## Don Metzger

**From:** Lein, Jerry R. [jlein@nd.gov]
**Sent:** Monday, April 27, 2009 3:47 PM
**To:** Don Metzger; Mary Horner
**Cc:** Hamre, John G.; Marquart, Janet R.
**Subject:** FW: Information Request - Case No PU-07-54

In follow-up to the working session this morning, the Commission is requesting Just Wind provide the following additional information:

1. For each turbine proposed to be located less than 1400 feet from a residence or place of business, please provide the specific reason(s) why Just Wind is proposing that location.
2. Regarding p.28 that appears to have been appended to the Mitsubishi 2.4 MW turbine specifications Just Wind filed on April 17, 2009:
   a. What is the source of page 28?
   b. Please provide the noise diagram and additional information referred to on page 28 as being "included as figure 13" and specifically identify the threshold distance at which the expected noise level is below 50 dB.
3. Regarding the article "Ice Tossing Turbines: Myth or Hazard" included with the icing information filed by Just Wind on April 17, 2009:
   a. What is the source of this article?
   b. Please provide a copy of the American Wind Energy Association's brief and handbook or relevant portions of the handbook.
   c. Please provide a copy of the 2006 publication by G.E. Energy warning that "rotating turbine blades may propel ice fragments some distance from the turbine – up to several hundred meters if conditions are right."
   d. Please provide a copy of the Swiss report titled "Wind Turbine Ice Throw Studies in the Swiss Alps" and the "earlier German study referenced in that section.
   e. Please provide a description of what efforts Just Wind will take to minimize any risk of ice throws.

Please let me know If you have any questions or difficulties providing any of this information. Thanks.

Jerry Lein
701 328-1035


Just Wind, LLC

# Reasoning For Proposed Turbine Locations Under 1400 Ft.

Turbine locations were based on the optimal positions calculated by the WindPro computer model. The wind farm analysis and energy calculations were produced by EAPC Architects Engineers (Grand Forks, ND) in accordance with the current Logan County zoning ordinances.

T-95 located 884 ft. West of the Marcella Bitz residence

T-156 located 903 ft. North of the Scott Schumacher residence

T-153 located 945 ft. Southeast of the Ryan Johnson residence

T-91 located 1007 ft. Northeast of the Charles Nord residence

T-155 located 1076 ft. South of the Allen Foster abandoned farm

T-16 located 1186 ft. Northeast of the Jeff Metzger residence

Figure 15

American Wind Energy Association

# FACTS ABOUT WIND ENERGY AND NOISE

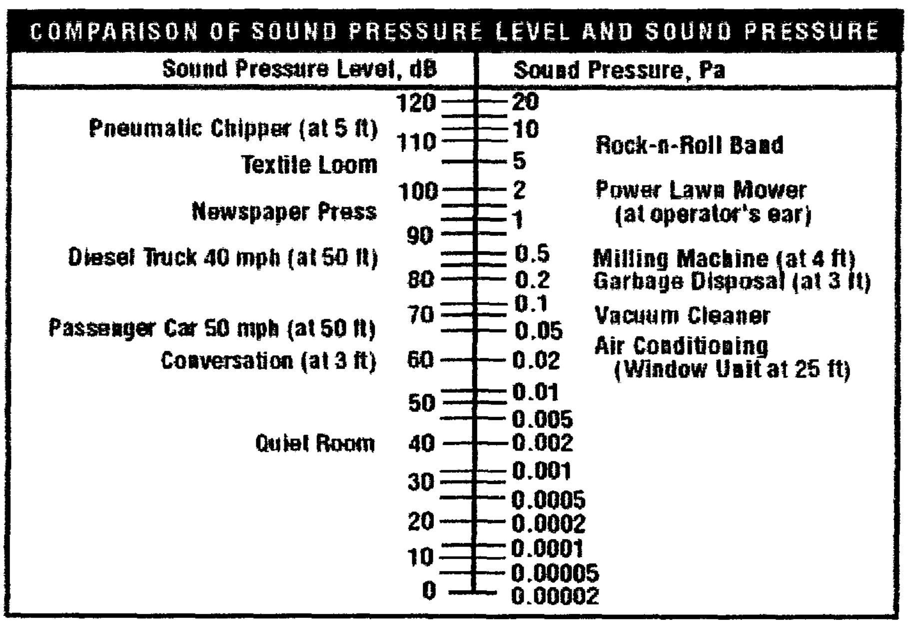
## What is noise?

"Noise," when one is talking about wind energy projects, basically means "any unwanted sound."

Whether a noise is objectionable will vary depending on its type (tonal, broadband, low-frequency, impulsive, etc.) and the circumstances and sensitivity of the individual who hears it (often referred to as the "receptor").

As with beauty, often said to be "in the eye of the beholder," the degree to which a noise is bothersome or annoying is largely in the ear of the hearer. What may be a soothing and relaxing rhythmic swishing sound to one person may be quite troublesome to another.

