Report on Wind Turbines

Report to the Town of Enfield Town Board

Enfield Wind Farm Advisory Committee
4-12-2016

Contents

About this report

In response to the controversy surrounding the proposed Black Oak Wind Farm, the Town of Enfield created the Wind Farm Advisory Committee to:

"to advise the Town Board and other Town agencies on matters pertaining to the siting and placement of wind turbines in the Town, any potential recommended updates or amendments to the existing local law, and to strengthen and improve public understanding of wind turbines generally, including matters as pertain to public health and safety. Thus, the Committee is charged with gathering factual information regarding wind turbine health and safety issues and making this information available to the Town Board after deliberation and considered recommendations thereupon. Towards this end, the Committee should review, recommend, and prioritize strategies as they relate to Town policies and local laws for wind turbines, and to further become informed about wind farming in the Town and generally, including both their positive and negative potential impacts."

The committee was formed in January, 2016 with a balance of members supporting Black Oak Wind Farm and wind energy technology as well as those that have raised concerns about its negative effects. The committee began meeting weekly to research and discuss the science of wind turbines. In a short time, it has sought technical advice from industry, science, and technical experts. Although, the committee could spend many more months of research, the report here is the result of information it has learned so far. Not all members are in agreement this is represented by a couple different sections on wind turbine noise and its effects.

Committee Members:

Mike Carpenter
Charlie Elrod
Martha Fischer
Marcus Gingerich
Jude Lemke
Mimi Mehaffey
Michael Miles, chair
Julie Schroeder
Rob Tesori

Former Members:

Marguerite Wells
Peter Bardaglio

Clerk:

Sue Thompson

Report on Wind Turbines and Noise

Introduction

The links and publications to be found when one searches "wind turbine noise health" number in the hundreds of thousands. Peer-reviewed publications investigate wind turbine noise in Australia, Canada, the United States, and in European countries. Some conclude that noise from wind turbines may have negative effects on human health, while others conclude that it has no effect on human health. Popular literature makes claims ranging from horrible outcomes of living next to turbines to people having no problem whatsoever. Coming to any one conclusion is next to impossible, and making recommendations is challenging. In this report we outline the complicated phenomenon that is noise, list the health concerns, and try to spell out whether or not those concerns are caused by noise from wind turbines.

What is Noise and how is it measured?

Measuring noise is extremely complex. While one can measure a sound, factors such as atmospheric conditions (air temperature, moisture, wind speed and direction, etc.), the contour of landscape, propagation of sound, and the instrumentation used in acoustic studies play into the accuracy of the measurement. This subcommittee is far from competent to explain the nuances in measuring sound and in interpreting reports of sound measurement.

That said, we will do our best to explain the parts that we do understand. A couple of references stand out as aids to our understanding: Gracey & Associates Acoustic Glossary[1] and Acoustics and Vibration Terminology Glossary, Definitions and Abbreviations.[2]

Noise is basically undesirable sound. Sound originating from wind turbines exists as audible and inaudible to the human ear. Analysis of sound shows that it consists of frequencies (or pitches) measured in hertz (Hz) at varying levels of loudness (or pressure levels) measured in decibels (dB). Sound with frequencies 0 – 20Hz are known as infrasound, and are inaudible to most people. Very low frequency sound is generally between 20 to 200Hz. Humans hear best at frequencies between 300 to 16,000Hz.

Human perception of loudness is influenced by the frequency of sound. With regard to infrasound generated by wind turbines, 'loudness' should be thought of in terms of strength. Acousticians measure the strength of sound with a sound pressure level meter. Most acoustic studies measure the strength of audible sound (which the term 'loudness' can easily describe). These studies de-emphasize frequencies below and above the threshold of human hearing are written as dBA. Note that the measurements reported in the Black Oak Wind Farm Acoustic Study are A-weighted. The strength of infrasound is difficult to measure.

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[1] http://www.acoustic-glossary.co.uk/

[2] http://infrastructure.planninginspectorate.gov.uk/wp-content/ipc/uploads/projects/TR030001/2.%20Post-Submission/Application%20Documents/Environmental%20Statement/File%208-12/File%2012%20-%20Vol%201%20Annexes/16%20-%20Annex/16.1%20-%20Acoustics%20Vibration%20Glossary.pdf

Complaints

Wind Turbine Syndrome

Many objections about wind farms center around noise and infrasound. Nina Pierpont coined the term Wind Turbine Syndrome (WTS) and wrote the book (published in 2009)[3] to describe a suite of symptoms in 38 individuals from 10 families. The symptoms include "disturbed sleep, headaches, tinnitus, a sense of vibration, nervousness, rapid heartbeat, nausea, difficulty with concentration, memory loss, irratibility and anger." The common thread among people with these symptoms is that they live within a mile and a quarter of wind turbines. Physically moving away from wind turbines has been the most effective antidote to the symptoms. As soon as the presence of a wind turbine is removed, people experience relief from their symptoms.[4]

Vibroacoustic Disease

Vibroacoustic Disease (VAD) is less widely known except in aviation and military circles and journals such as those of the Aerospace Medical Association, It is "a consequence of long-term (years) exposure to low frequency noise." A thorough description of the disease at the following website includes stages and symptoms of the disease. (noiseoff.org/document/vibroacoustic .disease.1.pdf) While WTS symptoms disappear after a person moves away from a turbine, VAD symptoms persist. VAD "causes direct tissue or organ damage," as written at the website https://windwisema.org/about/noise/wind-turbine-syndrome-and-vibroacoustic-disease/

What peer-reviewed literature says

Measuring infrasound and low frequency sound is a topic of much discussion among acousticians. Many agree that acoustic measurements of sounds lower than 200Hz should not be taken with A-weighted filtering mechanisms. Studies of infrasound pressure levels are more accurately measured with G-weighted filtering. Jacobsen in 2001 published recommendations on noise limits for infrasound, writing that the limit for environmental infrasound must be a sound pressure level of 85dBG.[5]

Using the G-weighting function, comparison of measurements taken at homes adjacent to wind farms before and during a planned shutdown of the 2.1MW turbines showed no noticeable difference in sound level. During low wind periods, 40dBG was measured at locations close to and far from a turbine;

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[3] Pierpont, Nina. Wind Turbine Syndrome: A Report on a Natural Experiment. K-Selected Books. Santa Fe, NM. 2009.

[4] https://windwisema.org/about/noise/wind-turbine-syndrome-and-vibroacoustic-disease/

[5] Jakobsen, Jorgen. 2001. Danish guidelines on environmental low-frequency noise, infrasound, and vibration. Journal of Low Frequency noise, Vibration, and Active Control. pp 141-148. http://docs.wind-watch.org/jakobsen-2001_danish-guidelines.pdf

during higher wind periods, levels as high as 70dBG were found at locations at wind farm sites and non-wind farm sites.[6]

Peer-reviewed journal articles were inconclusive when reporting results of studies on the adverse effects of wind turbines on human health. Schmidt and Klokker 2014[7], performed a systematic review of the literature up to the end of 2013 "with the purpose of identifying any reported associations between wind turbine noise exposure and suspected health related effects. They searched for literature from peer-reviewed scientific sources (such as PubMed, Web of Science, and Google Scholar) as well as from internet sources which were not peer-review (such as wind-watch.org, windturbinesyndrome.com, and waubrafoundation.org.au). The researchers describe their method for narrowing the plethora of search results (over 1,000 articles) down to 252 studies. They concluded that noise from wind turbines annoys some people who live near them and may disturb some people's sleep. They caution that annoyance and disturbed sleep findings may be influenced by selection and information bias. The authors state:

> "Larger cross-sectional surveys have so far been unable to document a relationship between various symptoms such as tinnitus, hearing loss, vertigo, headache and exposure to wind turbine noise. One limitation causing this could be that most studies so far have only measured L_{Aeq}* or L_{den}**. An additional focus on the measurement of low-frequency sound exposure as well as a more thorough characterization of the amplitude modulated sound and the relationship between objective and subjective health parameters could lead to different conclusions in the future. Finally, in regards to the objective measurement of health-related disorders in relation to wind turbine noise, it would be valuable to demonstrate if such health-related outcomes fluctuate depending on exposure to wind turbine noise."
>
> [[Definitions from www.acoustic-glossary.co.uk/definitions-l.htm:
>
> * LAeq is A-weighted sound measured over a period of time
>
> ** Lden is A-weighted sound measured over the 24 hour period with a 10dB penalty added to the levels between the hours of 11:00pm and 7:00am and a 5dB penalty added to the levels between 7:00pm and 11:00pm to reflect people's sextra sensitivity to noise during night and evening.]]

