turbines) operating from 1993 to 2012.
(13) Katsaprakakis DA. A review of the environmental and human impacts from wind parks. A case study for the Prefecture of Lasithi, Crete. Renewable and Sustainable Energy Reviews 2012;16(5):2850-2863. (2012)	2006	Cross-sectional	A three part survey was administered to 100 individuals—the survey is not described in depth, but includes a question about general opinion on wind turbines	Crete, Greece	100 individuals selected from towns and villages in the four prefectures. 40% of people live in proximity to wind turbines. The characteristics of the respondents seem to be consistent between the different regions, but the sample size is small and there is little description of the specific demographics.

Citation	Year of Study	Study Design Type	Study Description	Country	Study Participants
(14) Mroczek B, Kurpas D, Karakiewicz B. Influence of distances between places of residence and wind farms on the quality of life in nearby areas. Annals of Agricultural and Environmental Medicine 2012;19(4):692-696. (2012)	2010	Cross-sectional	Randomly chosen adults using a two-stage sampling technique from rural Poland in areas with wind turbines were given a survey (SF-36 General Health Questionnaire in Polish), the Visual Analogue Scale (VAS) for health assessment, and answered questions about approximate distance between a house and a wind farm, age, gender, education, and professional activity.	Poland	1277 adults (703 women and 574 men) from areas near wind farms in Poland. The mean age was 45.5 ± 16.10. Some 33.2% of participants lived more than 1,500 m from wind farms; 17% – below 700 m.
(15) Mulvaney KK, Woodson P, Prokopy LS. A tale of three counties: Understanding wind development in the rural Midwestern United States. Energy Policy;56:322-330.(2013)	N/A	Cross-sectional	Their research utilized a multiple case study approach in three rural counties. Within each of the three counties, a mixed methods approach was used including surveys, interviews and a document review of newspaper articles and published reports.	Indiana, USA	A stratified sample in Boone and Tippecanoe counties was done to favour rural respondents for 35% of the surveys. 1000 surveys were sent to Boone and Tippecanoe counties and only 750 surveys were sent to Benton County residents. The overall response rate was over 40% (46% Benton, 41% Boone, 41% Tippecanoe) key stakeholders including planners, extension agents, county commissioners, wind industry representatives, major land owners, and opposition leaders were identified for a total of 11 standardized open-ended interviews. Respondents were more likely to be male, better educated and own their own homes as compared to the general US population.
(16) Mulvaney KK, Woodson P, Prokopy LS. Different shades of green: a case study of support for wind farms in the rural midwest. Environ Manage May;51(5) 1012-1024. (2013)	2010	Cross-sectional	Surveys were mailed to 750 random households in the study area. Interviews were done with key respondents	Indiana, USA (Benton County)	Response rate was 46% for the mail-out survey to 750 households. Comparison of demographic information with available census information shows respondents were more likely to be male (54.8 % as compared to 49.5 %), better educated (21.8 % as compared with 13.8 %), and own their houses (89.0 % as compared with 77.7 %) than the general population.
(17) Tampakis S, Santopoulos G, Arabatzis G, Rerras I. Citizens' views on various forms of energy and their contribution to the environment. Renewable and Sustainable Energy Reviews;20:473-482.(2013)	2010	Cross-sectional	Questionnaire with 10 questions administered to random sample of participants and face-to-face interviews.	Andros, Greece	Respondents were 57.7% women (discrepancy between the text and the table information) with age range 18 to >50. Most respondents are 18-40 years old and have completed tertiary education, either at university or at a technological educational institute. Most respondents are self-employed (27.3%) or civil servants (18.6%).

Citation	Year of Study	Study Design Type	Study Description	Country	Study Participants
(18) Taylor J, Eastwick C, Lawrence C, Wilson R. Noise levels and noise perception from small and micro wind turbines. Renewable Energy;55:120-127 (2013)	N/A	Cross-sectional	The study assessed the effect of personality traits on the relationship between actual and perceived noise from turbines by assessing the prevalence of certain personality characteristics of those in two cities in the UK. 1327 households living within 500m of a small or micro wind turbine were contacted to participate in a voluntary survey, with 138 respondents (~10.86% response rate). Sound levels were measured at each wind turbine and sound levels were modelled with software.	UK	Households within 500 m of 8 0.6 kW micro turbine installations and within 1 km of 5 kW small turbine installations were sent a household questionnaire by mail. The 138 respondents were between the ages of 20-95 (mean age 53.8) and representative of the relevant wider populations. 74 were male and 62 female (2 did not specify their sex).
(19) Maffei L, Iachini T, Masullo M, Aletta F, Sorrentino F, Senese VP, et al. The effects of vision-related aspects on noise perception of wind turbines in quiet areas. Int J Environ Res Public Health Apr 26;10(5):1681-1697. (2013)	N/A	Experimental	Researchers studied the impact of the number of turbines, distance of turbines and color of turbines on the level of annoyance using Immersive Visual Reality technology.	Italy	Adults with a mean age of 25.3 years who lived in urban and rural areas.
(20) Van Renterghem T, Bockstael A, De Weirt V, Botteldooren D. Annoyance, detection and recognition of wind turbine noise. Sci Total Environ Jul 1;456-457:333-345.(2013)		Experimental	The researchers assessed annoyance by wind turbine noise relative to road traffic noise during a quiet leisure activity by participants unaware of the experiment's purpose. The participants were then asked about sounds during that time and to rate their annoyance level from 0-10. Individuals were then asked to detect wind turbine noise in sound samples that may or may not contain it to find detection limits of wind turbine noise. Participants completed a questionnaire about the opinion of renewable energy, previous experience with wind turbine noise, and their self-reported noise sensitivity.	Netherlands	The study included 50 participants with normal hearing. Individuals with abnormal hearing were excluded with audiometric hearing tests. Participants were 54% female, 46% male, ages ranged from 19-71 years. 40% were students, 44% were employed, 6% were unemployed, 2% were housewife/man, and 8% were retired. 82% of the participants had a positive attitude towards renewable energy, 18% called themselves neutral. No one reported to be against renewable energy.
(21) Whitfield Aslund ML, Ollson CA, Knopper LD. Projected contributions of future wind farm development to community noise and annoyance levels in Ontario, Canada. Energy Policy;62:44-50. (2013)	N/A	Experimental	Publicly available noise assessment reports for 13 wind power developments were downloaded and the modeled sound pressure levels for all of the identified receptors were compiled in a single file. For each receptor, the distance to and identity of the nearest noise source (i.e., wind turbine or transformer substation) was also recorded. Predicted Ontario noise level results were categorized as <30 dB(A), 30–35 dB(A), 36–40 dB(A), 41–45 dB(A),and >45 dB(A). Levels of wind turbine noise related annoyance in Ontario were then estimated	Ontario, Canada	13 wind power developments

Citation	Year of Study	Study Design Type	Study Description	Country	Study Participants
(22) Seong Y, Lee S, Young Gwak D, Cho Y, Hong J, Lee S. An experimental study on annoyance scale for assessment of wind turbine noise. Journal of Renewable and Sustainable Energy;5(5).(2013)	N/A	Experi-mental	Participants were exposed to wind turbine noises (from 28 different stimuli) in a standardised environment	South Korea	32 subjects, with 17 male and 15 female, aged 20-34 years (average age 25.7 years)
(23) Crichton F, Dodd G, Schmid G, Gamble G, Cundy T, Petrie KJ. The Power of Positive and Negative Expectations to Influence Reported Symptoms and Mood During Exposure to Wind Farm Sound. Health Psychology (2013).	N/A	Experi-mental	54 university students were exposed to 10 min of infrasound and 10 min of sham infrasound (no sound) in a controlled experimental setting. Participants were told they were being exposed to infrasound during both 10-min exposure sessions and the experimenter was also unaware when exposure was to infrasound or to sham infrasound. Following completion of baseline assessments, participants were shown the relevant expectancy (high or low) video presentation, both of which were of 5 min 45 s duration. Participants ranked physical symptoms before and during exposures.	Auckland, New Zealand	54 university students (34 women, 20 men)
(24) McCallum LC, Aslund ML, Knopper LD, Ferguson GM, Ollson CA. Measuring electromagnetic fields (EMF) around wind turbines in Canada: is there a human health concern? Acta Vet Scand 2014:9.	2013	Exposure	Magnetic field measurements were collected in the proximity of 15 Vestas 1.8 MW wind turbines, two substations, various buried and overhead collector and transmission lines, and nearby homes. Data were collected during three operational scenarios to characterize potential EMF exposure: 'high wind', 'low wind' and 'shut off'.	Goderich, Ontario	600 magnetic field measurements were collected at various distances from the wind turbines, homes, collector/transmission lines, and substations within the Kingsbridge 1 Wind Farm near Goderich, Ontario.
(25) Anderson C. The networked minority: How a small group prevailed in a local windfarm conflict. Energy Policy;58:97-108.(2013)	2009	Quali-tative	A qualitative case-study that examined the factors that led to opposition to a wind farm in a rural community in Australia. The authors used a social capital analytical framework and conducted semi-structured interviews, including with 14 community members	Victoria, Australia	Interviews were done with representative key actors within the community that were involved in the wind turbine conversations, as well as regulators and developers.

