

A REVIEW OF THE SCIENCE, LITERATURE AND RECOMMENDATIONS CONCERNING PUBLIC SAFETY AND ICE THROWS FROM WIND TURBINES

Kenneth Jaffe, MD Meredith, NY June 2006

During a recent roundtable discussion concerning wind power projects at the Delaware County Historical Society a participant¹ affiliated with two local wind development companies stated that there were three issues where the health and safety impacts were predictable and avoidable---- ice throws, noise, and flicker. Since the statement was made in the presence of planners who are advising towns in the process of writing regulations to protect the health and safety of residents, I felt that a fuller discussion of the known science of these issues was important, and have prepared this report to that end.

This concern about misinformation and poor science was compounded by the recent presentation by the New York State Department of State. The talk was designed to provide information and guidance to help planners and town officials of Delaware County write ordinances. Unfortunately, in the areas of health and safety the presentation was filled with misleading and incorrect statements. It did not accurately present the health risks as described by public health bodies (including, among others, the World Health Organization) and did not mention stricter public health regulations that have been written elsewhere to conform to recommendations of those public health groups.

In fact, the science, engineering, and planning surrounding icing are not well established. Analysis of the literature does not provide us with enough real world information to permit the prediction and avoidance of community impact and risk. There is an absence of peer review literature on icing risk; most of the literature comes from industry magazines and reports that are not reviewed objectively for validity. The existing literature is scant and does not support our ability to predict or prevent negative impact on communities from either ice throws or noise.

Below is a discussion of the state of knowledge concerning the public safety issues created by ice throws. A discussion of the noise issues will follow at a later date.

ICE THROWS

It is safe to say that there are several areas of agreement on the part of all who have thought about icing

1. Icing is a safety issue.
2. Icing occurs frequently in upstate New York, and at the altitude of Delaware County.
3. There have been no reported deaths or injuries from wind turbine ice to date, except for workers.

¹ Mr. Dermot McGuigan who is affiliated with both Delaware Wind Energy, LLC and Airtricity
See page 12 of Delaware Co. Electrical Coop grant application to NYSERDA

4. The theoretical distance of thrown ice can be calculated from the height, angle and speed of the tip of the turbine blade.
5. Setbacks from homes, roads and public spaces are necessary to prevent injury or death and property damage.

There are also areas of uncertainty which have led to controversy. Essentially the controversy is over

1. how to quantify the safety risk to people and property from thrown ice.
2. how to determine the appropriate setbacks to minimize risk.

I will review the key literature on the areas of agreement and controversy.

Consensus on Icing Being a Public Safety Issue

In his December 2005 presentation² entitled ‘Ice and Snow- and the Winds Will Blow’ Ian Baring-Gould of the U.S. Department of Energy’s National Renewable Energy Laboratory identified the following icing problems. These statements are quoted from his report:

1. “Ice is an issue.”
2. “Increases safety risk for staff and the public”.
3. “It’s not a winter wonderland.”
4. “The latest on ice throw—an inexact science”.
5. “Little data has been collected in the US on impacts of cold and ice.”
6. “Sites with severe weather require rethinking the current paradigm of measurement.”
7. “In Europe, safety considerations are paramount in the siting of wind turbines in icing climates.”
8. “Very little scientific study exists but as the issues grow in Europe more will be conducted.”

Peer review literature demonstrates that New York State has the highest risk of ice storms in the lower 48 states.³

² “Ice and Snow---and the Wind Will Blow, Ian Baring-Gould, National Renewable Energy Laboratory, U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, NWCC Technical Considerations in Siting Wind Developments, Dec. 1-2, 2005.

At <http://www.nationalwind.org/events/siting/presentations/baring-gould.pdf>

³ Characteristics of Wind Storms in the United States, Stanley A Changnon, Climatologist, Journal of Applied Meteorology, vol 42, p 630-639, 2003. See figures 3, 4, 5.

Ice throw distance---theoretical calculations

We know the theoretical distance that an object can fly when thrown from a known height, speed and angle. The physics of this calculation is settled science. For the turbines proposed for Delaware County, this theoretical distance is over one half mile. There is no real argument about this being the theoretical distance that an object can travel when thrown at the speed and height of a turbine blade.⁴

The problem with the theoretical distance calculation with respect to a determination of the real effect and safety is that two forces can act upon a thrown object---one to increase and one to decrease the distance an object travels. These forces are lift and drag. The effect of lift can be seen in gliders, Frisbees, and the discus and extends the theoretical distance. Drag occurs with non aerodynamic objects, and shortens the distance the object travels.