Because of this, there is no completely satisfactory and impartial way to measure how upsetting a noise may be to any given person. Still, it is possible to objectively measure how loud a noise is. Here is a table showing the loudness ("sound pressure level") of some common noises:




Source: Canadian Centre for Occupational Health and Safety
(see www.ccohs.ca/oshanswers/phys_agents/noise_basic.html ).

**What kinds of noise do wind turbines produce?**

Wind turbines most commonly produce some **broadband** noise as their revolving rotor blades encounter turbulence in the passing air. Broadband noise is usually described as a "swishing" or "whooshing" sound.

Some wind turbines (usually older ones) can also produce **tonal** sounds (a "hum" or "whine" at a steady pitch). This can be caused by mechanical components or, less commonly, by unusual wind currents interacting with turbine parts. This problem has been nearly eliminated in modern turbine design.

**How noisy are wind farms?**

Good question, and a difficult one.

Wind plants are very, very quiet compared to other types of industrial facilities, such as manufacturing plants, but most industrial plants are not located in rural or low-density residential areas. In those types of areas, background noise tends to be lower than in urban areas.

On the other hand, wind plants are always located where the wind speed is higher than average, and the "background" noise of the wind tends to "mask" any sounds that might be produced by operating wind turbines—especially because the turbines only run when the wind is blowing. The only occasional exception to this general rule occurs when a wind plant is sited in hilly terrain where nearby residences are in dips or hollows downwind that are sheltered from the wind—in such a case, turbine noise may carry further than on flat terrain.

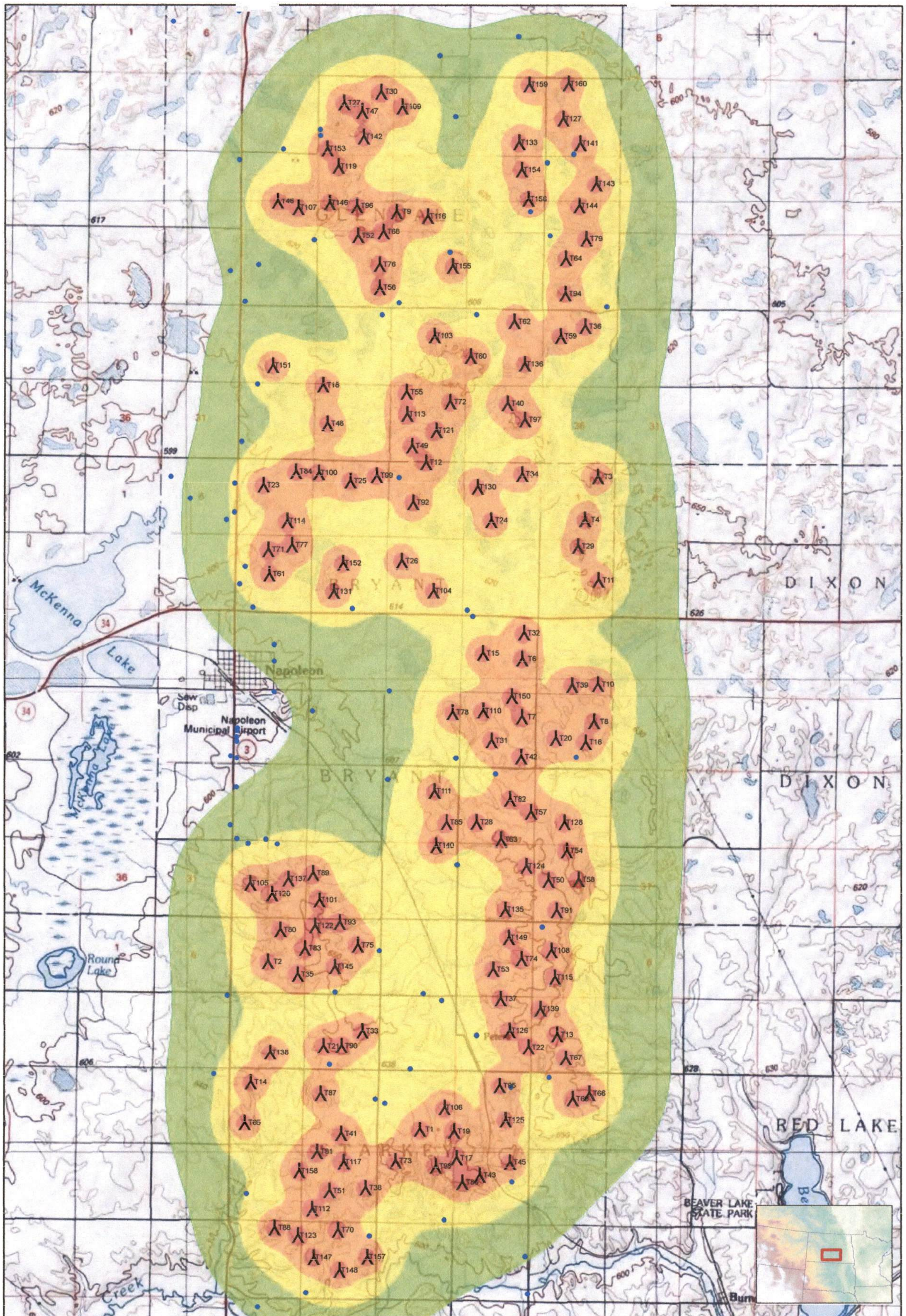
Virtually everything with moving parts will make some sound, and wind turbines are no exception. However, well-designed wind turbines are generally quiet in operation, and compared to the noise of road traffic, trains, aircraft, and construction activities, to name but a few, the noise from wind turbines is very low.