Citation	Year of Study	Study Design Type	Study Description	Country	Study Participants
(26) Ariza-Montobbio P, Farrell KN. Wind farm siting and protected areas in Catalonia: Planning alternatives or reproducing 'one-dimensional thinking'? Sustainability ;4(12):3180-3205 (2012)	N/A	Qualitative	Discourse analysis using Critical Theory perspective	Catalonia, Spain	The researchers did 68 interviews total, including informal interviews with local civil servants, local politicians, landowners, and representatives of local community platforms opposing the current siting policies in their first phase, followed by semi-structured interviews with civil servants in the Catalan Department of Environment, environmentalist non-governmental organizations (NGOs), representatives of the Catalan Institute for Energy (ICAEN), environmental consultants, members of the Catalan parliament, wind entrepreneurs and representatives of the wind industry lobby association Eolicat
(27) Deignan B, Harvey E, Hoffman-Goetz L. Fright factors about wind turbines and health in Ontario newspapers before and after the Green Energy Act. Health, Risk and Society 2013.	2011	Qualitative	Newspapers were searched from May 2007 to April 2011 for selected communities with wind turbine installations (17 newspapers; 4 national and 13 local). 421 Articles related to wind turbines within the newspapers were found by using specific search terms. Each identified article had a content analysis.	Ontario, Canada	The authors examined communities in Ontario with wind turbines; including three large and two small wind energy installations, which began operation between 2006 and 2009, were selected. The large installations were Melancthon Phase II, Ontario Wind Power Farm and Prince Wind Farm with 88, 110 and 126 turbines, respectively. The small installations were Dunnville Wind Turbine and Proof Line Wind Turbine with one and four turbines, respectively.
(28) Groth TM, Vogt CA. Rural wind farm development: Social, environmental and economic features important to local residents. Renewable Energy;63 1-8. (2014)	2011	Qualitative	The authors used first a set of formal interviews with 11 local stakeholders. They then mailed out a survey that included 21 questions using 5-point Likert scale to 1000 homeowners	Michigan, USA (four rural townships in Huron County)	Random selections were made in townships #1 (Bingham, n = 220) and #4 (Sand Beach, n = 357). In townships #2 (Oliver, n = 246) and #3 (Rubicon, n = 177), with fewer land owning residents, the survey was sent to all permanent residents. A total of 497 useable surveys were returned for a response rate of 50%. Respondents were almost exclusively homeowners without turbines (only 2 respondents reported to have turbines on their property). Two of the townships (#1 and #2) contained operating wind farms and two coastal townships, (#3 and #4), were used as comparison sites. The percentage of useable surveys varied slightly between townships: #1-51% (n = 113); #2-46% (n = 112); #3-51% (n = 91); #4-50% (n = 178).

Citation	Year of Study	Study Design Type	Study Description	Country	Study Participants
(29) Hall N, Ashworth P, Devine-Wright P. Societal acceptance of wind farms: Analysis of four common themes across Australian case studies. Energy Policy;58:200-208. (2013)	2011	Quali-tative	Qualitative interviews with stakeholders for seven case study wind farm development sites. Analysis was done using methods informed by grounded theory. Secondary data, including media articles and other publicly available documents, were used for additional information regarding the case studies, and to provide additional stakeholder views.	Australia	Purposive sampling was used to select interview participants to ensure that the most relevant views were captured. In total, 27 interviews were undertaken in early 2011. These included representatives from wind development companies; local government; community members publicly stating their opposition ('local opposition'); community members publicly stating their support ('local support'); and turbine hosts.
(30) Richards G, Belcher K, Noble B. Informational barriers to effective policy-public communication: A case study of wind energy planning in Saskatchewan, Canada. Canadian Public Policy ,39(3):431-450. (2013)	2009-2010	Quali-tative	The researchers used an inductive, exploratory, case study approach based on grounded theory	Saskatchewan, Canada	The researchers undertook a document review of policy information on Saskatchewan's large-scale wind energy development, conducted between August 2009 and March 2010. Document collection and review was a constantly evolving process, and public data sources consulted included Canadian Centre for Energy Information (website), Canadian Electricity Association (website), Canadian Wind Energy Association (website), Crown Investments Corporation of Saskatchewan (website), EcoLogo (website), Enterprise Saskatchewan (website), Environment Canada Wind Energy Atlas, Global Wind Energy Council (various reports), Government of Saskatchewan (news releases), Government of Saskatchewan Throne Speeches, Government of Saskatchewan (website), Ministry of Energy and Resources (various annual reports), Natural Resources Canada (various reports on wind energy), North American Electric Reliability Corporation (website), NorthPoint Energy Solutions (website), SaskPower (annual environment reports), SaskPower (annual corporate reports), SaskPower (news releases), SaskPower (website), Standing Committee on Crown and Central Agencies (various reports), and Western Producer (weekly agricultural news publication)

Table 2: Analytical table of Observational and Experimental Studies

Citation	Exposure of Interest	Exposure Measurement	Health Outcomes	Other Outcomes	Outcome Measurement	Results	Validity
(10) Baxter J, Morzaria R, Hirsch R. A case-control study of support/opposition to wind turbines: Perceptions of health risk, economic benefits, and community conflict. Energy Policy 61:931-943. (2013)	Wind turbine community exposure impact on support for wind turbines		Health risk concern	Support for wind turbines.	Questionnaire using 5 point Likert scale questions (35 questions total)	69% of residents in the case community would vote in favour of local turbines, only 25% would do so in the control community. The key predictors for wind turbine support in this study are: health risk perception, community benefits, general community enhancement, and a preference for turbine-generated electricity. Concern about intra-community conflict is high in both the case (83%) and control (85%) communities as is concern about the fairness of local economic benefits (56% and 62%, respectively) where neither is significant in the models. Mean support for wind energy in Ontario is higher than local support in both the case (4.00 vs 3.75) and control (2.83 vs 2.48) communities. The control community residents are most concerned about health impacts: 77% agree (53% strongly) they are concerned with a 4.14 mean in the control community compared to 49% (23% strongly) and a 3.19 mean in the case community. The results do not support NIMBYism according to the authors.	Sample Size: 225–109 cases and 116 controls respondents. Control: Matched rural community Data Collection/Recruitment: Case and control communities' response rates of 31% and 33% respectively. Control of confounders: Yes, respondents generally similar between communities, similar community profiles other than presence of wind turbines and history with wind turbines

Citation	Exposure of Interest	Exposure Measurement	Health Outcomes	Other Outcomes	Outcome Measurement	Results	Validity
(11) Bockstael A, Dekoninck L, Can A, Oldoni D, De Coensel B, Botteldooren D. Reduction of Wind Turbine Noise Annoyance: An Operational Approach. Acta Acust United Acust MAY-JUN;98(3):392-401.(2012)	Wind turbine noise with recorded sound levels from two separate sites.	Noise is measured with microphones at two separate locations taking 1 min recording every 15minutes. The operational data for the three wind turbines is recorded. Meteorological data was taken from a weather station close by. A web-based complaint registering software was used, and a questionnaire was used for non-responding families (5/8 families)	N/A	Annoyance was self-reported using the online tool as well as by interviews with the non-respondents based on the questionnaire.	An online survey that allowed participants to rate their annoyance on a scale.	The risk of high annoyance especially increases with increasing angular blade velocity ($p < 0.0001$) followed by the wind direction ($p < 0.001$). The probability for high annoyance is highest for wind coming from the North and lowest from southern wind. The results for wind coming from the East should not be taken into account due to lack of data. The risk of high annoyance increases with decreasing relative humidity ($p < 0.001$).	Sample Size: 8 Comparison Group: No Data Collection/Recruitment: 3/8 families participated in the study Control of Confounders: No

Citation	Exposure of Interest	Exposure Measurement	Health Outcomes	Other Outcomes	Outcome Measurement	Results	Validity
(12) Chapman S, St George A, Waller K, Cakic V. The Pattern of Complaints about Australian Wind Farms Does Not Match the Establishment and Distribution of Turbines: Support for the Psychogenic, 'Communicated Disease' Hypothesis. PLoS One Oct 16;8(10):e76584.(2013)	The presence of complaints following the establishment of a wind turbine	records of complaints	n/a	n/a	n/a	There are large historical and geographical variations in wind farm complaints. 33/51 (64.7%) of Australian wind farms including 18/34 (52.9%) with turbine size >1 MW have never been subject to noise or health complaints. These 33 farms have an estimated 21,633 residents within 5 km and have operated complaint-free for a cumulative 267 years. Western Australia and Tasmania have seen no complaints. 129 individuals across Australia (1 in 254 residents) appear to have ever complained, with 94 (73%) being residents near 6 wind farms targeted by anti-wind farm groups. The majority 116/129(90%) of complainants made their first complaint after 2009 when anti-wind farm groups began to add health concerns to their wider opposition. In the preceding years, health or noise complaints were rare despite large and small-turbine wind farms having operated for many years.	Sample Size: N/A Comparison Group: N/A Data Collection/Recruitment: In September 2012 all wind farm owners in Australia were asked to provide information about complaints and daily media monitoring records were searched from August 2013 to January 2013. Control of Confounders: No

Citation	Exposure of Interest	Exposure Measurement	Health Outcomes	Other Outcomes	Outcome Measurement	Results	Validity
(13) Katsaprakakis DA. A review of the environmental and human impacts from wind parks. A case study for the Prefecture of Lasithi, Crete. Renewable and Sustainable Energy Reviews 16(5):2850-2863. (2012)	Specific area in which individuals live (rural vs town) and prefecture	N/A	N/A	Preference on setback distance for wind turbines	Questionnaire data using a mix of open ended and close ended multiple choice questions.	No negative opinions of wind turbines identified. 36% of respondents were concerned about noise, a smaller amount were concerned about the visual impact, shadow flicker and impact on birds. The setback distance from villages was most commonly identified as should be 3000m (70%) (compared to 800m, 1600m and >3000m). Noise is identified as the most common concern associated with wind turbines, at ~36%. No respondents had a negative opinion on wind turbines. Wind energy was rated higher than nuclear or oil/coal as an energy source (80% said it should be a high share of the energy production in Crete, ~15% said it should a medium share and ~5% said it should be a low share, where ~10% ranked oil/coal as a high share and 5% ranked nuclear as a high share.	Sample Size: 100 survey respondents Comparison Group: None Data Collection/Recruitment: response rates not provided, sampling method not well described but appears to be selected, not random Control of Confounders: Not well described as sampling method unclear.