Other reviews of literature echo the findings of Schmidt and Klokker. The Wisconsin State Legislature asked the Public Service Commission staff to update the review done in 2014 by Wisconsin's Wind Siting

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[6] Evans, T., Cooper, J., and Lenchine, V. 2013. Infrasound levels near windfarms and in other environments. Study undertaken for the Environment Protection Authority, Adelaide, South Australia. www.epa.sa.gov.au/files/477912_infrasound.pdf

[7] Schmidt JH, Klokker M (2014) Health Effects Related to Wind Turbine Noise Exposure: A Systematic Review. PLoS ONE 9(12): e114183. doi:10.1371/journal.pone.0114183 http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0114183

Council.[8] Among other articles, it lists the Health Canada Study (http://www.hc-sc.gc.ca/ewh-semt/noise-bruit/turbine-eoliennes/summary-resume-eng.php). The Wisconsin paper also referenced a publication titled "Evaluation of community response to wind turbine related noise in Western New York State" (http://www.noiseandhealth.org/article.asp?issn=1463-1741;year=2014;volume=16;issue=71;spage=228;epage=239;aulast=Magari).

With regard to sleep disturbance attributed to noise from wind turbines, Michaud et al, 2016[9], performed subjective and objective measures of sleep with 1,238 people randomly selected from residences between .25 and 11.22 kilometers from working wind turbines. The authors could find no pattern or correlation with wind turbine noise levels. They found that sleep quality was influence by factors such as caffeine intake, other health effects (such as disease and sleep disorders), and annoyance with blinking lights on the turbines.

Conclusions and Recommendations

It appears that illness caused by noise from wind turbines is a phenomenon not proven by science at this point in time. What has been revealed clearly is that noise from turbines annoys some people. Annoyance is no trivial matter, and if enough people complain about noise from the wind farm, action should be taken with the cooperation of the town, residents, and company to investigate the origin of the noise, the intensity of the noise, and possible ways of mitigation. Resolution on the best mitigation measures should be reached and then implemented.

In the future, monitoring should follow the protocols set out in Results of an Acoustic Testing Program: Cape Bridgewater Wind Farm (The Acoustic Group Report 44.5100.R7:MSC 26th November, 2014), especially with respect to land/home owner involvement in planning and implementation. http://www.pacifichydro.com.au/files/2015/01/Cape-Bridgewater-Acoustic-Report.pdf

Any acoustic studies should be undertaken with instruments that are properly calibrated and suitable for measurements across humanly audible and inaudible (within reason) frequencies and pressure levels.

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[8] Staff of Public Service Commission. 2015. Review of Studies and Literature Relating to Wind Turbines and Human Health. https://psc.wi.gov/reports/documents/2015WindReport.pdf

[9] Michaud DS, Feder K, Keith SE, Voicescu SA, Marro L, Than J, Guay M, Denning A, Murray BJ, Weiss SK, Villeneuve PJ, van den Berg F, Bower T. Effects of wind turbine noise on self-reported and objective measures of sleep. *SLEEP* 2016;39(1):97–109. http://www.ncbi.nlm.nih.gov/pubmed/26518593

Wind Turbine Noise

Summary

The complexities related to wind turbine noise are well summed up by a quote from the Frey, Hadden report of 2012[10],

> "Wind turbine noise is especially complicated because of the 'cocktail' of physical acoustic characters that comprise the noise pollution. The pulsating noise, characteristic of wind turbines, can be more intrusive than other types of noise and the pulsations include both audible and inaudible components, i.e., low frequency noise, infrasound, and vibration. Noise with these characteristics is more intrusive, and the World Health Organization (WHO) guidelines recommend lowering the permissible decibel levels when noise contains these characteristics. WHO makes these recommendations not merely to reduce annoyance or nuisance. WHO makes these recommendations because epidemiological studies indicate clearly that environmental noise is prejudicial and injurious to health."

While there is yet no scientific consensus as to the effects of wind turbine noise on people, *the precautionary principle should be followed until definitive scientific studies can be conducted to address the questions surrounding the health risks related to wind turbine noise. If there is no clear scientific consensus regarding safety, the town must err on the side of caution and have strict sound limits and significant setbacks to protect residents.*

Based on the research of papers, reports and communications, the following conclusions and recommendations were made:

Conclusions

1. The greater the distance which wind turbines are set back from residences the less likely there is to be adverse affects for the residents.
2. Audible noise 200-20kHz is more easily monitored and controlled than lower frequencies.
3. The lower the frequency of the noise, the farther the sound will carry before being dissipated.
4. Any health risks of infrasound (sound below 20Hz in frequency) and low frequency noise (sound from approximately 20-200Hz) are generally dismissed by the wind industry as insignificant; thus, they are generally not regulated or monitored.[11]
5. Wind turbines emit infrasound, and the larger the turbine, the slower the rotation, the lower the infrasound frequency; thus, the farther the propagation.

Mitigations

1. One method of mitigation is to establish an absolute setback distance such that the risks to residents are well within an acceptable range. This method is the simplest; however, if properly implemented, this method is likely to result in the greatest setback as no consideration would be given to wind turbine size and/or design. Also, since the configuration of multiple turbines can

10 http://waubrafoundation.org.au/wp-content/uploads/2014/06/Frey-Hadden-Wind-Turbines-Proximity-to-Homes.pdf

11 https://docs.wind-watch.org/Infrasound-wind-turbines-4-August-2015.pdf

have a significant effect on sound attenuation,[12] the setback must be large enough to provide protection against multiple wind turbines operating simultaneously. Based on the available studies, the only safe limit seems to be that greater than about 1mi. (~1.5km)[13] minimizes the risk of adverse reactions. Distances less than that seem to have some increased risk of adverse reaction, but this depends upon many factors which are not yet fully understood.

2. A second possible method of mitigation is to establish a setback based upon the size of the wind turbine such as the rotor diameter and/or total height or some combination of both. This has the effect of allowing for different size turbines; thus, smaller turbines would require less separation from residents.
3. A third method of mitigation is to establish a setback based on predicted noise levels which the wind developer must guarantee will be met or mitigation must be implemented such that the noise levels are met. This method must include both criterion for audible or A-weighted noise levels, LFN and IS noise. There seems to be a tolerable level of audible sound around L_{Aeq} of 35dB,[14] this would be most important during the nighttime. Somewhat louder appears to be acceptable during daytime, for example 40 dBA, or some limit, such as 3-5dBA above ambient.
   A method for addressing acute noise annoyance was proposed by Kelley, et al., based on the SERI/NASA/DOE studies in the 80's.[15] Another paper developed a method of calculating a safe setback distance for a single wind turbine based on thresholds for annoyance and physiological effects threshold for different turbines and frequencies.[16] However, additional consideration would need to be given to multiple turbines and/or arrays of wind turbines and the 'Heightened Noise Zones' produced by the interacting noise fields. The calculations also require accurate data on the noise spectrum produced by the wind turbine(s).

Introduction

In general, environmental noise is known to cause health problems. The question is, what levels and characteristics of noise are responsible for those adverse effects?