Noise used to be a very serious problem for the wind energy industry. Some early, primitive types of turbines built in the early 1980s were extremely noisy, to the point that it was annoying to hear them from as much as a mile away. The industry quickly realized that this problem needed to be dealt with, however (particularly in Europe, where turbines are often located in or near residential areas), and manufacturers went to work on making their machines quieter.

Today, an operating wind farm at a distance of 750 to 1,000 feet is no noisier than a kitchen refrigerator or a moderately quiet room.

| Source/Activity | Indicative noise level dB (A) |
|---|---|
| Threshold of hearing | 0 |
| Rural night-time background | 20-40 |
| Quiet bedroom | 35 |
| Wind farm at 350m | 35-45 |
| Car at 40mph at 100m | 55 |
| Busy general office | 60 |
| Truck at 30mph at 100m | 65 |
| Pneumatic drill at 7m | 95 |
| Jet aircraft at 250m | 105 |
| Threshold of pain | 140 |

Source: The Scottish Office, Environment Department, Planning Advice Note, PAN 45, Annex A: Wind Power, A.27. Renewable Energy Technologies, August 1994. Cited in "Noise from Wind Turbines," British Wind Energy Association, http://www.britishwindenergy.co.uk/ref/noise.html .




**Logan County Wind Farm MWT 95-2.4MW Noise**

*Client*

Just Wind, LLC

*Project #:* 20064001

*Location:* Napoleon, ND

*Issue Dates*

B. Storm - 04-28-2009

*Project Description*

Noise Calculations for
MWT 95-2.4MW WTGs
Layout as of 04-28-2009



*Legend*

- Potential Occupied Residence

Noise from WTGs

- 40 dB
- 45 dB
- 50 dB
- 55 dB

EAPC

0 0.25 0.5 1 1.5 2 Miles

The New York Times
Monday, April 27, 2009

# Energy & Environment



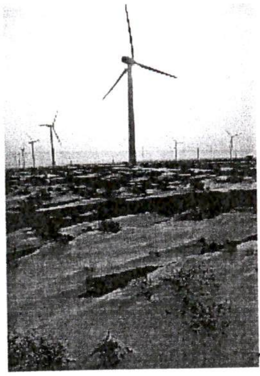
**Green Inc.**

**Energy, the Environment and the Bottom Line**

December 9, 2008, *10:00 pm*

## Ice-Tossing Turbines: Myth or Hazard?

By *Kate Galbraith*


They produce clean energy, sure, but they can also hurl a mean snowball. (Photo: Getty Images)

How do wind turbines fare in winter weather?

Not so well, according to one little town in England. The Wisbech Standard reports a harrowing tale in which "lumps of ice three or four feet long flew through the air" and smashed into a carpet showroom and a parking lot.

They apparently came off the spinning blades of a 410-foot-tall wind turbine.

No one was hurt, but residents of Whittlesey, in the southeastern part of England, would not rest until the turbine was shut down. One local businessman described the ice shards as "javelins" coming off the blades.

The wind industry concedes that, as with all tall things (buildings, for example, or trees), ice and snow can build up and, eventually, fall down, creating a hazard to people and structures below.

But the industry denies that "ice-throwing" — another concern surrounding wind power — is a problem. "Ice can end up at places other than exactly at the base of the turbine, but it's a myth that a turbine will (and can) operate at high speed with ice on it and fling ice for miles," said Ron Stimmel of the American Wind Energy Association, in an e-mail message.

Just as an airplane will not be able to fly with too much ice on its wings, Mr. Stimmel said, wind turbines are designed to stop or shut off automatically, he said, when they sense the extra weight of ice.

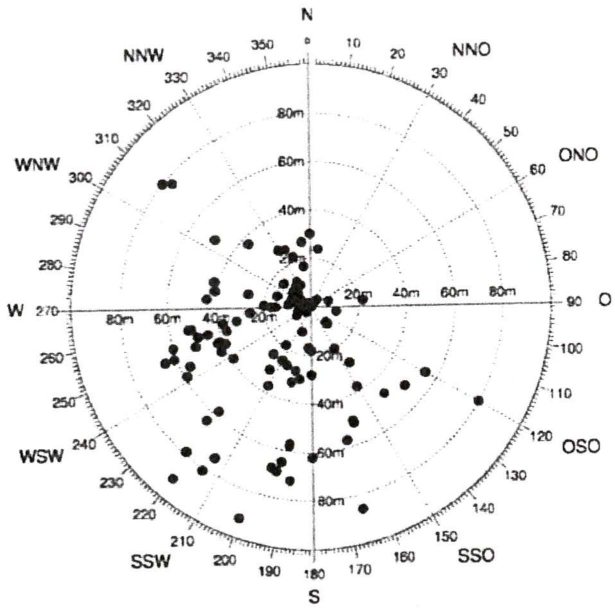
The American Wind Energy Association has posted a brief on the subject, and also discusses the issue in its handbook for siting new wind projects.