Citation	Exposure of Interest	Exposure Measurement	Health Outcomes	Other Outcomes	Outcome Measurement	Results	Validity
(14) Mroczek B, Kurpas D, Karakiewicz B. Influence of distances between places of residence and wind farms on the quality of life in nearby areas. Annals of Agricultural and Environmental Medicine;19(4):692-696.(2012).	Distance from wind turbines: *Distance 1:below 700 m, *Distance 2: 700-1000 m, *Distance 3: 1000-1500 m, *Distance 4: more than 1500 m, *Distance 5: knows nothing about the plans of wind farm construction	?self-reported vs measured distance from wind turbines	Self-reported health via the survey tools	N/A	Standardised surveys (SF-36 and VAS) for health assessment which use Likert scales, and original questions.	Regardless of the distance between a place of residence and a wind farm, the highest quality of life was noted within the physical functioning subscale (mean 76±27.97), and the lowest within the general health (mean 55.28±24.06), the other quality of life indicators were role-physical (mean 59.83 ±39.29), bodily pain (mean 63.66 ± 32.22), vitality (mean 58.23 ± 24.14), social functioning (mean 58.74 ± 36.30), role-functioning emotional (mean 62.73 ± 40.36), and mental health (mean 60.13 ± 23.05).The obtained results suggest a high internal consistency of the 5 scales: PF, RP, BP and RE (Cronbach's alpha coefficient from 0.82-0.94, depending on the scale), and slightly lower consistency of the other scales, but in no case was alpha coefficient is lower than 0.70. Within all scales, the quality of life was assessed highest by residents of areas located closest to wind farms, and the lowest by those living more than 1,500 m from wind farms.	Sample Size: 1,277 Polish adults (703 women and 574 men), living in places located near wind farms. Comparison Group: None Data Collection/Recruitment: Response rates not given Control of Confounders: The authors used regression analysis to estimate the parameters of a model describing the QoL perception, with reference to socio-demographic and health variables within particular subscales. Certain factors may have impacted the reported QoL indicators, but statistically significant ones had limited influence.

Citation	Exposure of Interest	Exposure Measurement	Health Outcomes	Other Outcomes	Outcome Measurement	Results	Validity
(15) Mulvaney KK, Woodson P, Prokopy LS. A tale of three counties: Understanding wind development in the rural Midwestern United States. Energy Policy;56:322-330.(2013)	Acceptance of local wind farm development	Mixed methods	N/A	Attitudes towards wind farm development	Quantitative data from survey responses and qualitative data from open-ended interviews. The authors used a questionnaire that could be mailed in or answered online that had close-ended and open-ended questions.	Seventy-five percent of respondents believe that wind energy development is a smart investment for the state of Indiana and 59% of respondents supported the development of a state renewable energy policy. When asked if they supported wind turbines within their county, 88% of respondents agreed or strongly agreed. Support was highest in Tippecanoe County (91%) and lowest in Boone County (84%). In this study, among the respondents in the three counties, age, gender, income, education and other factors are not able to predict who will support wind energy. The support of those who could/would hear the turbines is lower (77%) than of those who could/would not hear the turbines where the level of support was 92%. Rural residents who moved to the country to escape development want to protect the landscape and do not necessarily support wind farms. Residents were not concerned with visual or noise impact of turbines. Residents were not concerned with health effects from turbines. Generally welcomed turbines for direct or indirect financial gain. Major concerns were related to workers, farmers receiving more financial benefit and energy bills not decreasing. Media was not representative of the views of the community (more negative).	Sample Size: ~345 Comparison Group: No Data Collection/Recruitment: Stratified sampling/Randomly selected (depending on county, as authors wanted rural representation in stratified areas). The overall response rate was over 40% (46% Benton, 41% Boone, 41% Tippecanoe) Control of Confounders: N/A

Citation	Exposure of Interest	Exposure Measurement	Health Outcomes	Other Outcomes	Outcome Measurement	Results	Validity
(16) Mulvaney KK, Woodson P, Prokopy LS. Different shades of green: a case study of support for wind farms in the rural midwest. Environ Manage May;51(5):1012-1024.(2013)	Social acceptance of wind turbines	Survey responses and interviews with key informants	N/A	Key informant interviews revealed that local government was supportive of wind turbine development. The planning process was transparent.	Survey responses, interview responses	More than half (56 %) of respondents believed that it was necessary to have a renewable energy standard for the state of Indiana (at the time of study, there was no renewable energy standard for Indiana) and 76 % of respondents think that wind energy is a smart investment for Indiana. Although our results show that significantly fewer residents would place a turbine on their property than declare that they are supportive of wind farms in their community (P\0.001, df = 1, n = 313), this research finds that Benton County has high community acceptance of wind farms, with 89 % of survey respondents supporting wind turbines in their community completely or with some reservations. The high community acceptance of wind turbines could be related to the financial benefits to the wind turbines. In Benton County, 86 % of respondents could see at least one wind turbine from their home, yet there was no difference in support between those who could see the turbines and those who could not (P = 0.859, df = 1, n = 334). Transparency and participation was not crucial for the acceptance by the population. 6% believe wind turbines harm human health. 36% of respondents believe that wind turbines detract from the visual environment. 7% were bothered by wind turbine noise. Most respondents (84 %) believed that the energy produced on the wind farms in Benton County should be used within Indiana.	Sample Size: 7345 (not stated directly, but 46% of 750 samples) Comparison Group: None Data Collection/Recruitment: Surveys were sent to 750 people with a response rate of 46% Control of Confounders: N/A

Citation	Exposure of Interest	Exposure Measurement	Health Outcomes	Other Outcomes	Outcome Measurement	Results	Validity
(17) Tampakis S, Santopoulos G, Arabatzis G, Rerras I. Citizens' views on various forms of energy and their contribution to the environment. Renewable and Sustainable Energy Reviews;20:473-482. (2013)	Attitudes regarding renewable energy and for wind turbines specifically.	Closed ended/open ended Questionnaire responses	N/A	Attitudes towards wind turbine installation	Survey responses: Questions range from 4-5 point Likert scales to multiple choice questions with space for "other" open field responses.	Solar energy most favoured, then wind energy. Generally favourable to renewable energy (including wind turbines). Citizens' views about the installation of wind turbines at various parts of the island: for "in the North of the island" 35.7% fully agree, 48.0% agree, 10.7% disagree and 5.6% totally disagree; for "at a point that will be visually perceptible from their home" 18.2% fully agree, 49.1% agree, 21.1% disagree and 11.6% totally disagree; for "offshore" 29.4% fully agree, 38.0% agree, 23.0% disagree and 11.6% totally disagree. There is broader acceptance for the inland installation of new wind parks, and in particular in the northern part of the island, where a wind park has been installed since 1992.	Sample Size: Targeted at 385 respondents, unclear if sample size is 385 Comparison Group: None Data Collection/Recruitment: random sampling--no discussion of response rate, the authors mention that they would try to make three attempts to do face-to-face interviews Control of Confounders: Not discussed

Citation	Exposure of Interest	Exposure Measurement	Health Outcomes	Other Outcomes	Outcome Measurement	Results	Validity
(18) Taylor J, Eastwick C, Lawrence C, Wilson R. Noise levels and noise perception from small and micro wind turbines. Renewable Energy 55 120-127. (2013)	Wind turbine noise from small and micro size wind turbines (measured at representative sites for each wind turbine and modeled by software to create a representative sound map).	Direct and modeled measurement of wind turbine noise. Sound maps were generated using an existing model to assess sound levels. Participants were divided into three separate sound categories	The survey data recorded about personality and mental health ratings (Frustration Discomfort Scale, Frustration Sensitivity subscale of the Situational Triggers of Aggressive Responses (STAR) scale, Neuroticism scale, Positive and Negative Affectivity Scale (PANAS)) and physical health was measured using a ten symptom question 5 point scale. Non-specific somatic symptoms (12 common symptoms including headache and fatigue)	Perceived wind turbine noise. Participants rated using a seven point Likert scale, attitude to wind power in general (1 =very positive, 7=very negative). Participants were asked if there was a wind turbine on their residence or if they could see one from their residence. For noise intrusion, participants were asked to identify how often (occurrence) they heard 10 types of sounds.	Self-reported surveys for health measures and attitudes.	Respondents generally reported a positive attitude to wind turbines. The most commonly occurring and loudest sounds from all the turbine types are 'humming', 'swooshing', 'whistling' and 'low frequency'. Attitude to wind power significantly predicted noise perception with more negative attitudes predicting increased perceived noise. Perceived noise significantly predicted symptom reporting, with those reporting higher noise levels from the wind turbine reporting more symptoms. The results show that if a respondent can see a small wind turbine installation from their dwelling they report higher and more frequent noise levels from that turbine. Perception of noise was linked to symptom reporting ($p<0.05$), but not actual sound levels. Personality characteristics were linked to symptom reporting, neuroticism ($p<0.05$), discomfort intolerance ($p<0.05$) Emotional intolerance modified the relationships between perception of noise and symptom reporting ($p<0.05$).	Sample Size: 138 households living 500 m to one of 12 micro or small wind turbine installations Comparison Group: Yes Data Collection/Recruitment: All households (number contacted = 1327) were sent a survey by postal mail. 138 completed returns with a response rate of 10.86%. Control of Confounders: Yes
(19) Maffei L, Iachini T, Masullo M, Aletta F, Sorrentino F, Senese VP, et al. The effects of vision-related aspects on noise perception of wind turbines in quiet areas. Int J Environ Res Public Health Apr 26;10(5):1681-1697 (2013).	Perception of wind turbines	Simulated by researchers according to the number of turbines, distance from the turbines and the color of the turbines using immersive virtual reality.	n/a	Annoyance, stress	A questionnaire on their perception of the image on a continuous scale from 0-100.	Distance from turbines had the largest impact on determining annoyance and stress. The number of turbines was significant with more turbines perceived as more annoying, but the effect was not large. White and green turbines were considered more visually appealing than red and brown.	Sample Size: 46 Comparison Group: no Data Collection/Recruitment: n/a Control of confounders: no