It is not known how often the ice formed on a turbine blade will fly further than the theoretical distance because the ice formed on a blade retains the shape of the blade which was designed to be aerodynamic; or whether the ice assume a shape that is less aerodynamic and have drag which reduces its theoretical distance.

In spite of a lack of information of lift and drag, we will see that the wind industry consultants and employees publish ice throw distance and risk calculations which ignore the impact of lift and assume a massive drag effect. Both assumptions will shrink the distance of thrown ice and tend to underestimate the safety risks.

ABSENCE OF ACCURATE DATA FROM ICE THROW SURVEILLANCE STUDIES

Given that there is general agreement that icing safety risks are inherent in large wind turbine technology, it would be useful to planners and regulators to have data from surveillance studies designed to accurately record the frequency, distance and mass of ice throws in areas which share with Delaware County a high risk of icing. This is particularly so since there is no certainty as to whether the theoretical distance calculations under estimate or overestimate actual the distance traveled by thrown ice in real world settings.

⁴ Calculation of Ice Throw Distances for Wachusett Wind Power Site, Prof. Terry Matilsky. Also see in this report, item number 3, the ice speed at impact is over 200 mph. Found on pages 31-33 <http://www.mollica.com/windfarm/ICE%20-%20WACHUSETT%20EENF%20COMM.pdf>

In a discussion of a public health approach to environmental protection by Barry Levy, President, American Public Health Association surveillance is the first of 10 recommendations given.⁵ He defines surveillance---

Surveillance, the ongoing, systematic collection, analysis, and dissemination of data to prevent disease andWe need surveillance for exposures of public health concern and for adverse health events. Despite many advances in our capabilities for environmental and occupational health surveillance, there is a disturbing trend that the local and state public health infrastructure across the country is deteriorating, especially for surveillance systems.

Unfortunately the literature on icing does not provide us with actual surveillance data for assessing the risk from icing nor does it permit quantification of the risk to persons at various setbacks based on empirical data from surveillance studies.

Both the presentation by Baring-Gould referenced above, and NYSERDA's publication "Public Health and Safety"⁶ cite articles published by Morgan and Seifert as offering data which permits risk assessment. These articles are extremely important in the realm of safety and ice throws since they are the sources of most industry recommendations for safety and icing. We will review Morgan and Seifert's articles below.

NYSERDA deals with the issue of ice throws in its publication "Public Health and Safety". This NYSERDA publication refers to a single paper (by Morgan et. al) as the source for its discussion of ice throws, describing the paper as the 'most complete study' to date, which 'quantified the risk of possible strikes from ice throws, in terms of distance from the turbine'.

This paper by Morgan⁷, its risk calculations, and the articles that Morgan cites to arrive at his risk conclusions are also the basis of much of the current industry advice on setbacks and the wind industry risk predictions. It is therefore worthwhile to evaluate the validity this series of papers and their models to get a sense of their usefulness in predicting risk.

Understanding the deficiencies of these papers is crucial for planners and others concerned and responsible for public safety from thrown ice. Unfortunately, a careful review of the data and techniques employed in these studies demonstrates that the studies do not provide a scientific basis for assessing risk to people and property from thrown ice. We will see

⁵ Barry Levy, MD, at the Symposium on a Public Health Approach to Environmental Health Risk Management, Commission on Risk Assessment and Risk Management, 1997.
<http://www.riskworld.com/Nreports/1997/risk-rpt/miscinfo/nr7mi003.htm>

⁶ Public Health and Safety, Power Naturally, NYSERDA, 2005. see pages 5-6 for discussion of 'ice shedding' and page 10 for references used to source the discussion.
At http://www.powernaturally.org/Programs/Wind/toolkit/18_publichealthandsafety.pdf

⁷ Assessment of Safety Risks Arising from Wind Turbine Icing, Colin Morgan, Ervin Bossanyi, Henry Seifert, Boreas IV, 1998. At http://virtual.vtt.fi/virtual/arcticwind/boreasiv/assessment_of_safety.pdf