But a 2006 publication by G.E. Energy, a maker of large wind turbines, warns that "rotating turbine blades may propel ice fragments some distance from the turbine — up to several hundred meters if conditions are right."

Its recommendations include placing fences and warning signs around turbines, and locating them a safe distance from buildings or roads. They also recommend deactivating turbines when ice begins to form.

A Swiss report last year, titled "Wind Turbine Ice Throw Studies in the Swiss Alps," focused on a turbine near a ski area. That report found ice throw to be a "significant safety risk." The most dangerous place for ice was underneath the turbine, but about 5 percent of fragments landed more than 80 meters — or 260 feet — from the turbine.

A chart from the study shows where and how far ice and snow were flung, relative to the position of the turbine:




Distribution of ice throw relative to the wind turbine. (Source: Wind Turbine Ice Throw Studies in the Swiss Alps)

An earlier German study came to a similar conclusion:

> As a general recommendation, it can be stated that wind farm developers should be very careful at ice endangered sites in the planning phase and take ice throw into account as a safety issue. Each incident or accident caused by ice throw is an unnecessary event and will decrease the public acceptance of wind energy.

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**From Around the Web**

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**20 Comments**

1. 1. December 10, 2008 3:05 am Link

   Hmmmm….I wonder if they made the blades with a teflon type coating if that would help.

   — *Tim*
2. 2. December 10, 2008 9:01 am Link

   de-icing heaters have long been a staple on other high structures, notably broadcast towers. back when i was an fm dj in the 70s one of my many jobs was activating the de-icers when the engineers called. back then it was simple push button affair. today's systems are totally automated.

   - js.

   — *JackSpratts*
3. 3. December 10, 2008 9:10 am Link

   The cure is simple - use less electricity. Don't build these things - they also attract NIMBYs.

   — *marcelduchamp*
4. 4. December 10, 2008 9:10 am Link

   Tim - might that same coating also reduce air friction, effectively reducing energy production?

   — *max*
5. 5. December 10, 2008 9:19 am Link

   i guess the only law that is certain is the law of unintended consequences.

   — *j.w.*
6. 6. December 10, 2008 9:30 am Link

   max- if you applied Teflon to the curved side of the blade, that would increase wind speed over the curved part thereby enhancing the Bernoulli effect, and Increasing energy production. Also prevents ice/snow attachment to the blade as in tim's brilliant post..

   — *donkee*
7. 7. December 10, 2008 9:35 am Link

   max — no, reducing air friction is a good thing. wind turbines work like airplane wings, and in general, you want less skin friction so the air can flow around the wings (or in this case turbine blades) and create a lifting force. though I doubt such a coating would make any noticeable difference.

   seems like it would be trivial though to divert some of the energy created by the turbine to a de-icer.

   — *Benton*
8. 8. December 10, 2008 9:37 am Link

   Red Lobster is bragging about burning wood
   to cook it's food.
   Put a Red Lobster under a turbine.
   Write the bragging wood burner and tell
   them about carbon

   — *Al Louard*
9. 9. December 10, 2008 9:51 am Link

   This is something to be encouraged, not cured. Teach young boys about the javelin-throwing potential of windmills, and you'll create a lot more youth interest in green energy.

   We could have teams of turbines set up to throw snow at each other. The cost of periodically knocking one down would be more than made up for by the enthusiasm such windmill snowbattles would generate. You could create betting pools, tailgate parties, sell tickets, all sorts of great green possibilities.

Green needs to embrace a bit more macho, and these snow turbines are a big step in that direction.

http://www.boldizar.com

— *Boldizar*

10. 10. December 10, 2008 10:15 am Link

I find it maddening that the distance from wind turbine to town was not mentioned in article. Sounds like it would have had to have been less than 300 feet away.

— *Brooks*

11. 11. December 10, 2008 11:14 am Link

It should be noted that a modern turbine will have a rotor diameter of roughly 80M, so any ice falls within the 40M circle on the rose chart likely aren't even ice throws, just ice falling off the blades. Don't stand directly underneath the turbine and you'll be fine.

Also, turbine setbacks are often 750-1000 feet, well beyond any reported distance of ice throw.

— *Windy*

12. 12. December 10, 2008 11:29 am Link

Given their ability to dodge serious safety issues, siting issues and damage to wildlife, I'd say that teflon has already been applied to the developers, the government and local planning bodies….