Wind turbines produce significant amounts of noise throughout the audible noise spectrum as well as down into the LFN range and IS range. Wind turbine noise was first studied here in the U.S. back in the late 1970s and early 1980s under a joint project between the Department of Energy (DOE), the National Aeronautics and Space Administration (NASA), and the National Renewable Energy Laboratory (NREL) which was known at that time as the Solar Energy Research Institute (SERI). The MOD-1 turbine, a downwind design, unexpectedly caused what was termed 'annoyance' among residents as far away as ~2km. A subsequent study of the MOD-2 turbine, a downwind design more comparable to wind turbines of present day, indicated that model produced less infrasound and was not expected to produce adverse effects beyond 1km.[17]

No comparable and comprehensive studies of more modern wind turbines have been found; thus, no assessments or comparisons can be made. More recent studies of wind turbines have focused on the effects on people (and animals) living in the vicinity of industrial wind turbine installations.

12 http://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/19910007366.pdf
13 https://www.nhmrc.gov.au/_files_nhmrc/publications/attachments/eh57a_information_paper.pdf
14 Schmidt, et al., http://www.ncbi.nlm.nih.gov/pmc/articles/PMC4256253/pdf/pone.0114183.pdf
15 Kelley, et. Al, http://www.nrel.gov/docs/legosti/old/3261.pdf
16 Thorne, et. al, https://www.acoustics.asn.au/conference_proceedings/INTERNOISE2014/papers/p599.pdf#page=1&zoom=auto,-12,843
17 Kelley, et. al., http://www.nrel.gov/docs/legosti/old/3036.pdf

Though not confirmed via scientific rigor, many health issues have been attributed to living near wind turbines including: tinnitus, hearing loss, vertigo, headaches, and nausea to name a few. More generally accepted effects include noise annoyance and sleep disturbance. One very significant confounding factor is the variability between individuals and the specific susceptibility of each to the different effects. A few of the notable reports of findings and effects on animals and human health are presented in the following sections.

Animal studies

There is not a large body of data available in the peer-reviewed literature on the effect of wind turbines on animals; however, there are a small number of peer-reviewed studies. Most studies are not controlled studies, rather they are specific case-studies. A couple of examples are:

1. One controlled study was conducted on the reaction of two groups of domestic geese raised at two distances from a wind turbine, one group was 50m from the WT and the second group was 500m from the WT. The study found that the closer group experienced less weight gain and an increased concentration of cortisol in blood which is a stress indicator.[18]
2. One case study, while not definitive, seemed to point toward wind turbines causing equine flexural limb deformities (as well as human health problems).[19]
3. The Army performed low frequency vibration studies on chick embryos and found serious development problems and death of the developing chick embryos. Developing chick embryos are considered a model for human embryonic development.[20]

Human studies

There are many studies involving human health, but these are primarily based on surveys of individuals living in the vicinity of industrial wind turbines. While some short term laboratory studies have been conducted on the effect of infrasound humans, these definitely do not address the reported long-term effects. There are also numerous anecdotal reports of the adverse effects attributed to wind turbine noise and LF or IS noise, in particular. These are often not accepted as valid, thus some of the more generally accepted findings and rigorous studies are described below.

1. The effect of low frequency noise (LFN) and infrasound (IS) on human physiology is a subject of some debate, but there is evidence that humans are affected and can sense sounds much lower in frequency and at much lower amplitudes that previously thought. Recent studies have demonstrated that this is true using EEG,[21] fMRI and MEG[22] to monitor brain activity. Salt, et al., showed that there is a plausible pathway for infrasound to be perceived by the inner ear.[23]
2. By directly quantifying the inner ear sensitivity to LFN through measurement of spontaneous otoacoustic emissions, another study demonstrated the potential for hearing damage as there is a significant discrepancy between perception and the risk potential of LFN.[24]
3. The annoyance of infrasound to receptors (residents) at distances as high as 2km has been noted as early is the late '70s or early '80s by a joint SERI/DOE/NASA study.[25]

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18 http://www.ncbi.nlm.nih.gov/pubmed/24597302
19 http://doc.wind-watch.org/Castelo-Branco-follow-up-WT-near-home.pdf
20 http://www.usaarl.army.mil/techreports/95-1.pdf
21 http://psjd.icm.edu.pl/psjd/element/bwmeta1.element.bwnjournal-article-appv125n4a04kz
22 http://waubrafoundation.org.au/wp-content/uploads/2015/07/Bauer-et-al.-Investigation-of-Perception-at-Infrasound-Frequencies-by-MRI-and-MEG.pdf
23 http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2923251/
24 http://rsos.royalsocietypublishing.org/content/1/2/140166
25 http://www.nrel.gov/docs/legosti/old/1166.pdf

4. A recent Australian study did not establish a scientific link between wind turbine noise and health based on the body of direct evidence which was reported as being small and of poor quality. The study also indicated that, based upon parallel evidence, beyond about 1.5km any effects should be minimal except in the area of annoyance.[26]
5. One seemingly safe assessment of the literature is that greater setback distances from residences will decrease the likelihood of adverse effects such as annoyance, sleep disturbance or other health issues including tinnitus, hearing loss, vertigo or headache. While many completely disregard all effects except noise annoyance and sleep disturbance, and those are usually trivialized; sleep disturbance resulting in chronic sleep loss is a significant health issue which has been shown to have very serious ramifications including permanent neural damage and may have implications to Parkinson's and Alzheimer's disease.[27,28,29]
6. Onakpoya et al., found that the odds of being annoyed is significantly increased by wind turbine noise. The odds of sleep disturbance was also significantly increased with greater exposure to wind turbine noise. Four studies reported that wind turbine noise significantly interfered with quality of life (QOL). Visual perception of wind turbine generators was associated with greater frequency of reported negative health effects. In conclusion, there is some evidence that exposure to wind turbine noise is associated with increased odds of annoyance and sleep problems. Individual attitudes could influence the type of response to noise from wind turbines. Experimental and observational studies investigating the relationship between wind turbine noise and health are warranted.[30]
7. Prof. Alan Hedges of Cornell U. indicates that vibrations in the frequency range of 0.5 Hz to 80 Hz have significant effects on the human body because of the natural resonance frequencies of the human body and its various parts or organs. The resonant frequencies can result in as much as a 350% amplification of the vibration depending on the frequency and location in the body (20 to 30 Hz between the head and shoulders). According to Prof. Hedges, whole body vibration may create chronic stresses and sometimes even permanent damage to the affected organs or body parts. Suspected health effects of whole body vibration include:[31]

    –Blurred vision

    –Decrease in manual coordination

    –Drowsiness (even with proper rest)

    –Low back pain/injury

    –Insomnia

    –Headaches or upset stomach

   As pointed out by the Kelley studies of 30 years ago, one of the significant issues was the sensation of vibrations in the structure of the affected homes.[32] There is evidence that the strong resonances found in the acoustic pressure field measured within rooms indicates a coupling of

26 https://www.nhmrc.gov.au/_files_nhmrc/publications/attachments/eh57a_information_paper.pdf
27 https://www.urmc.rochester.edu/news/story/3584/scientists-discover-previously-unknown-cleansing-system-in-brain.aspx
28 https://www.urmc.rochester.edu/news/story/3956/to-sleep-perchance-to-clean.aspx
29 https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3880190/
30 http://www.ncbi.nlm.nih.gov/pubmed/25982992
31 http://ergo.human.cornell.edu/studentdownloads/dea3500pdfs/whole-bodyvibration.pdf
32 http://www.nrel.gov/docs/legosti/old/3261.pdf

sub-audible energy to human body resonances at 5, 12, and 17-25 Hz, resulting in a sensation of whole-body vibration.[33]

8. As mentioned in the animal study section, the Army studied the potential health issues related to low frequency vibration based on their own studies of developing chick embryos (as a model for human embryos) and because of the potential health hazard restricted pregnant aviators from rotary-wing flying duties.[34]

Conclusion

With the potential life altering implications for people and, in particular, for children, the elderly and other more susceptible individuals, it is very important to err on the side of safety when determining appropriate siting for industrial wind turbine installations. Audible noise studies are very important, but it is very apparent that LFN and IS must also be strictly controlled and monitored. It is very difficult to make an accurate and/or specific minimum setback distance without knowledge of all of the variables. The variables include, but are not limited to, the specific noise power spectrum of the given wind turbine model being used, exact locations and interactions of multiple wind turbines in a given wind farm, and topography. Some variables are constantly changing such as atmospheric conditions, wind, etc., thus, a setback must always allow for a worst case scenario plus an appropriate safety margin.