Citation	Exposure of Interest	Exposure Measurement	Health Outcomes	Other Outcomes	Outcome Measurement	Results	Validity
(20) Van Renterghem T, Bockstael A, De Weirt V, Botteldooren D. Annoyance, detection and recognition of wind turbine noise. Sci Total Environ Jul 1;456-457:333-345. (2013)	Exposure to controlled amounts of wind turbine noise compared to road traffic noise (highway or local roads).	Annoyance level (Self-reported on 0-10 scale) Ability to detect wind turbine noise in samples.	N/A	Annoyance	Self-rated annoyance level (0-10). Ability to identify sample containing wind turbine noise out of pairs of noise.	Wind turbine noise, with or without highway noise, did not increase the average noise annoyance rating for participants. Different multiple comparison tests (Tukey-Kramer, Bonferonni) show no differences between wind turbine noise alone and highway noise alone at the 1%-significance level. Combinations at different signal-to-noise ratios for these types of sounds have a similar noise annoyance rating. In general, the participants do not rate (pure) wind turbine noise as more annoying than e.g. highway noise at the same (low) equivalent noise level. Local road traffic noise, combined with wind turbine noise, was significantly more annoying. Annoyance ratings relative to wind turbine noise (set to 1), where highway noise was mean 2, highway + wind turbine (0dbA or -10dBA) was mean 2, and local road and wind turbine (0 or -10 dBA) was mean 4. Noise from a single wind turbine, in highway noise, can be detected once it is known at a detection limit as low as ~23 dBA. Participants that easily recognized wind-turbine (-like) sounds could detect wind turbine noise better when submersed in road traffic noise. Recognition of wind turbine sounds is also linked to higher annoyance.	Sample Size: 50 individuals Comparison Group: None Data Collection/Recruitment No discussion of incomplete results. Recruiting methods not described Control of Confounders. participants were blinded to the purpose of the study and the visual aspects of the room were controlled not to suggest wind turbines.

Citation	Exposure of Interest	Exposure Measurement	Health Outcomes	Other Outcomes	Outcome Measurement	Results	Validity
(21) Whitfield Aslund ML, Ollson CA, Knopper LD. Projected contributions of future wind farm development to community noise and annoyance levels in Ontario, Canada. Energy Policy;62:44-50. (2013)	Modelled wind turbine sound levels	Modelled from noise assessment reports	n/a	annoyance (estimated)	Estimated based on previous studies in the Netherlands.	Predicted wind farm related noise levels were compiled for 8123 individual receptor locations. Overall, a distinct exponentially decreasing relationship was observed between distance to the nearest noise source and sound pressure level predicted (y=44.4e−0.00022x, r^2=0.86, p<0.0001). Predicted sound pressure levels at a set distance varied by approximately 5–10dB(A) and the distance at which a set sound pressure level was met varied by approximately 1000m. Even in the categories expected to experience the highest noise exposure (i.e. less than 1km to nearest noise source), over 60% of receptors were predicted to be 'not annoyed' and an additional 18–19% were predicted to be 'slightly annoyed' even when outdoors, while the remaining 17–18% were predicted to be 'rather' or 'very' annoyed when outdoors. In terms of the rates of community annoyance from wind farm related noise in Ontario in the future "for non-participating receptors it was predicted that the rates of noise-related annoyance (when indoors) would not exceed 8%, with further reductions in the rates of annoyance at increased distances (i.e., 41 km)."	Modelled Exposure Study

Citation	Exposure of Interest	Exposure Measurement	Health Outcomes	Other Outcomes	Outcome Measurement	Results	Validity
[22] Seong Y, Lee S, Young Gwak D, Cho Y, Hong J, Lee S. An experimental study on annoyance scale for assessment of wind turbine noise. Journal of Renewable and Sustainable Energy;5(5) (2013)	Different modelled wind turbine noises	Rating of each exposure using a 7 point scale ranging from highly annoyed to not noticing the exposure	N/A	Each respondent evaluated their subjective annoyance for different wind turbine noises	7 point scale for subjective annoyance	Annoyance was increased with LAFMax, implying that the maximum noise level increases annoyances. The authors state that "since the experiment was a subjective evaluation of wind turbine noise and the results of annoyance response were represented as average values, within-subject design in analysis of variance was conducted to find out whether there were any significant differences among values. As a result, except for a few pairs, p-values were less than 0.05 indicating a confidence level higher than 95% at most of pairs." However, the data and its calculations are not presented in this paper	Sample Size: 32 people Comparison Group: N/A Data Collection/Recruitment: Recruitment poorly described, the data was collected using a questionnaire--no mention of incomplete questionnaires. Control of Confounders: Controlled for hearing loss.

Citation	Exposure of Interest	Exposure Measurement	Health Outcomes	Other Outcomes	Outcome Measurement	Results	Validity
(23) Crichton F, Dodd G, Schmid G, Gamble G, Cundy T, Petrie KJ. The Power of Positive and Negative Expectations to Influence Reported Symptoms and Mood During Exposure to Wind Farm Sound. Health Psychology (2013).	Infrasound exposure	Presence or absence of infrasound in controlled experimental setting.	Physical symptoms specified to be typical of infrasound exposure: headache, ear pressure, ringing in the ears, itchy skin, sinus pressure or irritation, dizziness, pressure in the chest, vibrations within the body, racing heart, nausea, tiredness, feeling faint; and physical symptoms specified to be less typical of infrasound exposure: stomach ache, aching legs, aching arms, sore joints, stiff muscles, back pain, numbness or tingling in the body, difficulty swallowing, sore jaw, chills, hot flushes, hand tremble or shake. Blood pressure and heart rate were monitored during the experiment	Participants rated concern about health effects of wind turbines at baseline and after screening of the video presentation.	Physical symptoms were evaluated by self-report before and during each 10-min exposure session. Participants rated their current experience of symptoms on a 7-point Likert scale ranging from 0 (not at all) to 6 (extreme). Ratings were given in relation to 12 symptoms specified to be typical symptoms of infrasound exposure and in relation to 12 symptoms identified as less typical symptoms of infrasound exposure	The high-expectancy group ($M = 72.78$, $SD = 18.99$) was shown to be significantly more concerned than the low-expectancy group ($M = 38.00$, $SD = 20.01$) about the health effects of sound generated by wind turbines, following the expectancy manipulation, $F(1, 51) = 48.93$, $p < .001$, n2p = .49, controlling for baseline scores (high expectancy: $M = 44.49$, $SD = 23.78$; low expectancy: $M = 36.89$, $SD = 22.85$). Analysis confirmed a main effect of expectancy group on both symptom change scores, $F(1, 52) = 8.05$, $p < .01$, $r = .37$, and symptom intensity change scores, $F(1, 52) = 8.04$, $p < .01$, $r = .37$. There were no interaction effects between group and either symptom change scores or symptom intensity change scores during exposure periods. The effect of expectancy group on change scores did not differ whether exposure was to sham or to infrasound. Low-expectancy participants did not report any significant change from pre-exposure in either the number or intensity of symptoms experienced during sham or infrasound exposure. In the high-expectancy group, both the number of symptoms, $F(2.1, 53.55) = 7.57$, $p < .001$, N2p = .23, and symptom intensity score, $F(2.1, 54.52) = 8.66$, $p < .001$, np2 = .25, increased during exposure. There was a significant increase from pre-exposure assessment in the number of symptoms reported during exposure to infrasound, $F(1, 26) = 8.16$, $p < .01$, $r = .49$, and during exposure to sham, $F(1, 26) = 12.16$, $p < .01$, $r = .66$, as well as in symptom intensity reported during exposure to infrasound, $F(1, 26) = 7.55$, $p < .05$, r | .47, and during sham exposure, $F(1, 26) = 12.88$, $p < .001$, $r = .58$. Importantly, elevated symptom reporting seen in the high expectancy group was the same during sham and infrasound exposure, confirming that	Sample Size: 54 Comparison Group: Yes Data Collection/Recruitment: Not described, but experiment involved university students Control of Confounders: Yes

Citation	Exposure of Interest	Exposure Measurement	Health Outcomes	Other Outcomes	Outcome Measurement	Results	Validity
(24) McCallum LC, Aslund ML, Knopper LD, Ferguson GM, Ollson CA. Measuring electromagnetic fields (EMF) around wind turbines in Canada: Is there a human health concern? Acta Vet Scand 2014:9.(2014)	EMF levels	Magnetic field measurements	n/a	n/a	n/a	Background levels of EMF (0.2 to 0.3 mG) were found under the 'shut off' scenario. Magnetic field levels detected at the base of the turbines under both the 'high wind' and 'low wind' conditions were low (mean = 0.9 mG; n = 11) and diminished with distance, becoming indistinguishable from background within 2 m of the base. Magnetic fields measured 1 m above buried collector lines were also within background (≤ 0.3 mG). Beneath overhead 27.5 kV and 500 kV transmission lines, magnetic field levels of up to 16.5 and 46 mG, respectively, were recorded. These levels diminished with distance. None of these sources appeared to influence magnetic field levels at nearby homes located as close as just over 500 m from turbines, where measurements immediately outside of the homes were ≤ 0.4 mG.	Exposure study