— *David*

13. 13. December 10, 2008 12:11 pm Link

Teflon is a good idea or apply the de-icing method that the Coast Guard uses on it's helicopters up in Alaska.

— *Capt. Concernicus*

14. 14. December 10, 2008 12:34 pm Link

Looks like this turbine had a ridiculously small setback. The linked article from the Wisbech Standard says:
>>>
"The Danish government will not accept turbines being built within 600 metres of homes or businesses, and we have a turbine 65 metres from my son's home," he said. "If the ice hit someone, it would definitely kill them."

Mr Randall is furious that the £2million turbine, which stands 125-metres high, was erected so close to buildings.
<<<

— *JT*

15. 15. December 10, 2008 8:45 pm Link

simply drilling for more oil will eliminate the need for these things. Once the north pole melts we will have lots of new locations for drilling

— *Scott Oman*

16. 16. December 11, 2008 3:45 pm Link

I doubt teflon per se will fit the bill in this case - the teflon layer would be too prone to damage…. well there are plenty of alternative materials that would have the same effect. One of them should be durable enough i would think.

On another note, this makes me glad i don't live in Toronto. Several are located beside major thoroughfares. I can just see the headlines if someone's car get skewered.

— *Sean*

17. 17. December 16, 2008 8:31 am Link

Wind power is not a solution.
The whole truth about wind turbines is never told by lobbyists and governments.
How could the very weak and extremely unreliable initial energy source of a wind turbine ever produce a steady power of any significance, despite the fact that modern wind turbines are really sophisticated machines?
Please think!
And read: "Wind energy- the whole truth" at: http://www.windenergy-the-truth.com/

— *Alexander*

18. 18. December 17, 2008 12:23 am Link

Very clever observation, David, Oct. 10th on "Teflon" coated developers, the government, local planning bodies" are in effect above the law.

We can sue ourselves when regulators fail to provide adequate protection to the public and endangered wildlife in their consideration of wind turbine permits.

http://blog.aklandlaw.com/2008/10/articles/ceqa/wildlife-protected-by-the-public-trust-doctrine-but-doctrine-can-only-be-enforced-against-public-agencies/index.html

"Ice throw has been reported to 140m."

"These are indeed only a very small fraction of actual incidences - a report* published in 2003 reported 880 icing events between 1990 and 2003 in Germany alone. 33% of these were in the lowlands and on the coastline."

Caithness Windfarm Information Forum
30 September 2008

http://www.caithnesswindfarms.co.uk/page4.htm

The summary may be downloaded in printable form:

http://www.caithnesswindfarms.co.uk/accidents.pdf

The full accident list may be downloaded here:

http://www.caithnesswindfarms.co.uk/fullaccidents.pdf

*— Barbara Durkin*

19. 19. December 21, 2008 12:42 am Link

Someone calling himself Marcel Duchamp posted a comment on this blog. I don't know him, but I want people to know that he and I are two different persons.

Mark Duchamp

*— mark duchamp*

20. 20. February 27, 2009 3:24 pm Link

We had a small windmill on the ranch when I was growing up, one of those kind you see in Depression-era photographs taken somewhere on the Great Plains. Beyond it's normal function of pumping water, it also could power a couple light bulbs if there was a modest breeze, and charge back-up batteries when we were somewhere else on the ranch.

And the part of Texas where the ranch is, isn't particularly given to wind power, rating out in the lower half of average. Say maybe around 40 on a 100-point scale.

I can see how ice coming of blades could be a concern, especially ice dropping directly below the windmill blades.

But somehow I doubt this will become a major concern. There are other reasons for requiring separation — noise springs to mind, since some folks find it irksome, even dangerous, in the sense of inducing stress and related symptoms (such as headaches).

Sure, the wind doesn't blow all the time, so there's that consideration in looking at this as a power source, but that angle isn't really what the article is about.

*— Mekhong Kurt*

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*— Lightbulb*
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**Tom Zeller Jr.**

Editor

After a year as an editor at large for National Geographic magazine, Tom returned to The New York Times in July 2008 to help expand the paper's coverage of sustainable energy development and green business. He has spent much of the last decade as a reporter and editor covering a variety of topics for The Times – from technology and cyberfraud to culture and politics.
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**Kate Galbraith**

Reporter

Ms. Galbraith joined The New York Times in June 2008 to write about renewable energy. She spent the previous year as a Nieman Fellow at Harvard University, and before that she was the Southwest correspondent for The Economist based in Austin, Tex. She is an avid runner and hiker, having grown up camping most summers in the Sierra Nevada.
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**James Kanter**

Reporter

Mr. Kanter has been a staff correspondent for The International Herald Tribune in Paris and Brussels since 2005, covering European business affairs and the business of green. His previous experience includes four years in Southeast Asia, where he was the editor in chief of The Cambodia Daily in Phnom Penh and oversaw coverage of environmental issues like uncontrolled logging.
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***Senior Contributors***
*Felicity Barringer, San Francisco; Clifford Krauss, Houston; Micheline Maynard, Detroit; Jad Mouawad, New York; Matthew L. Wald, Washington*