33 http://docs.wind-watch.org/kelley_ASME_1982.pdf
34 http://www.usaarl.army.mil/techreports/95-1.pdf

Ice and Blade Fragment Throw

Introduction

Ice and blade fragment throw events from wind turbines can and do happen. Therefore, it is important to understand how likely these events are and how to best mitigate against them.

According to a 2005 Dutch Handbook[35] that is frequently referenced in assessing risk associated with wind turbines, the rate of wind turbine blade failure was between 1 in 2,400 and 1 in 20,000 depending on rotor speed and whether it was a partial or full blade failure. This put the rate of failure between 0.0416% and 0.005%. However, this failure rate is based on data collected between 1980 and 2001.

According to a 2015 Windpower Monthly article[36], wind turbine rotor blades fail at the rate of 3,800 per year. Out of 700,000 or so blades that are in operation worldwide, the failure rate is 0.54%, a significant increase from the Dutch Handbook rates. It's important to note that this article doesn't say how many of these blade failures resulted in a detachment event. It is likely that some blade failures are detected and corrected before a detachment event occurs.

It has been difficult to find detailed data on wind turbine icing risks for our upstate NY climate. There has been a larger body of research from European scientist and engineers on icing risk and mitigation. According to an MMI Engineer presentation[37], risks or fatality from ice have been calculated around 3 orders of magnitude (x1000) higher than from blade failure. Data collection on actual wind turbine icing events is also limited. In one study of icing events in Gütsch, Switzerland over four winters (2005 to 2009), 32 icing events were recorded with 228 fragments documented. The maximum distance was one found at 92 meters. However it was noted that:

- Not all events could be captured
- Inspection partly delayed
- Exact time of ice throw unknown

There has been more investigations of ice and blade fragment throws using advanced modeling techniques. A 2015 paper from Uppsala University in Sweden that uses advanced modeling, the author found throwing distances up to 350 meters under certain conditions. For this paper and other similar research, the models were dependent on important wind turbine characteristics such as tower height, rotor diameter, and rotational speed.

Another risk researchers try to quantify is how likely a blade fragment or ice throw will hit something or someone. While there have been no reported deaths from a flying blade or ice fragment yet, there have

[35] H Braam et al., "Hanboek Risicozonering Windturbines", 2nd Edition, January 2005
[36] Annual blade failures estimated at around 3,800 (Windpower Monthly, May 14, 2005) http://www.windpowermonthly.com/article/1347145/annual-blade-failures-estimated-around-3800

[37] Advances and Cases Studies in Wind Turbine Risk Assessments Icing – how big a hazard? - by Chris Robinson, MMI Engineering, presented at RenewableUK Health & Safety 2013

been incidents of houses being hit [38] [39]. Most of the research puts the probability as very low. For example, according to a 2007 report by Garrad Hassan to the Canadian Wind Energy Association[40], the following scenarios were analyzed along with the probability for each scenario:

Scenario	Probability
A fixed dwelling 300 meters from a turbine	0.0002 strikes per year (1 in 5,000 years)
A vehicle travelling on road 200 meters away	0.0000038 strikes per year (1 in 260,000 years)
A individual 300 meters away	0.000000007 strikes per year (1 in 137,500,000 years)

While the report authors made assumptions about each scenario, it should give one a reasonable understanding of likelihood of an impact.

Setback Mitigation

Using setbacks is one of the best way to mitigate against blade and ice throw risks. The further from the turbine, the less likely an impact will occur. Below are two setback calculations. Calculation 1 is a common formula that is found throughout the literature. GE uses Calculation 1 in it's guidelines for ice throw mitigation (GER-4262)[41]

Calculation 1:

Setback = 1.5 * (Rotor diameter + hub height)

Calculation 2:

Setback (meters) = (Percentage of impacts inside distance * Fragment release velocity) / 11.9

Calculation 2 is found in a 2011 paper, "A method for defining wind turbine setback standards", Jonathan Rogers et al. The authors demonstrate that Calculation 1 provides "inconsistent and inadequate protection against blade throw" and propose Calculation 2 because "the release velocity of the blade fragment is the critical factor in determining the maximum distance fragments are likely to travel.". Jonathan Rogers discussed this paper as a technical expert for the Enfield Wind Farm Advisory Committee on March 1, 2016.

Below is a table that uses both calculations to find a setback for a Vestas 2.0 MW turbine (example used in the Rogers paper) and a GE 2.3 - 107 turbine. The probabilities and risks levels were kept the same.

	Vestas 2.0 MW	GE 2.3 - 107
WIND TURBINE CHARACTERISTICS		
ROTOR RADIUS (METERS)	40 meters	53.6 meters
TOWER HEIGHT (METERS)	67 meters	94 meters
ROTATIONAL SPEED (RPM)	16.7 RPM	15.9 RPM

[38] Wind turbine's deadly ice shower, http://www.peterboroughtoday.co.uk/news/latest-news/wind-turbine-s-deadly-ice-shower-1-120837
[39] House hit by debris following blade failure, http://www.windpowermonthly.com/article/1378289/house-hit-debris-following-blade-failure
[40] Recommendations for Risk Assessments of Ice Throw and Blade Failure in Ontario, 2007, Garrad Hassan Canada Inc.
[41] Ice Shedding and Ice Throw – Risk and Mitigation (GE Power, GER 4262, 2006)

ROTATIONAL SPEED (RADIANS/SECOND)	1.75	1.67
FRAGMENT SIZE (METERS)	2 meters	2 meters
PROBABILITIES		
RISK LEVEL - BLADE THROW PROBABILITY AT OR BEYOND SETBACK	1 in 20,000	1 in 20,000
RATE OF BLADE FAILURE PER TURBINE PER YEAR	1 in 3846	1 in 3846
OUTPUT VARIABLES		
FRAGMENT RELEASE VELOCITY (METERS/SECOND)	68.34 (m/s)	87.69 (m/s)
PERCENTAGE OF IMPACTS CONTAINED WITHIN THE SETBACK DISTANCE	80.77%	80.77%
SETBACK USING CALCULATION 1	723 feet	990 feet
SETBACK USING CALCULATION 2	1520 feet	1950 feet

Other Mitigation Measures

There are several additional ways to help mitigate against ice and blade throw from a wind turbine.

Ice Sensors – Being able to detect when an icing event occurs helps turbine operators so that they can take corrective measures. Ice sensors are becoming much more sophisticated, but are not 100% capable of detecting every event. GE's warns against this in it's GER-4262 (Ice Shedding and Ice Throw – Risk and Mitigation): "Detection of ice by a nacelle-mounted ice sensor which is available for some models (with current sensor technology, ice detection is not highly reliable)."

Thermal anti- and de-icing systems – Various systems exist to help heat the blades and other components. In cold climates where ice events often occur, doing so may actually be cost-effective since it will minimize downtime and underperformance.

Anti-freeze coatings for rotor blades – This is another area that can help mitigate icing events. However, according to the 2012 IEA Wind report[42]: "Antifreeze coatings have been investigated widely in the last years. Many coatings have been promising in the laboratory tests, but none of them has proved to be functional or enough wear resistant in field conditions."

Warning Signs and Fencing – It has been mentioned in several publications and reports that warning signs and fencing be included as a mitigation measure.

Summary

Wind turbine blade failure and ice throw are not rare events. Sophisticated modeling and analyses show that ice and blade fragments can land hundreds of meters from a wind turbine. However, the risks that a person will be hit by one is relatively small. Since ice and blade throw is not a rare event, it's important to be cautious and implement mitigation strategies such as setbacks, warning signs, fences, ice sensors, and anti-freeze coatings on blades. In cold climates researchers and engineers recommend having an ice risk and mitigation analysis done.