Citation	Exposure of Interest	Exposure Measurement	Health Outcomes	Other Outcomes	Outcome Measurement	Results	Validity
(25) Anderson C. The networked minority: How a small group prevailed in a local windfarm conflict. Energy Policy;58:97-108. (2013).	Opposition of wind farms	Semi-structured interviews	N/A	Acceptance of wind development	Individual interviews with community members	The social capital characteristics of bonding, bridging, linking and network brokerage, identified through the framework, explain how the windfarm was resisted. The developers attempted to include the community in the planning process by holding a town hall meeting, but did not answer any of the concerns raised. The community became divided over he proposed wind farm. The developers eventually decided to stop the project, but many of the community members originally opposed to the idea regretted standing against the project for a variety of reasons. This indicates they could have supported the project had the developers addressed their concerns initially.	Sample Size: 11 Comparison Group: No Data Collection/Recruitment: Identified different opinion groups Control of Confounders: N/A
(26) Arüa-Montobbio P, Farrell KN. Wind farm siting and protected areas in catalonia: Planning alternatives or reproducing 'one-dimensional thinking'? Sustainability;4(12):3180-3205 (2012)	Influences on attitudes towards wind farm siting policies	Interviews with discourse analysis	N/A	An analysis of the siting phases for wind turbines in Catalonia, Spain	N/A	Wind turbine siting is a 'wicked problem' according to discourse analysis. The authors looks at four different discourse storylines Building a sustainable industry"; "100% renewables now"; "Protecting the landscape", and "Protecting biodiversity". They argue that considering the place of the value-based propositions in discourses concerning wicked problems could help promote democratic and environmental conservation approaches to siting wind turbines	Sample Size: 68 interviews Comparison Group: N/A Data Collection/Recruitment The recruitment of informants was not described and the semi-structured interview was not discussed in detail Control of Confounders: No

Citation	Exposure of Interest	Exposure Measurement	Health Outcomes	Other Outcomes	Outcome Measurement	Results	Validity
(27) Deignan B, Harvey E, Hoffman-Goetz L. Fright factors about wind turbines and health in Ontario newspapers before and after the Green Energy Act. Health, Risk and Society (2013).	Content analysis of newspaper articles with wind turbines	Content analysis for fright factors in articles about wind turbines--One author coded all of the articles. To ensure reliability of data extraction, a randomly selected subset of 100 articles was coded by two independent readers, and interrater reliability was calculated. Descriptive statistics (frequencies, means and percentages) were developed.	N/A	N/a	N/A	In the national/provincial newspapers for full years of coverage, the number of articles were 13 in 2008, 32 in 2009 and 40 in 2010 ($X2 = 22.8$, $df = 2$, $p < 0.001$). Also of note is that for the 4 months of data collection in 2011 (January--April), there were 34 articles on wind turbines and health appearing in the national/provincial newspapers. In the local newspapers, the number of articles on wind turbines and health also increased: 15 in 2008, 90 in 2009 and 107 in 2010 ($X2 = 67.83$; $df = 2$; $p < 0.001$). For the 4-month period of January--April 2011, there were 45 articles on wind turbines and health in the local newspapers. The increase in newspaper articles over time was greater in community newspapers compared to national/ provincial newspapers ($X2 = 9.63$, $df = 4$, $p < 0.05$). There were differences in news coverage based on wind energy development size. The small wind energy developments included in this study, Dunnville and Proof Line, accounted for 15% (n = 42) of the community newspaper coverage collected on wind turbines and health. The large wind energy developments, in contrast, contributed 85% (n = 229) of the community newspaper coverage on wind turbines and health. The most commonly reported fright factors were 'dread', 'poorly understood by science', 'involuntary exposure' and 'inequitable distribution' occurring in 94% (n = 394), 58% (n = 242), 45% (n = 188) and 42% (n = 177) of articles, respectively. The other five fright factors occurred less frequently in the newspaper articles: 'identifiable victims' in 19% of articles (n = 80), 'inescapable' in 15% of articles (n = 64), 'contradictory statements from reliable sources' in 9% of articles (n = 39), 'damage to future generations' in 6% of [illegible]	Sample Size: 421 articles from 13 community and 4 national/provincial newspapers. Comparison Group: None Data Collection/Recruitment: Identification of local and national newspapers and scanning for articles with coding by one author with validation with other 2 individuals for 100 articles. Control of Confounders: Analysis of the differences between local and national newspapers.

Citation	Exposure of Interest	Exposure Measurement	Health Outcomes	Other Outcomes	Outcome Measurement	Results	Validity
(28) Groth TM, Vogt CA. Rural wind farm development: Social, environmental and economic features important to local residents. Renewable Energy;63:1-8. (2014)	Beliefs about wind farm development	A survey with 21 items. The survey was organized into the following four sections: primary residence, perceptions of wind turbines and wind energy, level of support for wind energy and general demographics.	n/a	n/a	n/a	The hypothesis that economic beliefs were the driving force of perception and support was not supported by the data. Social beliefs were the strongest predictor of support for wind development. Overall, social and economic belief factors in the form of concerns were found to be more influential than environmental belief factors in determining support for wind farm development within a specific township, while social and environmental belief factors were found to be more influential than economic factors in supporting wind farm development within the county. Positive and negative social belief factors are associated with wind farm development both within the respondent's immediate township and within the county at large. The difference in wind farm belief factors identified in two localities (within the respondents 9.6 km by 9.6 km [6 mile by 6 mile] township or within the entire county) indicates that NIMBYism may have an influence on residents' perceptions. Turbine placement close to residents may heighten their uncertainty and concern of the wind turbines and overshadow any positive inclinations towards the development	Sample Size: 497 surveys and 11 interviews Comparison Group: Yes Data Collection/Recruitment: A total of 497 useable surveys were returned for a response rate of 50%. Control of Confounders: The communities were matched in terms of characteristics.

Citation	Exposure of Interest	Exposure Measurement	Health Outcomes	Other Outcomes	Outcome Measurement	Results	Validity
(29) Hall N, Ashworth P, Devine-Wright P. Societal acceptance of wind farms: Analysis of four common themes across Australian case studies. Energy Policy;58:200-208. (2013)	Social acceptance of wind turbines	N/A	N/A	N/A	N/A	Despite the diversity of stakeholder views, the qualitative analysis identified strong community support for wind farms but four common themes emerged that influence this societal acceptance of wind farms in Australia: trust, distributional justice, procedural justice and place attachment.	Sample Size: 27 interviews Comparison Group: None Data Collection/Recruitment: Purposive sampling was used to identify informants for the interviews Control of Confounders: No
(30) Richards G, Belcher K, Noble B. Informational barriers to effective policy-public communication A case study of wind energy planning in Saskatchewan, Canada Canadian Public Policy;39(3):431-450. (2013)	informational barriers to public participation in policy	document review	n/a	barriers to public participation in policy	Analysis of policy documents	A document review showed four types of barriers to effective policy-public communication in the case study: non-intuitive information, misreported information, obsolete information, and absent information.	Sample Size: N/A Comparison Group: No Data Collection/Recruitment: N/A. Control of Confounders No

Many of the studies described above, particularly the cross-sectional surveys and qualitative studies, examined factors specific to the community of interest. Their findings may not be generalizable to other communities that have had different experiences with wind turbine development projects. A study in Greece, for example, had overwhelmingly positive attitudes towards wind energy,(13) a social factor that may be different in other regions. The generalizability of findings from experimental or exposure studies would likely be better, but cultural factors again may play into the perceptions of wind turbines.(19) Understanding the specific qualitative aspects of opposition towards wind energy development projects may require location-specific analysis. While findings from qualitative studies may be generalizable to communities that have similar characteristics and experiences with wind turbine projects, their applicability to communities with divergent demographic characteristics or policies in place for community participation or economic benefit from wind turbine development may be limited. Similarities may be greater between the English-speaking countries like Australia, Canada, the United Kingdom and the United States.

A number of the studies that met the inclusion criteria examined the social, political and economic factors that relate to community concerns about the health risks of wind turbines. Many more studies were found in the literature review that focused on the planning and policy aspects of siting wind turbines but did not meet the inclusion criteria, as they did not discuss health or annoyance concerns. Ontario was the setting for several of the research studies. The article by Baxter et al. looked at factors for community support or opposition for wind turbines in rural Ontario communities and found that the key predictors for wind turbine support were health risk perception, community benefits, general community enhancement, and a preference for turbine-generated electricity.(10) Deignan et al. looked at media stories in Ontario that discussed wind turbine developments in terms of the presence of 'fright factors', and found that the most commonly reported fright factors were 'dread', 'poorly understood by science', 'involuntary exposure' and 'inequitable distribution' occurring in 94% (n = 394), 58% (n = 242), 45% (n = 188) and 42% (n = 177) of articles, respectively. The fright factors were found more frequently in community newspapers than in national or provincial ones.(27) Other locations were discussed by researchers in a number of studies. Groth et al. looked at communities in rural Michigan to see how beliefs about wind turbine development affect support for this type of energy development, and they found that social beliefs were the strongest predictor of support for wind farm development.(28) Mulvaney et al. published two studies that looked at social acceptance of wind turbine development in rural Indiana, and found that support for wind turbine development in their county is lower (77%) for respondents that would hear the wind turbines compared to respondents that would not hear the turbines (92%), although the differences were not statistically significant.(15) In one of their papers, most residents were not concerned with health effects from turbines.(15) For one county, the primary factors in support for wind turbines were financial benefits. In the other paper, the authors found that "Most residents are not concerned with either visual impacts or noise from the wind turbines. "(16) Hall et al. looked at social acceptance of wind turbines in rural Australia and identified four common themes that influence the support of wind turbines: trust, distributional justice, procedural justice and place attachment.(29) Anderson examined factors that led to opposition to a wind turbine development in rural Australia and found that the social capital characteristics of bonding, bridging, linking and network brokerage were important in explaining how the wind turbine development was resisted in the community.(25) Richards et al. looked at informational barriers to public participation in policy formation and identified four types of barriers to effective policy-public communication: non-intuitive information, misreported information, obsolete information, and absent information.(30) A Spanish study by Ariza-Montobbio and Farrell used qualitative research to understand how discourse affected attitudes towards wind farm siting in Catalonia and identified four different discourse storylines that were important for forming attitudes: "Building a sustainable industry"; "100% renewables now!"; "Protecting the landscape"; and "Protecting biodiversity". (26) Understanding the social, political and economic factors that are influencing attitudes towards wind turbine development may be important for examining the reporting of adverse health effects from wind turbines, as attitudes towards wind turbines may impact annoyance from wind turbine noise. Annoyance may also be related to personal characteristics such as personality, subjective noise sensitivity and expectations of harm from exposure to wind turbines.