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- Los Angeles Times: Greenspace
- MapAWatt Blog
- Sustainablog
- The Inspired Economist
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- The Oil Drum
- Wall Street Journal: Environmental Capital
- World Changing

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- Green-e
- Greener Choices
- Grist
- Jamble Magazine

- MetroGreen+Business
- National Geographic Green Guide
- Solar Buzz
- The Daily Green
- Treehugger

**Institutions**

- Climate Matters @Columbia
- DOE: Office of Energy Efficiency and Renewable Energy
- Energy Star
- European and Chicago Climate Exchanges
- European Commission Directorate General for Environment
- European Federation for Transport and Environment

- International Energy Agency
- National Renewable Energy Laboratory
- United Nations Environment Program
- United Nations Framework Convention on Climate Change
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**News Sources**

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- Alternative Energy News
- BBC News: Global Climate Change
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- GreenBiz.com
- Greentech Media
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**Organizations**

- American Wind Energy Association
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- Interstate Renewable Energy Council

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*ADVICE FROM AN EXPERT*
***by Mick Sagrillo***

# HOME-SIZED WIND TURBINES AND FLYING ICE

One nagging question that frequently comes up at zoning permit hearings for home-sized wind turbines is the possibility of ice being thrown from the blades and causing property damage or injury. It seems that some anti-wind farm NIMBY (not in my back yard) groups around the country have slowed the permitting of wind farms by raising this concern, and the issue is beginning to show up at home-size turbine hearings too. Fortunately, there are factual ways to show that, while ice is a valid concern, wind turbines flinging ice is not.

A review of the literature available identifies several papers and reports that address ice throws at large wind farms, but none about home-sized turbines. Nonetheless, it is worthwhile examining these reports to understand their relevance to home-sized wind systems, and draw any applicable conclusions.

But, first, let's look at the ice-throw concerns raised on the anti-wind Web sites. These sites typically describe a conjured-up scenario where a large chunk of ice is dislodged from a blade tip rotating at the turbine's design speed or, worse, when the turbine is unloaded and spinning at maximum speed. The chunk of ice is then assumed to fly quite far along an ideal trajectory resulting in a maximum amount of damage at the end of its long path.

The described scenario is laid out as a classic physics problem with lots of idealized assumptions, or, as physics professors often stipulate, "on a frictionless plane." The professor will lay out a perfect scenario to prove a point. However, the assumptions in the anti-wind turbine scenario reveal either an ignorance or a disregard of the physics of wind turbines. A blade coated in ice can not achieve anywhere near its top speed, and therefore the ice, if it could be thrown, would not move very far from the base of the turbine.

Other "perfect" but unrealistic assumptions built into this theory are:

- The blade rotation is in the right plane to maximize the ice trajectory, distance, and subsequent damage;
- The ice chunk has an aerodynamically ideal shape for long-distance travel;
- The wind speed and direction are optimal; and
- The ice chunk remains in one piece long after detaching from the blade.

Looking more closely at the aerodynamics of wind turbine blades, one sees that they are designed as airfoils that operate on the principle of lift, just like an airplane wing. On airplanes, the lift caused by air rapidly passing over the wing's airfoil raises the wing and the plane off the ground. For wind turbines, it is this same aerodynamic lift that pulls the turbine blade through the air. However, there is also friction between the surface of the plane's wing or turbine's blade and the moving airflow which causes a certain amount of aerodynamic drag. The circular movement of a wind turbine blade, like the success of an airplane getting off the ground, depends upon a very high lift to drag ratio, and both are designed to optimize the lift-drag relationship. Reduce lift, or increase drag, and the wind turbine slows significantly. Similarly, the airplane cannot continue to fly.

Ice forms on a wind turbine's blades in relatively thin sheets, just as it does on trees, utility poles, power lines, and communication towers during an ice storm. But any ice buildup on a turbine's airfoil changes its shape, radically reducing the lift-drag ratio and increasing its surface friction. This results in the airfoil's lack of ability to develop any speed. If you watch a wind turbine operating during an ice storm, you will notice that it gradually slows down as ice adheres to the leading edge and windward surface of the blades. This phenomenon is well known to anyone who flies on a commercial airliner during the winter. Jets' wings are often "de-iced" before takeoff to prevent ice buildup on the wings that would result in the plane crashing on take-off, if it could take off at all.

A very interesting thing happened in my neighborhood this past January during one of our infrequent ice storms. Madison Gas & Electric (MGE) operates an eight-turbine wind farm about three miles west of my house. During the ice storm, the wind was still, and ice built up on roads, trees, utility poles, houses, cars, and the MGE's wind turbines. The next day, the sun broke through the clouds long enough to melt the ice off one of the MGE Vestas V-47 turbines. When the wind picked up, that turbine spun up to its normal rotor operating speed of 28 rotations per minute (rpm), while the others lagged along at about seven or eight rpm. The turbine that was spinning normally had shed its ice. Since the other seven did not shed their ice, the remaining ice destroyed the aerodynamics of their airfoils. It was a wonderful display of wind turbines operating side by side with and without ice, leaving me to lament the fact that I do not own a video camera.