[42] State-of-the-Art of Wind Energy in Cold Climates, IEA (International Energy Agency) Wind, 2012

Fire, Lightning, Mechanical Failure, Flicker and Other Miscellaneous Issues

Overview – Mechanical Failure, Fire, Lightning

Like any other mechanical machine, wind turbines can and do experience mechanical failures with attendant risks resulting. In 2013, GCube, the leading provider of renewable energy insurance services published a report summarizing the most common wind energy insurance claims made in the United States. The data based on 2012 US reported claims, shows that blade damage and gearbox failure account for the greatest number of losses – accounting for 41.4% and 35.1% of the total claims reported. Meanwhile, damage to foundations came in fifth. The top two most frequently reported causes of loss were cited as poor maintenance (24.5%) and lightning strikes (23.4%). Design defect (11.5%), wear and tear (9.3%) and mechanical defect (6.2%) featured in third, fourth and fifth when it came to assessing and understanding the reason cited for the initial claim. Although the majority of wind turbine blade damage can be attributed to lightning strikes; delamination and improper handling during the construction and installation phase are also frequent causes. Since 2008, GCube alone has paid out over $200,000,000 in claims to the renewable energy industry, with the majority of this figure coming from the wind sector.[43]

Array Loss/ Bearing Failure

While the various components of turbines are designed to meet the requirements of the IEC 61400-1 20-year wind turbine design standard, there are no requirements in the design standard for the reliability of the turbine system as a whole – nor is there a requirement for the reliability of major sub-systems, such as the gearbox. So, the reliability of a gearbox system can be substantially less than 20 years. And the single largest component of a gearbox system that causes gearboxes to fail is the bearings.[44] According to the insurer GCube, with approximately 175,000 geared turbines in operation in 86 countries worldwide, there are around 1,200 incidents of gearbox failure reported each year — one failure per 145 turbines per year.[45]

If turbines are sited such that the wind blows parallel to the rows of the turbines (see, e.g., turbines 1, B and C in the Black Oak Wind Farm project), then the turbine following the lead turbine in the row will have higher turbulence as well lower wind speed. The effect of the turbulence and fluctuating wind speed is not only loss in the production of electricity (i.e., array loss), but also the reduced life of the wind turbines due to fatigue failure.[46][47]

One type of fatigue failure is axial cracking in bearing races that has become common in large megawatt turbines. This damage can shorten bearing life to as little as one to two years. Axial cracking issues in bearings were not a prominent failure mode until larger megawatt and multi-megawatt class wind

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43 http://www.gcube-insurance.com/press/gcube-top-5-us-wind-energy-insurance-claims-report/
44 http://nawindpower.com/online/issues/NAW1505/FEAT_01_Meet-The-Achilles-Heel-Behind-Most-Gearbox-Failures.html
45 http://www.windsystemsmag.com/article/detail/878/gcube-targets-turbine-gearbox-failures-in-report
46 http://www.brighthub.com/environment/renewable-energy/articles/97151.aspx
47 http://www.windpowerengineering.com/design/how-turbulent-wind-abuse-wind-turbine-drivetrains/

turbines were put in service. It was not a common failure mode of earlier, smaller turbine models where the failure mode was more commonly bearing surface deterioration from pitting and scuffing. The issue of axial cracking grew along with turbine size.

The key to limiting fatigue failure, and the resulting dangers such as blade throw, fires, etc., is proper siting of the turbines.[48] Wind turbine studies have shown that turbines spaced eight to ten times the rotor diameter in the downwind direction and five times the rotor diameter in the crosswind direction have very little turbulence- as little as 10%.[49]

Fire

You need three things to start a fire: fuel, ignition and oxygen. And you can find all three of them in ample quantities within the nacelle of a wind turbine. Turbines catch fire because highly flammable materials such as hydraulic oil and plastics are in close proximity to machinery and electrical wires. According to Exelon, their 400 foot turbines contain 400 gallons of oil.[50] (The Final Findings Statement states that "the turbines have substantially less hydraulic fluid than most other turbines today" but doesn't disclose how much they contain.) And the nacelle itself is made with highly flammable plastics. Add high winds and you have all the ingredients for a fire.

Fires in turbines typically start one of two ways – a lightning strike (see further discussion on lightning below) or a technical fault. Once a fire starts there is little or nothing that can be done to prevent the turbine's complete destruction.[51] Catastrophic fires are not common although just how often they occur is the subject of some disagreement. The insurer, GCube, claims only 50 turbines a year or one in every 6,000 turbines go up in flames in any one year.[52] Daniel Kopte, an expert in safety systems for renewables certification at DNV GL estimates that approximately 120 turbines a year or one in every 2,000 turbines catch fire each year.[53] Kopte's number corresponds to a study done by Imperial College London which estimates that approximately 117 turbines catch fire every year.[54] Still others claim that wind farm accidents are actually much greater due to the fact that these accidents often are not reported.[55]

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48 http://www.windpowerengineering.com/design/how-turbulent-wind-abuse-wind-turbine-drivetrains/

49 For the GE 2.3MW-107 turbines, that translates to 2,808.4 feet to 3,510.5 feet for the downwind direction and 1,755.25 feet in the crosswind direction.

50 https://www.wind-watch.org/news/2016/03/02/fallen-turbines-oil-spill-shouldnt-be-a-problem/#.VtcNzNrM6ao.mailto

51 http://www.windpowermonthly.com/article/1361476/minimising-fire-risk-wind-turbines

52 http://www.gcube-insurance.com/press/gcube-tackles-turbine-fires/

53 http://www.windpowermonthly.com/article/1361476/minimising-fire-risk-wind-turbines. Note, however, that his estimate includes both damaged and destroyed turbines.

54 http://www3.imperial.ac.uk/newsandeventspggrp/imperialcollege/newssummary/news_17-7-2014-8-56-10

55 http://www.telegraph.co.uk/news/uknews/8948363/1500-accidents-and-incidents-on-UK-wind-farms.html

In the U.S., OSHA recommends that all wind turbines install fire detection and controls.[56] But, unlike Europe, the U.S. has no mandated regulations for fire suppression.[57] Given that, it is the local municipality's responsibility to develop their own fire emergency plans.[58] Most wind turbines do not have fire suppression systems installed by the manufacturers. In fact, GE's salesperson who attended the Wind Farm Advisory Committee stated that the 2.3MW-107 turbines being installed by Black Oak Wind Farm do not have such a system. However, Section 6.9.1 of the Final Findings Statement provides that the turbines will come standard with two fire extinguishers in the nacelle, and one in the base of the tower and that Black Oak will purchase an additional fire protection system from Firetrace International, LLC, which provides fire control devices in individual turbine components such as the electrical cabinets and converters. In addition, the SDEIS states there will be an updated Fire and Emergency Plan provided but it is not part of the filing.

Given the remote locations and enormous height of turbines today, there is not much a fire department can do to fight a fire in the nacelle. Gary Bowker, a retired fire professional with over 40 years of experience, including as fire chief with the U.S. Air Force and fire chief with Sumner County, Kansas, has this to say about fighting wind turbine fires:

> "…, due to the risk of falling debris over a wide area, approaching a burning turbine is usually not an option unless there is a life risk involved. If the turbine is turning, power is being generated and an electrocution hazard will be present.
>
> Typically, a good option for firefighters to consider is to evacuate any endangered areas, set up a collapse zone, and attempt to control any ground fires to prevent the fire from spreading to other units.
>
> In the case of a runaway or over-speed event, rotating turbines can throw debris thousands of feet away during a blade failure. Pieces of blades have been documented as traveling over 4,200 feet. Distance and time will fix this problem. Pre-incident planning and SOP development are keys to success for safely handling this unique danger."[59]

In addition to grass fires, the secondary fire on the ground can lead to forest fires, which can be difficult to extinguish. The remote locations of the turbines and strong winds can be factors that promote the quick spread of forest fires.[60] Section 2.8.2 of the DSEIS states: "Consultation with the Enfield Fire Company indicates that they are confident in their ability to control fires in open fields, but concerned regarding the ability to control fires if they spread to forests."