The cross-sectional surveys described were primarily focused on attitudes towards wind turbine projects. While self-reported adverse health outcomes were considered in a few of the surveys, none used external measurements of health outcomes. Taylor et al. looked at the perception of wind turbine noise and how it affected symptom reporting. They found that perceived noise significantly predicted symptom reporting, with those reporting higher noise levels from the wind turbine reporting more symptoms. However, while perception of noise was linked to symptom reporting ($p<0.05$), it was not linked to actual sound levels. Personality characteristics were also linked to symptom reporting in this study. (18) Mroczek et al. relied on self-reported health scores (SF-36 and VAS) to examine whether living at a certain distance from wind turbines impacted the quality of life of respondents. They conclude that "Quality of life was best assessed within all subscales by the respondents living the closest to wind farms, while the worst by those living farther than 1,500 m from a wind farm, and those who did not know about the plans of for the construction of a wind farm in their neighbourhood." They suggest that more research were needed to see whether people that lived further from wind turbines differed by some factor than those that lived closer to wind turbines.(14)

Chapman et al. examined the number of complaints about wind farm operations in Australia over time to see whether increased community awareness about possible health effects from wind turbines affected the rate of complaints.(12) The authors found that "18/34 (52.9%) of larger wind farms, and 15/17 (88.2%) of small farms have never experienced complaints." They also argue that "our hypothesis that the number of complainants living near those wind farms with any history of complaints would be a small proportion of the exposed population, was strongly confirmed" given the small number of complainants relative to the exposed populations near wind turbines. With respect to the frequency with which residents complain of adverse effects from wind turbines, the authors state "Of the 51 wind farms, 33 (64.7%) have seen no complaints; 6 (11.8%) saw complaints commence at times ranging from 2 months to 13.5 years after turbine operation; and 12 (23.5%) saw either on-going complaints continue from before the wind farms commenced operation or within the first month." The authors examine when the majority of complaints were made and found that the majority occurred after 2009—which is when anti-wind farm groups began warning the public about adverse health effects from wind turbines. The authors state "Sixty nine percent of wind farms began operating prior to 2009 while the majority of complaints (90%) were recorded after this date." The authors conclude that their findings are consistent the idea that reported symptoms from wind turbine exposure are "communicated diseases" with possible nocebo-related etiologies. (12)

Environmental factors can also affect the quality and characteristics of wind turbine noise and annoyance. Bockstael et al. conducted a study to look at how annoyance from wind turbines is related to operational, meteorological and noise data.(11) They found that wind direction and angular blade velocity were related to "high annoyance" and that "Wind turbine specific emission and fluctuation clearly increase the risk of high annoyance, whereas higher background noise slightly lowers it." The authors caution that "the established regression model is unable to pronounce upon possible causal relationships between annoyance, background level and fluctuation and even the strength of the parameters' individual influence has to be interpreted with caution since the two noise measures are correlated and possibly coding for underlying factors." Their study had a small sample size and low response rate, which affects its validity.

There have been a number of published experimental studies that have assessed aspects of wind turbines and their associated noise in relation to health and annoyance. Maffei et al. used an immersive virtual reality methodology in their study to examine how visual factors affect perception of wind turbine noise.(19) They found that the visual distance from wind turbines was the most influential factor on noise annoyance. The participants in the study also reported that having a larger number of wind turbines in the visual field increased noise annoyance, and the colour of the wind turbine did not affect annoyance when using ANOVA to assess its impact.

Seong et al. conducted an experimental study to examine what aspects of wind turbine noise (LAeq, loudness, fluctuation strength and LAFmax) were associated with increased annoyance using modelled wind turbine noise in an anechoic room).(22) They found that "the maximum sound pressure level with fast time A-weighting (LAFmax) explains well the annoyance characteristics compared to the other descriptors." Limiting the LAFmax could help reduce the annoyance associated with wind turbine noise.

The experimental study by Van Renterghem et al. to assess the annoyance, recognition and detection of wind turbine noise found that noticing wind turbine noise is moderately correlated with annoyance.(20) They state "A statistically significant ($p = 0.01$) but moderate ($R = 0.36$) correlation could be found between the success rate in detecting the samples containing wind turbine noise in the focused test, and annoyance by the pure wind turbine sample in the non-focused test." Wind turbine noise "from a single wind turbine, submersed in highway noise, can easily be detected once it is known and the detection limit is as low as −23 dBA. " The authors argue that there was an absence of masking or synergistic effects between wind turbine noise and road traffic noise. The authors assert that their research supports "the hypothesis that there is a personal factor that can influence the ability of people to detect and recognize wind turbine noise" and that while "the relationship between recognizing sounds and annoyance is strong, the relationship between being able to detect wind turbine sound and recognizing more sounds is weak and the relationship between being able to detect wind turbine sound and annoyance is practically non-existing, the existence of an underlying factor that affects both annoyance and recognizing sound sources is very likely." The authors state that their experiment "supports the hypothesis that previous observations, reporting that retrospective annoyance for wind turbine noise is higher than that for highway noise at the same equivalent noise level, is grounded in higher level appraisal, emotional, and/or cognitive processes." (20)

To understand how expectations can affect perceived symptoms from exposure to wind turbine infrasound, Crichton et al. used a "sham-controlled double-blind provocation study", where the subjects were exposed to 10 minutes of infrasound as well as 10 minutes of sham infrasound. The study subjects were randomized to high- or low-expectancy groups where they were presented material that would attempt to induce high- or low- expectations that exposure to wind turbine infrasound would result in physiological effects. (23) The researchers found that "low-expectancy participants did not report any significant change from preexposure in either the number or intensity of symptoms experienced during sham or infrasound exposure. However, in the high-expectancy group, both the number of symptoms...and symptom intensity score... increased during exposure." Additionally, the authors state "Importantly, elevated symptom reporting seen in the high-expectancy group was the same during sham and infrasound exposure, confirming that infrasound exposure itself did not contribute to the symptomatic experience. No direct physiological effect of genuine infrasound exposure on heart rate or blood pressure was indicated." The findings from this study support that expectations about physiological impacts from exposure to wind turbine infrasound can influence the reporting of symptoms during an exposure, irrespective of whether the exposure was genuine or sham. This study indicates that providing individuals with information about possible physiological effects from wind turbine infrasound can affect the likelihood symptoms will be reported. The authors conclude "If symptom expectations are at the heart of symptom expression, current proposals to address health concerns, such as increasing minimum set back distances for wind turbines from residences, may do little to alleviate health complaints and related opposition to wind farm development."

EXPOSURE STUDIES:

McCallum et al. published a study on the measurement of EMF levels at locations near wind turbines, including near buried collector lines and overhead collector and transmission lines.(24) They looked at EMF levels under three scenarios: "'high wind' (generating power), 'low wind' (drawing power from the grid, but not generating power) and 'shut off' (neither drawing, nor generating power)." They undertook measurements for 15 wind turbines, including one that was non-operational as a control and three that were excluded from analysis due to external EMF interference. The researchers determined the background EMF levels (0.2 to 0.3 mG) at each location using measurements from the 'shut off' scenario. They measured EMF levels at the same locations under the two other scenarios. They found that EMF levels "at the base of the turbines under both the 'high wind' and 'low wind' conditions were low (mean = 0.9 mG; n = 11) and rapidly diminished quickly with distance, becoming indistinguishable from background within 2 m of the base. Magnetic fields measured 1 m above buried collector lines were also within background (≤ 0.3 mG). Beneath overhead 27.5 kV and 500 kV transmission lines, magnetic field levels of up to 16.5 and 46 mG, respectively, were recorded. These levels also diminished rapidly with distance. None of these sources appeared to influence magnetic field levels at nearby homes located as close as just over 500 m from turbines, where measurements immediately outside of the homes were ≤ 0.4 mG." The authors conclude that "Collectively, these results suggest that the EMF surrounding wind turbines and their distribution systems (i.e., 27.5 and 500 kV power lines) are similar or lower than those commonly found throughout Ontario and across Canada. There was nothing unique about the EMF readings surrounding the wind turbines. Furthermore, the magnetic fields associated with power distribution systems, including those found in the vicinity of wind farms, are below levels that are expected to cause harm to human health based on international regulatory guidelines. Overall, our results do not support a potential causal link between power-frequency EMF and human health impacts at the low levels measured in the vicinity of the wind turbines." (24)

Whitfield Aslund et al. modelled wind turbine noise for Ontario wind power developments based on noise assessment reports to create predicted wind farm related noise levels, to which they then applied categories of noise levels results that were used by previous research studies on wind turbine noise and annoyance.(21) The authors then estimated annoyance levels based on the categorization of the modelled wind turbine noise to estimate wind turbine related annoyance levels for the wind power developments in Ontario. They compared 'participating receptor' locations (who are property owners that have entered into formal agreements with the wind power developers) to non-participating receptor locations and found the predicted noise levels were generally higher for the participating receptor locations. They found that "None of the non-participating receptors had predicted sound pressure levels that exceeded the minimum Ontario noise guideline for wind turbines of 40 dB(A)". The authors argue that based on their results of the modelling of wind turbine noise "The proportions of receptors predicted to be 'rather' or 'very' annoyed (when indoors) due to wind turbine and related noise, which range between 1.2 and 7.3% depending on distance to the nearest noise source, compare favorably with, or indeed are lower than, rates of noise-related annoyance reported for other more common noise sources such as traffic noise." They conclude that in terms of the rates of community annoyance from wind farm related noise in Ontario in the future "for non-participating receptors it was predicted that the rates of noise-related annoyance (when indoors) would not exceed 8%, with further reductions in the rates of annoyance at increased distances (i.e., >1 km)." They argue that "the current noise restrictions in Ontario that determine the siting of wind turbines and associated transformer substations are likely sufficient to limit community exposure to wind turbine related noise in such a way that levels of annoyance will not exceed those commonly experienced for non-wind turbine related noise source." (21)