What does all of this have to do with the aforementioned physics problem? When compared to the idealized ice-throw scenario postulated by wind turbine opponents, which assumes high speed blade rotation, this was a excellent display of the fact that ice covered wind turbine blades cannot "get up to speed." One experienced wind turbine dealer I know likened the situation to trying to drive a car with four flat tires. You can move, but not very fast. Anyone who has a home-sized wind turbine that has experienced ice buildup can verify this fact, as can wind farm operators. As a result, the ability of a wind turbine to fling ice great distances is pretty much an impossibility – a conclusion supported by the fact that this phenomenon has not been documented in the real world.

On the few occasions when ice does form on wind turbine blades, many homeowners and utility turbine operators will shut their wind machines down until the sun or warmer temperatures melt the ice off of the blades. The ice coating on blades is in sheets, just as it forms on trees, houses, cars, roads, and utility lines during an ice storm. As it melts, it breaks up into small fragments and falls from the tower and turbine – not large chunks as assumed by the "perfect" scenario.

This situation does bring up a valid safety concern, however. As the ice sheds, it falls to the base of the tower unless there is a wind, in which case it will fall with the wind. Any prudent person would be well advised to stay away from the tower base during this time, the same safety precaution anyone would take with ice falling off of trees, building roofs, utility poles, cell phone towers, or power lines. This is just common sense.

In the real world, wind farm operators report that the ice does not fall beyond the tower base during light breezes, and not even as far as the tower's fall zone during heavier winds. In fact, the biggest concern expressed about ice buildup on commercial turbines is not even about ice shedding, but about the loss of production time when the turbine is covered in ice and can't spin properly.

There has been one excellent paper done on the risk assessment of injury or property damage due to shedding ice. The work is titled "Assessment Of Safety Risks Arising From Wind Turbine Icing," by Colin Morgan, Ervin Bossanyi, and Henry Siefert. The study notes that, "there has been no reported injury from ice thrown from wind turbines, despite the installation of more than 6,000 MW of wind energy worldwide." The paper concludes that the risk of anything or anyone being hit by ice from a wind turbine is "10-6 strikes/m2/year, which is the typical probability of (being hit by a) lightning strike in the UK" (The authors are from the UK.)

Since it's essentially a nonexistent problem, there have been few studies of the ice throw scenario with wind farms, no studies on home-sized turbines, and no reports of personal injury or property damage. As even our wind turbine opponent friends would have to admit, any problems with wind turbines are well documented and well reported. One can only conclude that it is less than fruitful to spend valuable financial and personal resources to study a nonexistent problem.

*--Mick Sagrillo, Sagrillo Power & Light*

*[Editor's Note: The opinions expressed in this column belong solely to the author.]*

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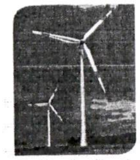
These risks and associated mitigation techniques may be incorporated into an overall emergency action plan to be used throughout construction and operation by project personnel in coordination with local emergency management officials. This coordination should be initiated early in the development process to ensure a sound emergency action plan to be carried through construction and operation.



**Public health and safety risks and associated mitigation techniques may be incorporated into an overall emergency action plan to be used throughout construction and operation by project personnel in coordination with local emergency management officials.**

### 5.8.1 Ice Shedding

Wind turbines can experience periods when the weather conditions will result in ice build-up on the exposed parts of the turbine. In addition, it has been observed that the moving turbine rotor is liable to accrete heavier quantities of ice than the stationary components of the wind turbine. It has also been observed that the rotor ice can break off, and if the rotor is moving, be cast some distance.

Field observations indicate that most ice shedding occurs as temperatures rise and ice thaws from the rotor. A typical scenario is that ice builds up on the rotor and on the wind sensors, which are mounted on the nacelle. Sensor malfunction normally causes automatic turbine shutdown in most modern wind turbines. In this situation, most turbines will restart only when the ice has thawed and fallen from the stationary turbine and the operator has reset the sensors. However, in certain situations the operator will accelerate the process by thawing the sensors and restarting the turbine with ice still on the rotor. This may lead to shedding of ice. Operations staff is more likely to be affected than the public.

Studies have been conducted to try to characterize how ice fragments are shed from the rotor blades. While limited information is available, evidence does suggest that there is a tendency for ice fragments to be dropped off, rather than thrown off, the rotor. Also, ice tends to shed more from the blade tips, and larger pieces of ice debris tend to fragment in flight.

#### 5.8.1.1 Mitigation

Key steps to reduce the risk to the public or operational staff of injury due to ice shedding are provided. This should also be detailed in the facility's emergency action plan.