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56 https://www.osha.gov/dep/greenjobs/windenergy_fire.html

57 Europe's Confederation of Fire Protection Associations (CFPA E) has published its own guidelines for wind turbine fire protection. See http://en.dbi-net.dk/files/CFPA/Guidelines/CFPA_E_Guideline_No_22_2012_F.pdf

58 http://www.windpowerengineering.com/maintenance/safety/what-regulations-exist-for-fire-protection-in-wind-turbines/

59 http://www.firerescue1.com/fire-attack/articles/1306390-3-wind-turbine-failures-firefighters-must-know/

60 http://en.dbi-net.dk/files/CFPA/Guidelines/CFPA_E_Guideline_No_22_2012_F.pdf

Furthermore, OSHA states: "Workers should be made aware that while fighting initial fires, toxic gases can be generated and oxygen can be depleted inside Nacelles, and they can be exposed to such gases or can be asphyxiated from lack of oxygen."[61]

In light of the risks involved, the use of safety features in the turbines whenever possible and a well-designed emergency plan are critical. The European guidelines as well as, in the U.S., the National Fire Protection Association recommend, among other things:

- Fire suppression systems in the nacelle
- Automatic early fire detection systems whereby the turbine is automatically shut down and disconnected from the power supply system
- Lightning and surge protection
- Protection systems, including measures to identify power system faults and other abnormal operating conditions
- Minimization of combustible materials in the manufacture of the turbines
- Use of cold procedures for repairs, assembling or disassembling work to avoid fire hazards or the use of mandatory fire precautions where fire hazards cannot be avoided
- Regular maintenance of mechanical and electrical systems
- Proper training
- Clearing brush and debris from around the turbine to create a fire break

Where a fire emergency arises, a plan should be in place that provides, among other things:

- 24/7 standby personnel monitoring the turbines
- Provision of emergency telephone numbers
- Notification of fire department and police
- On-site support for fire department and police
- Shut down of turbine and disconnection from power supply
- Training fire and police personnel about turbines, high-voltage components and combustible materials within the turbines[62], [63]

Lightning

As stated above, lightning is the second most frequent cause of blade failure as well as gearbox failures and fires. And for reasons that are not yet clearly understood, turbines seem to attract more than their fair share of lightning as compared with other structures of a similar size. As turbine size increases, so does vulnerability to lightning.[64] Furthermore, the move to carbon fiber in larger blades as a way of strengthening blades increases vulnerability to lightning.[65]

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[61] https://www.osha.gov/dep/greenjobs/windenergy_fire.html

[62] http://en.dbi-net.dk/files/CFPA/Guidelines/CFPA_E_Guideline_No_22_2012_F.pdf

[63] Chapter 10 of http://www.sentry-ds.com/images/nfpa850.pdf

[64] http://www.firetrace.com/wp-content/uploads/windandfirearticle.pdf

[65] http://www.firetrace.com/wp-content/uploads/windandfirearticle.pdf; It is not clear whether the GE 2.MW turbines are carbon fiber as they claim the material in their blades is proprietary but recent articles indicate that GE is moving in that direction. See http://exclusive.multibriefs.com/content/plastic-materials-and-processing-advancing-wind-energy.

Recent research by scientists at the Polytechnic University of Catalonia in Barcelona has shed new light on the risks of lightning strikes and wind turbines.[66] Turbine blades experience hundreds or thousands of "near strikes", creating microscopic levels of damage, before that fatal lightning strike that causes the blade to fail.[67] The researchers, using high-speed video of thunderstorms passing near turbines, found that near strikes occur even when a lightning storm is several kilometers away. Furthermore, they demonstrated that the turbines themselves can spark lightning strikes by sending up negative leaders into the clouds.[68], [69]

A properly installed lightning protection system will dramatically improve both the cost effectiveness and reliability of a wind turbine. Without the system a lightning strike on an unprotected blade can lead to temperature increases up to 54,000 degrees Fahrenheit and result in an explosive development of air within the blade. According to the updated National Fire Protection Association handbook, "While physical blade damage is the most expensive and disruptive damage caused by lightning, by far the most common is damage to the control system." Wind turbines have a concentrated amount of very expensive technology installed in a relatively small space and the presence of many different voltages in a wind turbine installation, which can easily lead to overvoltages and surges within the system.[70] Furthermore, turbine blades can explode when struck by lightning[71], [72] causing risk of blade throw in addition to fire.

Section 6.9.1 of the Final Findings Statement and Section 2.8.3 references lightning and surge protection systems to be installed on the turbines to help protect against the impacts of lightning and electrical surges causing fires. Despite these systems which decrease the risks, the risk of fires and blade throw still exists.

Foundation Failure/Turbine Collapse

Foundation failures that lead to turbine collapse are generally caused by design flaws, construction flaws or maintenance flaws.[73] In addition, design flaws and maintenance flaws with the turbine towers themselves can lead to turbine collapse for a wide variety of reasons.[74] In all circumstances, the root

[66] http://www.windpowerengineering.com/policy/environmental/damage-control-effects-of-near-lightning-strikes-on-turbine-blades/

[67] http://www.windpowerengineering.com/policy/environmental/damage-control-effects-of-near-lightning-strikes-on-turbine-blades/

[68] http://arstechnica.com/science/2014/01/lightning-bolts-love-wind-turbines-a-little-too-much/

[69] http://www.windpowerengineering.com/policy/environmental/damage-control-effects-of-near-lightning-strikes-on-turbine-blades/

[70] http://alltecglobal.com/wp-content/uploads/Why_Wind_Farms_Need_Lightning_Protection.pdf

[71] http://www.vaisala.com/Vaisala%20Documents/Scientific%20papers/1.Leick-How%20Lightning.pdf

[72] http://alltecglobal.com/wp-content/uploads/Why_Wind_Farms_Need_Lightning_Protection.pdf

[73] http://docs.wind-watch.org/Cracks-in-onshore-wind-turbine-foundations.pdf

[74] http://khatrinternational.com/docs/awea_wt.pdf

cause of the problems arises due to the enormous stress and forces to which a wind turbine is subjected requiring that both the foundation and the turbine tower's structure are up to the task at hand.

The main reason for foundation failures has been poor structural design. Furthermore, the site investigations are sometimes not conducted properly and the findings are not properly considered when designing the foundation.[75], [76] There are many different types of foundation designs for wind turbines. The foundation design will always have to be site-specific in that it needs to be designed for the prevailing local soil conditions.[77] Other reasons for construction flaws are poor workmanship performance and inappropriate material selection. As a result, it is critical to have a third party soil engineer as well as construction engineer on site during the construction of the foundations to ensure they are being built properly.

Once the turbine foundations have been built, it is also critical that they be inspected and maintained on a regular basis to check for cracking and/or softening of the foundation which can lead to collapse. Water entering the foundation followed by subsequent freezing and thawing can have negative effects on the integrity of the turbine's foundation.

In addition to foundation failure, the design flaws can lead to turbine collapse. Some of the maintenance or operational concerns related to the design of the turbines that can lead to turbine collapse include:

- Turbine over-speed;
- E-stops;
- Soil fatigue and/or foundation fatigue or cracking;
- Weld failures;
- Blade failures;
- Imbalance due to snow or ice loads
- Poor soil drainage leading to foundation softening; and
- Corrosion of foundation bolts.[78]

All of this leads to the conclusion that, in addition to strong oversight during construction, ongoing strong oversight of the operations and maintenance of the wind farm is critical to maintaining the safety of the town's residents.