REVIEWS:

Roberts and Roberts' review entitled "Wind turbines: Is there a Human Health Risk?" provided the historical context of wind turbines and their emergence as a form of power generation.(4) They discuss sound and human perception, as well as wind turbine noise. They undertook a literature review on PubMed to find 28 articles that were relevant to assessing the possible health effects of wind turbines. They describe the evidence surrounding the health effects of low frequency sound, and the relationship between wind turbine noise, annoyance and adverse health effects. They describe the limitations of current evidence for the health effects of wind turbines and argue for the need of objective measurements and blinding of participants to strengthen future studies in this area. They conclude that while the evidence is limited, "research has demonstrated that [low frequency sound] can elicit adverse physical health effects, such as vibration or fatigue, as well as an annoyance or unpleasantness response."(4) They assert that "the association and particular pathway between [low frequency sound] specifically generated from wind turbines, annoyance, and adverse physical health effects have yet to be fully characterized." They argue that more research is needed to determine the level of risk. They also discuss the role of risk perception in the experience of adverse health effects and state that "effective risk communication" is needed in communities with perceived risk from wind turbines. (4)

Tabassum-Abbasi et al. evaluate the environmental impact of wind turbines in their review, where part of their article covers wind turbine noise and its possible human health effects.(31) The authors discuss the possible mechanical sources for wind turbine noise, the quality of the noise produced and how the noise can be masked. The evidence regarding annoyance and human health effects stemming from wind turbine noise is briefly reviewed. The article focuses on the environmental impacts of wind turbines, wherein human health effects are a minor component of the review. The methodology of this review is not described.

Doolan undertook a literature review to "review studies that have previously examined human perception and annoyance by wind turbines and studies that report wind turbine low frequency noise emission."(32) While the methodology of the literature review was not described, Doolan describes the current state of the evidence about wind turbine noise and its potential impact on human health, as well as how low frequency noise can cause annoyance in general. He discusses evidence that social factors can mediate annoyance from wind turbines in his review. His review concludes that "Previous studies have shown that some people who live near wind farms are annoyed by them and the degree of annoyance is related to the level of the noise exposure. It was also found that many other factors, such as visual intrusion and psychological reaction have a significant influence on a person's response to wind turbines and perhaps noise...Infrasound from wind turbines has been measured and was shown by many that infrasound levels at typical residential set-back distances are most likely too low to be audible;

however, there is a possibility of annoyance due to window rattle caused by infrasound, yet this needs further study."(32) He discusses the need for further research to understand the relationship between aspects of wind turbine use and their potential to cause annoyance.

Farboud et al. published a review in The Journal of Laryngology & Otology which "addresses the effects of infrasound and low frequency noise and questions the existence of 'wind turbine syndrome'."(33) They used a search strategy to examine published articles from the previous ten years which included the terms 'wind turbine', 'infrasound' or 'low frequency noise'. They discuss infrasound and low frequency noise in general, and wind turbine noise specifically. The authors describe some of the complexities with measuring infrasound and low frequency noise and what its potential health effects could be. Annoyance is described, and the possibility that individuals may have variable sensitivity to infrasound and low frequency noise is discussed. The limitations of available evidence (being anecdotal and lacking understanding of the effects of long-term exposure) are discussed, and the authors conclude that "there is an increasing body of evidence suggesting that infrasound and low frequency noise have physiological effects on the ear. Until these effects are fully understood, it is impossible to state conclusively that exposure to wind turbine noise does not cause any of the symptoms described. The effects of infrasound and low frequency noise require further investigation." (33)

Kurpas et al.'s review article "Health impact of wind farms" has the objective to be a "critical review of available reports providing arguments both for and against the construction of wind farms."(34) The authors use Web of Knowledge and Google to find "available studies published in peer-reviewed journals, which had to comply with the principles of scientific research." They discuss the environmental impact of wind turbines on pollution, wind turbine noise, infrasound and low-frequency noise, light and shadow flicker caused by turbine rotors, electromagnetic radiation and impact on operation of telecommunication systems, 'wind turbine syndrome,' and visual impact, attitudes to wind turbines and other subjective factors. They are critical of the current state of evidence, and suggest stronger research is needed. They also recommend public announcements and consultations prior to developing wind turbines in a community. They conclude that "to date, direct correlations between the vicinity of modern wind farms, the noise (audible, low frequency noise, or infrasound) that they produce, and possible consequences to health have not been described in peer reviewed articles. Infrasounds are not generated exclusively by wind turbines, nor are health effects reported by people from wind farm areas exclusive to residents of these areas. Provided that visual aspects of wind turbines and attitudes towards them are stronger contributors to the state of annoyance than the noise itself, it can be assumed that the health effects reported by residents of wind farm areas are more likely to be a physical manifestation of annoyance than the effects of infrasound."(34)

Jeffery et al. published a review entitled "Industrial wind turbines and adverse health effects" in the Canadian Journal of Rural Medicine that echoed much of their previous commentary article in the journal Canadian Family Physician.(35,36) The authors discuss the case series presented by Nina Pierpoint in her self-published book and have the objective to "consider the hypothesis of Colby and colleagues that the health effects from [industrial wind turbines] are the result of annoyance from the noise of audible [industrial wind turbines]."(35) They describe their methods and included peer-reviewed articles as well as relevant grey literature sources. They use the argument from Michaud and colleagues that through the WHO definition of health "noise-induced annoyance is an adverse health effect." The authors state that "Systematic audits of reviews reveal that some works contain errors of omission or commission. One recurring error of omission is the failure to disclose that [industrial wind turbine] noise acting via the indirect pathway can cause health effects."(35) The authors discuss potential mechanisms for wind turbines causing adverse health effects, including "noise, visual impacts, stray voltage and socio-economic impacts" and state "Electromagnetic waves in the form of poor power quality and ground current can adversely affect people who are electrically hypersensitive",(35) although no references to these mechanisms are given. The authors conclude that "some people exposed to IWTs experience negative effects to their physical, mental and social well-being. There is sufficient evidence to support the hypothesis of Colby and colleagues that documented symptoms can result from annoyance to audible [industrial wind turbines]."(35) They argue that the setback distances and allowable noise limits for wind turbines may need to be developed based on "established noise management techniques" to prevent adverse health effects from wind turbines. (35)

The review article by James entitled "Wind Turbine Infra and Low-Frequency Sound: Warning Signs That Were Not Heard" describes "the historical evidence about what was known regarding infra and low-frequency sound from wind turbines and other noise sources during the period from the 1970s through the end of the 1990s."(37) The author mentions that he contacted several acoustic experts during the research process for the article, but the methodology of the article is not well described. He explores the evidence about adverse health effects from low-frequency sound and infrasound, including describing what is known about noise-related sick building syndrome. He critiques the use of A-weighted sound to measure wind turbine acoustical data as well as the models used to predict wind turbine noise. The author argues that "had past experience and information, which was available prior to the widespread implementation of the modern upwind industrial-scale wind turbine, been incorporated into the government and industry guidelines and regulations used to siting wind turbine utilities, many of the complaints and AHEs currently reported would have been avoided."(37)

Fortin et al. at the National Collaborating Centre for Environmental Health developed an evidence review entitled "Wind turbines and health" which updated the previous 2010 review and discusses the potential health issues associated with wind turbines including "Noise and Low Frequency Sound," "Electromagnetic Fields," "Shadow Flicker," and "Ice Throw and Structural Failure."(1)

GREY LITERATURE:

The South Australia Environmental Protection Agency produced a report in 2013 entitled "Infrasound levels near wind farms and in other environments" that "presents the findings of a study into the level of infrasound within typical environments in South Australia, with a particular focus on comparing wind farm environments to urban and rural environments away from wind farms."(38) The study took measurements at a small number of sites in urban and rural environments, both indoors and outdoors, including two residences that were approximately 1500m from wind turbines. The study found that "Infrasound levels at houses adjacent to wind farms... are no higher than those at houses located a considerable distance from wind farms... Organised shutdowns of the wind farms adjacent to [two sites near wind farms] indicate that there did not appear to be any noticeable contribution from the wind farm to the G-weighted infrasound level measured at either house. This suggests that wind turbines are not a significant source of infrasound at houses located approximately 1.5 kilometres away from wind farm sites."(38) Based on their findings, the authors conclude "that the level of infrasound at houses near the wind turbines assessed is no greater than that experienced in other urban and rural environments, and is also significantly below the human perception threshold." While the sample size is small for this study, it does provide evidence supporting that infrasound levels are not elevated at sites close to wind turbines. (38)

A report prepared for the Scottish government by von Hünerbein et al. is a "rapid, desk based analysis of peer reviewed UK and international literature from the last four years on the effects of wind turbines on human health."(39) They looked at peer-reviewed articles and specific other sources by request. They found that "All studies present evidence for annoyance due to wind turbine noise and most concur that there is evidence for sleep disturbance in the presence of wind farms but not necessarily from noise... Other health effects are increasingly reported in the presence of wind turbines but the reviewed literature does not provide firm scientific evidence of a causal relationship with wind turbines or even more specifically wind turbine noise. The most widely quoted cross-sectional studies show correlations between annoyance and visual impact, economic benefit and attitude related to wind turbines. Wind turbine sound is reported to be comparatively weakly related to annoyance and inseparable from the other contributing factors." The authors were critical of the three papers by Salt et al., writing that "these three documents propose that low frequency and infra-sound (LFIS), and specifically LFIS generated by WTs, may differentially stimulate structures in the human inner ear, and may instigate health effects even when inaudible. The authors seek to build a case for what appears to be a prior assumption utilising reflections from laboratory experimental data gleaned from another species (guinea pig), some observations on human experiences with specific pathological conditions (endolymphatic hydrops and superior semi-circular cabal syndrome), conjecture, and speculation." In terms of mitigating wind turbine noise, the authors write that "a more effective means of managing wind turbine noise impacts is to set noise level limits at the noise sensitive receptors likely to be significantly affected, and require these to be met by planning conditions."(39)

Other than the previously described peer-reviewed article, Chapman has published several pieces online about the health effects associated with wind turbines. In "Factoid Forensics: Have "more than 40" Australian families abandoned their homes because of wind farm noise?" he assess the claim that "more than 40 families" have abandoned their homes in Australia due to wind turbine noise.(40) From analysing multiple sources of information, Chapman found approximately "12 Australian households permanently (n=10) or periodically (n=2) leaving their homes were found. However, no house appears to have been permanently "abandoned" without sale, as the expression implies." He argues that the number quoted by anti-wind farm organizations in Australia does not have a factual basis. In "How the factoid of wind turbines causing 'vibroacoustic disease" came to be "irrefutably demonstrated"", Chapman also assessed the evidence behind the claim that wind turbines cause vibroacoustic disease.(41) He argues that vibroacoustic disease lacks scientific recognition and that "There is no evidence of even rudimentary quality that vibroacoustic disease is associated with or caused by wind turbines."