1. As described in the words of one the study author himself (Dr. Henry Seifert), that the data presented *does not involve actual measurement* of distance and mass of thrown ice.
2. The studies *do not involve true surveillance* of thrown ice in the sense of actually seeking out evidence of ice fragments after icing events.
3. *The participation rate of the icing survey is too low* to conclude that the data is a representative sample of icing frequency and distance.
4. That the final safety *risk assessment is based not on observation but on calculations*. In doing these calculations the authors make assumptions concerning lift and drag. They assume zero lift and severe drag. These assumptions are not based on facts, and serve to dramatically reduce the calculated ice throw distance, and underestimate the public safety risk.

The fact that the papers by Morgan and Seifert are not peer review in part explains their publication with these deficiencies. They are funded by DEWI, the German Wind Energy Institute, and many are published in the company magazine “DEWI magazine”, which is not a peer review journal.

Peer review, meaning a review of the paper by non partial experts in the field, is considered crucial in avoiding bias and securing validity especially when the paper is funded by a company sponsored entity, such as DEWI, which has a proprietary interest in the conclusion of the paper. For instance, when a pharmaceutical company funds research on one of its own medications the study findings are regarded with suspicion unless the research reports are published in a peer review journal. These papers by Morgan and Seifert were not reviewed by objective experts in the field prior to publication. In fact, a search of the literature on icing and wind turbines turned up no papers in peer review journals concerning icing, this in spite of the consensus of the public safety issues concerning ice throws.

The data presented by Morgan in his paper on risk assessment is not derived from a published study, peer review or otherwise. The data used for his risk assessment, (which in turn is referenced by NYSERDA as the basis for its own risk assessment of thrown ice) is from ‘private communications’ from Henry Seifert at DEWI ⁸.

Morgan himself recognizes the lack of useful information on icing when he states ⁹

“As regards the size of ice fragments shed from rotor blades their mass and the distance which they are cast, there is very limited objective and subjective information. The only objective source of information is that collected in the recently completed EU Joule project *Icing of Wind Turbines*. As part of this work, carried out by DEWI and FMI, a questionnaire was circulated to a large number of turbine operators as described by Seifert. The questionnaire asked for information on the occurrence of icing including mass and location of any observed ice debris flung off the rotor. “

⁸ See above paper, page 121, reference number 4, ‘Private Communication from H. Seifert, DEWI, 1996’

⁹ see above paper, page 116

The methodology and results of this questionnaire were not published. In his paper Morgan cites 'personal communication' concerning the EU Joule project as the source of his data from this survey. The sum total of this information used by Morgan in his papers on risk assessment is presented in a chart with 17 point of data.¹⁰ Again, Morgan did not actually gather this data. These 17 points of data derived from a source that is not published but are the only data that forms the basis for Morgan's (and in turn NYSERDA's) recommendations concerning safety risk.

This is quite unusual. Typically, in valid studies the methods of the derivation of the data, the 'survey' used to derive the data, how the survey was administered, and the compliance rate of the survey would all be given. None of this is available for the study by Seifert that Morgan, and in turn NYSERDA rely on for risk assessment.

Evaluating the quality of this data which has an unpublished source is critical to understanding whether a risk assessment can accurately be derived from the information.

Since Henry Seifert was the source of the personal communications to Morgan, and Seifert's data remains unpublished, I communicated directly with Dr. Seifert to better understand the source of this critical data.¹¹

It turns out Seifert's data is derived from a survey done in the early 1990s of operators of wind turbines.

In this survey

1. The response rate was 13% of operators.
2. Ice was discovered in the context of going to and from a turbine to repair or service the turbine in winter conditions.
3. Dr. Seifert acknowledges that snowy winter conditions tend to prevent thrown ice from being noticed.
4. There study was not designed to include a systematic examination of the area surrounding the turbine after icing events to catalogue the frequency and distance of the thrown ice. Therefore a pro-active search for thrown ice was not performed.
5. **The data, as described by Seifert himself, is inaccurate and did not involve actual measurement.**

¹⁰ see above paper, figure 2, page 116.

¹¹ Email stream between Henry Seifert, PhD and Kenneth Jaffe, MD concerning Dr. Seifert's Survey on Ice Throws, 2006.