Flicker

Shadow flicker only occurs in certain specific combined circumstances, such as when the sun is shining and is at a low angle (after dawn and before sunset), the turbine is directly between the sun and the affected property, and there is enough wind energy to ensure that the turbine blades are moving. A considerable amount of international research has been undertaken on the impacts and management of

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[75] http://www.windfarmbop.com/cracks-in-onshore-wind-turbines-foundation/#comment-14776

[76] http://docs.wind-watch.org/Cracks-in-onshore-wind-turbine-foundations.pdf

[77] http://home.eng.iastate.edu/~jdm/engr340-2011/ENGR%20340%20-%20Foundations%203%20-%20Ashlock%20-%20Schaefer.pdf

[78] http://khatrinternational.com/docs/awea_wt.pdf

shadow flicker. Generally in Europe[79], the standard for flicker is to place turbines at least 500 – 1,000 meters[80] from dwellings and limit the amount of flicker to no more than 30 hours per year, and in some cases, no more than 30 minutes per day. Careful site selection, design and planning, and good use of relevant software can help avoid the possibility of shadow flicker in the first instance. Research has shown that when turbines are placed at least 10 rotor diameters[81] or more from a dwelling, the potential for shadow flicker is very low.[82] However, the U.S. Bureau of Land Management has stated that shadow flicker is not considered as significant an issue in the United States as in Europe where the high latitude and low sun angle exacerbate the effect.[83] In fact, a common standard within the United States is to merely limit the amount of flicker to not more than 30 hours per year which is the standard which Black Oak Wind Farm uses in the DSEIS.

There are many complaints by residents living near wind turbines about the impacts of flicker.[84], [85], [86] These complaints and concerns include, among other things, headaches, tinnitus, nausea, dizziness, earaches, vertigo and seizures. In many cases, residents have abandoned their homes because they were unable to sell them and could no longer stand living with the effects of the flicker. But others maintain that there is no scientific proof that flicker causes adverse health effects.[87]

The document produced by the Bureau of Land Management referenced above does note that flickering effect may be considered an annoyance. With respect to seizures however, the BLM points out that modern three-bladed wind turbines are unlikely to cause epileptic seizures in the susceptible population[88] photo-sensitive epileptics due to the low blade passing frequencies.[89] The World Health Organization defines annoyance as a feeling of discomfort which is related to adverse influencing of an individual or a group by any substances or circumstances. Annoyance express itself by malaise, fear, threat, trouble, uncertainty restricted liberty experience, excitability or defencelessness.[90] While there has yet to be a direct causal link established between flicker and adverse health effects, the World

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[79] These shadow flicker recommendations are based on the survey by Predac, a European Union sponsored organisation promoting best practice at energy use and supply which draws on experience from Belgium, Denmark, France, the Netherlands and Germany.

[80] This equates to roughly 1,750 to 3,500 feet.

[81] This equates to 1,070 meters or 3,500 feet for the GE 2.3MW-107 turbines.

[82] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/48052/1416-update-uk-shadow-flicker-evidence-base.pdf

[83] Final Programmatic Environmental Impact Statement on Wind Energy Development on BLM-Administered Lands in the Western United States, US Department of the Interior – Bureau of Land Management (2005) Synopsis

[84] https://www.bostonglobe.com/metro/2013/04/04/turbine-flicker-effect-draws-complaints/UKgf7nOwMHm8CWAtZ47V5L/story.html

[85] http://www.telegraph.co.uk/news/earth/earthnews/8386273/Shadow-flicker-rotating-blades-can-cause-headaches.html

[86] https://www.youtube.com/watch?v=RD6q3ixq0-s

[87] https://nccleantech.ncsu.edu/wp-content/uploads/Health-Impacts-Factsheet-7.pdf

[88] Around 0.5 % of the population is epileptic and of these around 5 % are photo-sensitive. Of photo-sensitive epileptics less than 5 % are susceptible.

[89] http://onlinelibrary.wiley.com/doi/10.1111/j.1528-1167.2008.01563.x/epdf

[90] http://www.euro.who.int/__data/assets/pdf_file/0015/105144/WHO_Lares.pdf

Health Organization does link annoyance to various diseases such as diabetes and cardiovascular disease. Furthermore, the NIH's National Center for Biotechnology Information points out that there has been little if any research conducted on how flicker could heighten the annoyance factor of those living in proximity to turbines.[91]

Various mitigation steps can be taken to minimize the impact of flicker on nearby residents. For example, in one municipality in Alberta, Canada, the wind farm either shuts down the machines between the time the sun is rising and setting for approximately an hour, or programs their computers to control the direction of the turbine so the blades are directly parallel to the sun. Other suggested mitigation tools include the use of blinds at residential properties or tree/shrub planting to screen shadow flicker to help minimize potential impacts.[92] Nonetheless, many people complain that blinds do little to actually block the impact of flicker and do nothing to alleviate its effects while outdoors.

The Impact of Flicker on Horses

One area of particular concern related to flicker involves its impact on horses. A detailed 2012 survey by the British Horse Society establishes that as many as 20% of horses are adversely effected by the flicker of wind turbines. This is of particular concern due to the fact that Turbines B and C surround a property being used by a professional horse trainer to train horses.[93][94]

Stray voltage

In the U.S., the NEC requires that alternating current (AC) systems connected to the utility must have one of the current-carrying wires grounded to the earth at the electrical service entrance. This grounded wire is termed the "neutral" wire, and is un-fused. The other wire, termed the "hot" wire, is wired through a fuse or circuit breaker. This configuration, involving a grounded current-carrying conductor, was adopted for perceived safety reasons, essentially to protect folks working on the electrical lines or wiring from getting zapped. It is this grounded un-fused 2 "neutral" wire that actually creates two potential paths for electricity to follow: through the wire itself as well as through the earth.

Because one of the current-carrying conductors is connected to the earth, there can be situations where small amounts of electricity can flow to complete a circuit through the earth that is below the threshold that will blow a fuse or trip the circuit breaker in the hot wire. This unintentional flow of electricity is what is referred to as "stray voltage." Stray voltage is usually defined as a measurable level of voltage that may occur between a metal object and the adjacent floor or earth.[95]

Problems with the condition of the hot wire can also cause stray voltage.

One particular place where stray voltage becomes a serious issue is in a dairy barn, where you have all the components for parallel electrical paths: concrete or dirt floors that are likely wet from manure,

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[91] http://www.ncbi.nlm.nih.gov/pmc/articles/PMC4063257/

[92] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/48052/1416-update-uk-shadow-flicker-evidence-base.pdf

[93] Wind turbine experiences, 2012 Survey results, The British Horse Society

[94] Advice on Wind Turbines and Horses – Guidance for Planners and Developers, The British Horse Society

[95] http://www.renewwisconsin.org/wind/Toolbox-Fact%20Sheets/Stray%20voltage.pdf

urine, and moist animal breath; metal confinement structures and water systems; metal rebar in the concrete floor; and metal walls often with moisture condensed on them. In addition, it turns out that dairy cattle (with an electrical resistance of only about 500 ohms) can detect electrical currents at a level about one one-fiftieth to one one-hundredth of what humans are able to detect.

The Final Findings Statement provides the following with resepct to stray voltage:

> "While the concerns surrounding stray voltage are legitimate, it is important to note they are largely preventable with proper electrical installation and grounding practices. The Project's power collection system will be properly grounded, and will be electrically isolated (in accordance with required electricity regulations) from the local electrical distribution lines that provide electrical service to on-site structures or off-site buildings and homes. It will be physically and electrically isolated from all of the buildings in and adjacent to the Project. Additionally, the bulk of the wind farm's electrical collection lines will be located a minimum of three to four feet below ground, and will use shielded cables with multiple ground points. This type of design eliminates the potential for stray voltage."