OTHER PEER REVIEWED PUBLICATIONS:

James Lane's MSc thesis at the University of Waterloo titled "Association Between Industrial Wind Turbine Noise and Sleep Quality in a Comparison Sample of Rural Ontarians" examined whether "the presence of a grid connected WT is a risk factor for poor sleep quality and if wind turbine noise is associated with sleep parameters" by using sleep diaries and "actigraphy-derived measures of sleep quality" for 12 individuals from a community with wind turbines and 10 comparison individuals from a community without wind turbines.(42) He found that "Although numerous actigraphy sleep parameters were poorer in the exposed group, including lower average sleep efficiency (89% vs. 92%), longer sleep onset latency (6 min vs. 4 min), and longer wake after sleep onset (42 min vs. 29 min), the differences were not statistically significant" as well as that "No significant differences in sleep parameters derived from the sleep diaries were found between the groups". This was a pilot study with a small sample size which could inform future research endeavours. Lane argues that "to confidently estimate noise exposure, WT noise measurement requires a combination of indoor and outdoor sound pressure level, along with wind speeds and direction". (42)

An in depth news article in Environmental Health Perspectives by Seltenrich describes community concerns about wind turbines in Falmouth, Massachusetts.(43) The article examines the background information about the relationship between noise and human health, as well as the controversy about whether or not wind turbines are associated with adverse human health effects. The author contrasts the position that wind turbines are harmless against the view that they have numerous adverse health effects through the perspective of whether or not direct or indirect health effects are considered. The author describes aspects of wind turbine noise and why they may cause wind turbine noise to be annoying to susceptible individuals in a rural context. The role of expectations and the nocebo effect in the etiology of adverse health effects are discussed. The author comments that the existing evidence is limited in its ability to ascertain causality as most of the studies were cross-sectional surveys.

Moynihan describes in her brief article the possible worker health and safety issues associated with working on wind energy. She describes the reported potential hazards as "Falls from as high as 500 feet, severe burns from fires, electrical shock, crush injuries, and oil, lubricant, or dust exposure." She discusses needed aspects for prevention of accidents, including "adequate training and protective measures". (2)

Discussion

The issue of wind turbines potentially causing adverse human health effects is complex and controversial. Much of the current evidence shows that wind turbines have the potential to cause annoyance and possible sleep disruption to those that live in their immediate vicinity. The current minimum setback distance for wind turbines is 550m in Ontario, and studies have looked at the impact on residents at varying distances from wind turbines. For example, Nissenbaum et al. found that individuals living within 1.4km of an industrial wind turbine "had worse sleep, were sleepier during the day, and had worse SF36 Mental Component Scores compared to those living further than 1.4 km away." (44)Exposure to wind turbines, and specifically wind turbine noise or disruption to the visual landscape, has been associated with increased annoyance among individuals. As Knopper and Ollson write, "Studies on the health effects of wind turbines, both published and peer-reviewed and presented in the popular literature, tend to conclude that wind turbines can cause annoyance for some people." (3)

Annoyance is not itself a direct health effect. Some have argued that definition of health by the World Health Organization could be extended to include annoyance. Others have argued that annoyance may result in indirect health effects,(35) possibly mediated by the stress response. The research covered in this literature review does not provide evidence that wind turbines have direct effects on human health. It does support that wind turbines can cause annoyance whether through noise or other factors, detract from the visual aesthetic of the landscape for certain individuals, and may disrupt sleep. Personality factors, such as negative-oriented personality traits, may play a role in being annoyed or reporting symptoms from wind turbine noise exposure.(45) Adverse physiological effects from exposure to wind turbine infrasound may be mediated by expectations as Crichton et al. describe.(23) Visual factors, such as the distance from wind turbines and the number of visible wind turbines, may affect annoyance from wind turbine noise. Attitudes towards wind turbines may influence whether an individual will find wind turbine noise annoying. Some of the recent research has looked at what factors influence attitudes towards wind turbines. The role of financial benefit, communications from the media or community organizations about possible adverse health effects from wind turbines, as well as the political, social and economic factors in specific communities have been considered in their contribution to forming positive or negative attitudes towards wind turbine developments. While some of the recent research has examined what specific features of wind turbine noise are most annoying to individuals, as well as environmental factors that can influence the annoying characteristics of wind turbine noise, given that attitude towards wind turbines and expectations of adverse health effects from wind turbine noise can substantially impact whether or not an individual is annoyed or experiencing symptoms from wind turbine exposure, focusing on the technical aspects of wind turbine noise may not reduce the rates of annoyance from wind turbines as much as addressing the underlying aesthetic, social, economic and political issues that contribute to negative attitudes towards wind turbines.

Many of the more recent articles found by this literature review have extended into the social aspects of wind turbine development. While the findings of these qualitative or cross-sectional studies may be specific to the community of interest, they provide insights into the social, economic and political aspects of opposition to wind turbine developments that may underlie negative or positive attitudes towards wind turbine development that may be linked to reports of effects on health.

Most studies to date are cross-sectional surveys with few objective measurements of health effects. Unlike the literature on air pollution and health outcomes or chemical carcinogens, well designed case-control or cohort studies are conspicuously absent. The experimental studies that have been published are informative with respect to the stimulus presented but do not replicate exposures as they occur in the community. Recently published evidence does not indicate that wind turbines result in EMF levels significantly different from the background levels.(24) Adverse effects of low frequency noise and infrasound from wind turbines have not been demonstrated although studies of chronic exposure to low frequency noise or infrasound are lacking. Infrasound exposure to the general population occurs from sources of natural and human origin.(46) Technical challenges in measuring infrasound or low frequency noise make it unlikely that definitive studies on the presence or absence of health effects will be conducted in the near future.

Conclusions

Over 20 papers meeting inclusion criteria were published in the time period covered by this review. Although many papers provide insights into the reasons behind opposition to wind energy developments, none of the papers reviewed provided evidence of a direct link between exposure to noise from wind turbines and adverse health effects. Proximity to wind turbines and associated sound levels has been linked to annoyance and reports of sleep disturbance. Annoyance is influenced by numerous individual and community characteristics, including personality, expectations, financial benefit, social and political factors. Successful efforts to address the annoyance associated with wind turbine development will likely require an integrated approach that considers the contribution of all these factors.

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APPENDIX A: ORIGINAL SEARCH TERMS

health OR disease OR illness OR anxiety OR attention OR "aural pain" OR earache OR "ear ache" OR headache OR "head ache" OR migraine OR balance OR cardiovascular OR heart OR cognition OR cognitive OR concentrat* OR depressi* OR disturbance OR dizziness OR "hearing loss" OR "hearing disorder" OR "sensitivity to low-frequency noise" OR hypertension OR impairment OR impaired OR "mental health" OR nausea OR "neuroaccoustic disease "OR "neuroacoustic disease" OR "neuro acoustic disease" OR panic OR respiratory OR sleep OR somatosensory OR vertigo OR vestibular activation OR "vestibular annoyance" OR "vestibular system" OR "vestibular disease" OR "vestibule ocular reflex" OR "vibroacoustic disease" OR "vibroacoustic syndrome"

annoyance OR effect OR exposure OR impact OR "acoustic stimulation" OR "auditory stimulation" OR "seismic sensitivity" OR "public health "

traffic OR airplane OR aircraft OR airport OR "substrate-borne vibration" OR vibration OR "20-200Hz" OR "200Hz" OR "200 Hz"

"low frequency noise" OR "noise pollution" OR "turbine noise" OR "transportation noise" OR "white noise" OR "amplitude modulation of aerodynamic noise" OR "sound pressure level" OR "auditory threshold" OR "loudness perception" OR "hearing threshold"

"wind turbine" OR "wind farm" OR "wind mill" OR "wind park" OR windfarm OR windmill OR "wind energy" OR "wind electricity" OR "wind power" OR "ambient noise" OR "audible noise" OR "background noise" OR "environmental noise" OR "inaudible noise"

"wind turbine" OR "wind farm" OR "wind mill" OR "wind park" OR windfarm OR windmill OR "wind energy" OR "wind electricity" OR "wind power" OR "ambient noise" OR "audible noise" OR "background noise" OR "environmental noise" OR "inaudible noise"

"traffic noise" OR "airplane noise" OR "aircraft noise" OR "airport noise" OR "substrate-borne vibration" OR vibration OR "20-200Hz" OR "200Hz" OR "200 Hz"

"low frequency noise" OR "noise pollution" OR "turbine noise" OR "transportation noise" OR "white noise" OR "amplitude modulation of aerodynamic noise" OR "sound pressure level" OR "auditory threshold" OR "loudness perception" OR "hearing threshold"

Appendix B
Database: Ovid MEDLINE, Embase, BIOSIS
Search strategy:

#	Searches	Results
1	(wind turbine or wind power or wind farm? or wind farm?).mp.	1166