Elaborating on the lack of actual measurement of ice throw distance and weight, Seifert describes the data on mass and distance of thrown ice as ‘rough guesses’ rather than measurements. His description of this process follows¹²

“In most of the cases the numbers given in the questionnaires are rather inaccurate, meaning that the mass of the fragments as well as the distances were rough guesses rather than exact measurements. Normally you don’t go to the site with a weighing machine and a tape measure.”

Given these limitations and study biases, it is likely that the actual number and distance of the ice fragments are both greater than presented in this data.

The key point of this discussion is that we simply do not have empirical data to make predictions or judgments about icing risk to people and property. The ‘studies’ discussed above are really not an adequate basis for risk assessment or forming public policy.

RISK CALCULATIONS, BIASED ASSUMPTIONS

In spite of his lack of data on ice throws, Morgan makes an attempt to quantify the public safety risk. In doing so he resorts to a calculation based on a series of assumptions which are not based on data, and which dramatically minimize the distance traveled by thrown ice. This calculation is done in another of his papers which he uses as his source.¹³

Morgan assumes that drag on thrown ice is very high (leading to shorter throw distance) and the lift is non-existent (also leading to shorter throw distance). He assumes that the drag coefficient is 1.0. For context I have included a list of drag coefficients of various objects. Please note that the drag coefficient of an aircraft wing (shaped similarly to the turbine blade on which the ice is formed) approaches zero.¹⁴ Morgan’s own calculations show that as drag approaches zero, the throw distance is over 1500 feet for a 75 foot turbine blade --- 4 times the calculation using his assumptions.¹⁵

¹² See above reference, page 1

¹³ Wind Turbine Icing and Public Safety---A Quantifiable Risk?, Morgan and Bossanyi, 1996. Presented at the wind industry conference Boreas III.

At <http://www.easthavenwindfarm.com/filing/feb/ehwf-ml-reb4.pdf>

¹⁴ Aerodynamic Database, Drag Coefficients, page 2, at <http://www.aerodyn.org/Drag/tables.html>

¹⁵ see Figure 5, the top line in the graph, which is the ‘no drag’ line in Morgan’s paper, reference no. 13,

A fuller discussion of the inappropriateness of Morgan's assumptions can be found in a paper by Dr. Terry Matilsky, a Professor of Physics and Astronomy at Rutgers University.¹⁶

Comments on inclusions of drag coefficients and risk assessment

Friction is not a fundamental force. What this means in practice is that any attempt to take into account air resistance in a description of ice throw can be fraught with model dependent errors. The drag coefficient usually quoted in wind developers' "papers" of 1.0 is totally inappropriate for the study. They assume a perfect ice cube of size = 4 inches. Then, they assume it always tumbles. But these are chunks of ice that are forming on propeller blades. Ice that forms on propeller blades tends to be shaped like propeller blades. And they can be QUITE aerodynamic (as are the blades). Any models employing ice cubes are at best, useless, and at worst, deceptive.

Moreover, the study of "harvested" ice that is subjected to wind tunnel testing is likewise demonstrably without merit. The procedure is to break off chunks of ice, make molds, and then subject them to wind tunnel tests. But real ice melts. It changes shape. It becomes smoother. The "studies" ignore this, instead adopting a drag coefficient = 1.0 This is close to the drag that a half a tennis ball (say) would present if it were thrown into the wind with the open "cup" catching the wind at all times. A rather silly assumption and one that is totally inappropriate. Ice is not like this. While the developers tout their results as being representative (decidedly untrue), they ignore MacQueen's 1983 study that concluded that a maximum range of 800m (about 2500 feet) was quite possible. Indeed, even a range of 2 km. (over one mile) was conceivable. Developers discount this because he "assumed that the ice 'fragments' were actually large flat slabs weighing perhaps 80 kg." Actually, he was modeling BLADE throw, another issue that seems to be ignored despite the fact that within the past year there has been at least one documented instance of this; an entire rotor blade broke off from the hub. (Wethersfield, N. Y.) Incidentally, as near as I can tell, the MacQueen study is the ONLY peer reviewed analysis for throw possibilities. The rest are calculations done by wind company employees and/or consultants.