But wind farm collector systems experience a very demanding load on cables and accessories compared to utility distribution systems. Fast deterioration of cables and cable accessories has been reported at wind farms. Joints are known to be a weak point in a cable system since it is an area which has been worked on by tools and hands. Reports suggest that failed joints are over represented compared to the cable itself in failure statistics. Typical causes of failure are moisture ingress, heating in joint ferrule and partial discharges in cracks and voids. Compression type ferrules, more often than others, have caused heating in joints by heightened contact resistance.[96]

This highlights, once again, the importance of ongoing maintenance and repair of the components of a wind farm

Lighting of turbines

The FAA requirements specific to wind turbine farms may be found in chapter 13 of FAA Advisory Circular AC 70/7460-1L.[97] The FAA defines a wind turbine farm as *"wind turbine development that contains more than three (3) turbines of heights over 200 feet above ground level."* Not every wind turbine within a farm is required to be lit. The FAA requires unlit gaps of no more than ½ statue mile.

More specifically, the AC requires:

- Nighttime wind turbine obstruction lighting should consist of FAA L-864 aviation red flashing, strobe, or pulsed obstruction lights. Studies have shown that red lights provide the most conspicuity to pilots.
- In most cases, not all wind turbine units within a wind turbine farm need to be lighted. Obstruction lights should be placed along the perimeter of the wind turbine farm so that there are no unlit separations or gaps more than 1/2 statute mile (sm) (804 m). Wind turbines within a

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96 http://www.diva-portal.org/smash/get/diva2:566345/FULLTEXT01.pdf

97 http://www.faa.gov/documentLibrary/media/Advisory_Circular/AC_70_7460-1L_.pdf

grid or cluster should not have an unlighted separation or gap of more than 1 sm (1.6 km) across the interior of a grid or cluster of turbines.

- Any array of flashing, strobe, or pulsed obstruction lighting should be synchronized to flash simultaneously (within ±1/20 second (0.05 second) of each other).
- Light shields are not permitted because of the adverse effects they have on the obstruction light fixture's photometrics. In addition, these shields can promote undesired snow accumulation, bird nesting, and wind loading.

The FAA rules requires the lights to be visually or automatically inspected once every 24 hours. In addition, FCC rules require them to be inspected quarterly

Aeroelastic Flutter Stability

See pages 10 & 11 of http://mragheb.com/NPRE%20475%20Wind%20Power%20Systems/Safety%20of%20Wind%20Systems.pdf.

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Water Resources - Climate and Air Quality

Summary

Water resources and air quality are impacted primarily in the construction phases of the wind energy project more so than in its operational phase. Siting of access roads, construction staging areas and tower foundations must be done so as to minimize disruption, damage and permanent alteration of existing natural conditions of streams, wetlands and drainages. An inventory of these water resource elements for both the accepted project as well the potential modified layout has been documented in the DEIS and SEIS. Final site plans, as yet to be presented, will allow more specific analysis of impacts and all necessary mitigation. Monitoring of construction activities will be of critical importance to insure compliance with NYSDEC and USACE protection and restoration standards on site. Identification, analysis and mitigation plans for water resource issues that exist or may arise are addressed and documented in the DEIS, FEIS and SEIS. No water use is required in the operational phase of the completed turbines and therefore no impacts are anticipated to aquifers or groundwater resources once construction is complete.

Air quality may be impacted during construction by exhaust fumes of trucks and equipment in use on site as well as en route. Travel on unpaved roads, as well as excavation for access roads, staging areas and tower foundations may also produce significant dust depending on both weather and current road conditions on a short term and localized basis. Methods for addressing dust are outlined in the DEIS. Exhaust from trucks could be lessened by limiting the length of idling time allowed on site. There do not appear to be any methods for actual measurement of air quality changes during construction.

Numerous methods for evaluation and monitoring of water issues during the active construction phase of the project have been outlined and presented but can only be upheld in pre-construction planning and vigilant, thorough inspection and monitoring on site when excavation and building is actually underway. An Environmental Monitor will be hired for the duration of construction and will be responsible for identifying, reporting and recommending solutions to any problems as they arise, according to NYSDEC and USACE regulations and procedures. The Town of Enfield will have discretion in hiring for this position.

Geology, Soils & Topography

The approved plan had test borings done for all proposed turbine sights as well as the substation. The results of which were in Appendix D of the Draft EIS as well as the supplemental geotechnical report from Tectonic. They also had GEOPHYSICAL SURVEYS -MULTI-ANALYSIS OF SHEAR WAVE (MASW) done by ARM geophysics.

Test Borings:

No Test Borings were performed for the 3 proposed turbines A, B, C, 1 moved turbine # 5,`` the MET tower or the substation according to the Draft Supplemental EIS. On page 6 under 2.1.1 it is stated that " Similar investigations will be performed for the Modified Project prior to project approval (issuance of permit) and initiation of construction."

As was said in the Advocates for Stark letter on Trello: *"Once the lead agency approves the Final Environmental Impact Statement, the towns…and the county…are effectively trapped. They cannot withdraw. If on any issue, the towns demand more than the developer wants to give, the sponsor can simply threaten to sue the towns, and the towns will back down, because they cannot afford a lawsuit. Therefore, it is critical that the towns and the county negotiate all the terms before the SEQR process ends. Once the SEQR process ends, your negotiating powers will be significantly weakened, if not obliterated."*

The need for test borings at each turbine sight were stated in Appendix D of the Draft EIS On page 13:

9.0 RECOMMENDATIONS

The following sections provide our geotechnical recommendations for design and construction of the proposed foundations. The recommendations are based on our understanding of the proposed project as summarized in Section 3 of this report, and the results of the subsurface investigation as described previously. It is noted that if the proposed Turbine locations change, Tectonic will need to confirm the validity of the provided recommendations. This is due in part to the locally abrupt variations in bedrock depth identified by the borings and MASW surveys.

It is recommended that the test borings be done for all new or changes turbine sights as well as the substation and MET tower before the final EIS is approved so that the town will have a say in any mitigating directions.

Changes to the Turbines:

Given that not only the location, but also the size and power of the turbines have changed:

Appendix D of the Draft EIS On page 19:

12.0 LIMITATIONS

Our professional services have been performed using that degree of care and skill ordinarily exercised under similar circumstances by reputable geotechnical engineers and geologists practicing in this or similar situations. The interpretation of the field data is based on good judgment and experience; however, no matter how qualified the geotechnical engineer or detailed the investigation, subsurface conditions cannot always be predicted beyond the points of actual sampling and testing. No other warranty, expressed or implied, is made as to the professional advice included in this report.

The recommendations contained in this report are intended for design purposes only.

Contractors and others involved in the construction of this project are advised to make an independent assessment of the soil, bedrock, and groundwater conditions for the purpose of establishing quantities, schedules and construction techniques.
This report has been prepared for the exclusive use of Black Oak Wind Farm LLC for the specific application to the proposed wind farm project described in this report. We recommend that prior to construction, Tectonic review the project plans and specifications. It should be noted that upon review of those documents, some recommendations presented herein might be revised or modified. In the event that any changes in the design or location of the proposed structures are planned, Tectonic shall not consider the conclusions and recommendations contained in this report valid unless reviewed and verified in writing. It is further recommended that Tectonic be retained to provide construction monitoring and inspection services to ensure proper implementation of the recommendations contained herein, which would otherwise limit our professional liability.

It is recommended that the board ask Black Oak to inform Tectonic of the changes to turbine size, power and location to see if any revision or modifications are recommended.

Monitoring:

According to Tectonic:

11.0 CONSTRUCTION MONITORING

A geotechnical engineer familiar with the existing subsurface conditions and having the appropriate laboratory and field testing support should be engaged by the Owner to observe that all earthwork is performed in accordance with the specifications and the design criteria outlined in this report.
The following work should be performed under the supervision of a geotechnical engineer:

- Foundation subgrade preparation
- Rock anchor installation and load testing
- Fill placement and compaction
- Dewatering

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All materials proposed for use as soil fill should be tested and approved prior to delivery to the site. Additionally, all fill materials should be tested as they are being placed to verify that the required compaction is achieved. We further recommend that the project plans and specifications be reviewed by the geotechnical consultant prior to final completion of the bid documents. It should be noted that upon review of those documents, some recommendations presented herein may be revised or modified.

It is recommended that the town board carefully vets the geotechnical engineer or firm hired to oversee and monitor the construction.