¹⁶ Analysis of Ice and Rotor Throw from Wind Turbines, Matilsky, see part II, 'comments on inclusion of drag coefficients and risk assessment. At <http://xray.rutgers.edu/~matilsky/windmills/throw.html>

Let me summarize the situation with the studies by Seifert and Morgan that are being used as the basis of wind industry information and for NYSERDA's policy on risk to people and property from thrown ice.

1. We do not have true measurements.
2. We do not have true surveillance.
3. We do not have an adequate survey response rate.
4. We do not have risk calculations based on assumptions that are appropriate to the physical properties of ice formed on turbine blades.
5. We do not have publication (10 years after the data was gathered) in a peer review journal, to ensure accuracy and impartiality.

Earlier the calculated theoretical distance that ice could travel given the height and speed of a turbine blade was discussed. Until an actual icing surveillance study is available as an empirical guide we are left having to use this calculated theoretical distance---of one half mile--- as the basis for creating policy designed to protect public safety.

ADDENDUM

On June 7th the New York State Department of State made a presentation in Delaware County which included a discussion of safety risks from ice throws. Unfortunately the information was misleading, did not use credible sources and factually incorrect. The information concerning sound was even more problematic, and will be discussed in my note on noise at a later date.

The totality of the information presented concerning ice throws and public safety as guidance for planners and town officials was

1. A chart purporting to show the distance traveled by thrown ice. This chart actually concerns **stationary turbines, not turbines with blades moving** at 150 to 200 mph. The chart which the DOS used (copied from a paper by Seifert¹⁷) is titled “Typical result of an ice fall width calculation for a turbine at standstill”.
2. The DOS refers to two “Insurance Testimonials” on the NYSERDA website. These letters are from insurance brokers are in Palm Springs, California and Torrence, California, both desert areas of Southern California not subject to icing.
3. The main source used in the DOS presentation (described in the slide she showed and included in the handout) is a paper from Williams College. She states the “study reports icing in that climate typically 3 to 5 days a year and calculates the risk as acceptable”. A few points about this report will help one understand its scientific quality and how it reflects on the decision to use it as the primary reference in a presentation to government decision makers.
 - a) The Williams College “study” is not actually a study.¹⁸ It is a report written by undergraduate students (see page 8) in an environmental course at Williams in support of a local wind turbine project.
 - b) The Williams paper expresses concern about liability issues (page 22) being caused by injuries from thrown ice striking hikers using a trail near the proposed turbines and suggests moving the trails to avoid injury and liability issues.
 - c) The nearest residence to the proposed turbines in the project discussed in the Williams students’ paper is over one mile (as discussed in the report’s discussion of noise, page 16-17).

¹⁷ see figure 5, page 6 of Risk Analysis of Ice Throw from Wind Turbines, Seifert et al, presented at Boreas 6 conference. At <http://web1.msue.msu.edu/cdnr/icethrowseifertb.pdf>

¹⁸ Report of the Feasibility of a Wind Power Project on the Berlin Pass.
<http://www.williams.edu/CES/mattcole/resources/onlinepaperpdfs/papers/Wind.pdf>

- d) The students' paper cites a report by Schaffner¹⁹ as the source of their statement "Although our turbines would have blade diameters of 80 m (260 ft), ice throw danger from ice throws from any turbine with blade diameters over 40 m (130 ft) is the same." In fact *Schaffner makes no such statement and does not even address the issue of ice throw distance*. Rather, Schaffner's paper is simply a report of a technology (SODAR) designed to sense when ice forms on turbines in remote locations.

- e) The only information the Williams students use to form their risk assessment is discussed in my main report---Seifert's survey which did not use actual measurements to create his data (and presented as 17 points on a chart) and the paper by Morgan work (discussed above) which made a series of calculations that assumed thrown ice would not retain the shape of the turbine blade on which it was formed.

The point of this review is to indicate that the presentation by the NY State Department of State to officials in Delaware County did not give a true sense of the science concerning ice throws in the region, and did not provide adequate information or appropriate guidance for officials interested in protecting public safety.

¹⁹ Schaffner, Beat. "Wind Energy Site Assessment in Harsh Climatic Conditions: Long Term Experience in the Swiss Alps". Bern, Switzerland. At http://virtual.vtt.fi/virtual/arcticwind/reports/harsh_climate.pdf