**Possible Mitigation Measures to Reduce Threat of Personal Injury from Ice**

- ✓ Design of turbine layout with appropriate setbacks from sensitive receptors and areas of regular public use to minimize risk of ice shedding injury.
- ✓ Education of operational staff about the conditions likely to lead to ice accretion on the turbine, the risk of ice falling from the rotor, and the areas of risk.
- ✓ Use of warning signs alerting anyone in the area of risk.
- ✓ Implementation of special turbine features that prevent ice accretion or operation during periods of ice accretion.
- ✓ Curtailment of operation of turbines during periods of severe ice accretion.

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# Ice Shedding and Ice Throw – Risk and Mitigation

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# Ice Shedding and Ice Throw – Risk and Mitigation

## Introduction

As with any structure, wind turbines can accumulate ice under certain atmospheric conditions, such as ambient temperatures near freezing (0°C) combined with high relative humidity, freezing rain, or sleet. Since weather conditions may then cause this ice to be shed, there are safety concerns that must be considered during project development and operation. The intent of this paper is to share knowledge and recommendations in order to mitigate risk.

## The Risk

The accumulation of ice is highly dependent on local weather conditions and the turbine's operational state.[2,4] Any ice that is accumulated may be shed from the turbine due to both gravity and the mechanical forces of the rotating blades. An increase in ambient temperature, wind, or solar radiation may cause sheets or fragments of ice to loosen and fall, making the area directly under the rotor subject to the greatest risks[1]. In addition, rotating turbine blades may propel ice fragments some distance from the turbine—up to several hundred meters if conditions are right.[1,2,3] Falling ice may cause damage to structures and vehicles, and injury to site personnel and the general public, unless adequate measures are put in place for protection.

## Risk Mitigation

The risk of ice throw must be taken into account during both project planning and wind farm operation. GE suggests that the following actions, which are based on recognized industry practices, be considered when siting turbines to mitigate risk for ice-prone project locations:

- **Turbine Siting:** Locating turbines a safe distance from any occupied structure, road, or public use area. Some consultant groups have the capability to provide risk assessment based on site-specific conditions that will lead to suggestions for turbine locations. In the absence of such an assessment, other guidelines may be used. Wind Energy Production in Cold Climate[6] provides the following formula for calculating a safe distance:

  **1.5 * (hub height + rotor diameter)**

  While this guideline is recommended by the certifying agency Germanischer Lloyd as well as the Deutsches Windenergie-Institut (DEWI), it should be noted that the actual distance is dependant upon turbine dimensions, rotational speed and many other potential factors. Please refer to the *References* for more resources.

- **Physical and Visual Warnings:** Placing fences and warning signs as appropriate for the protection of site personnel and the public.[4]

- **Turbine Deactivation:** Remotely switching off the turbine when site personnel detect ice accumulation. Additionally there are several scenarios which could lead to an automatic shutdown of the turbine:
  - 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)
  - Detection of rotor imbalance caused by blade ice formation by a shaft vibration sensor; note, however, that it is possible for ice to build in a symmetric manner on all blades and not trigger the sensor[2]
  - Anemometer icing that leads to a measured wind speed below cut-in

- **Operator Safety:** Restricting access to turbines by site personnel while ice remains on the turbine structure. If site personnel absolutely must access the turbine while iced, safety precautions may include remotely shutting down the turbine, yawing to place the rotor on the opposite side of the tower door, parking vehicles at a distance of at least 100 m from the tower, and restarting the turbine remotely when work is complete. As always, standard protective gear should be worn.

## References

The following are informative papers that address the topic of wind turbine icing and safety. These papers are created and maintained by other public and private organizations. GE does not control or guarantee the accuracy, relevance, timeliness, or completeness of this outside information. Further, the order of the references is not intended to reflect their importance, nor is it intended to endorse any views expressed or products or services offered by the authors of the references.


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GER-4262 (04/06)

# WIND TURBINE ICE THROW STUDIES IN THE SWISS ALPS

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## ABSTRACT

Icing is an important issue when operating wind turbines in high altitude or arctic areas as it can cause significant production losses and represent a safety risk.

In 2004, a 600 kW Enercon E-40 wind turbine with integrated blade heating was installed on Gütsch mountain, Switzerland, at 2'300 m asl. Coincidentally, a fully equipped test station of the Swiss meteorological network SwissMetNet is situated about 200 m from the wind turbine. The immediate proximity of the two facilities operating under icing conditions led to the launch of the national research project "Alpine Test Site Gütsch" which is embedded in the European "COST Action 727: measuring and forecasting atmospheric icing on structures".

As the wind turbine is located close to ski slopes, ice throw is an important safety issue. Since October 2005, the area around the wind turbine was inspected after every icing event for ice fragments that had fallen off the blades. Distance from and direction relative to the turbine as well as size and weight of the recovered fragments were mapped and, together with photos, collected in a data base. After data analysis, the following main conclusions could be drawn:

- Ice throw from the wind turbine occurs regularly during icing events at Gütsch.
- Ice throw can happen at any time of the year, even in summer.
- Most of the ice throw occurs underneath the blades of the wind turbine. This is therefore the most dangerous area.
- Ice throw is a significant safety risk at Gütsch.

## 1. INTRODUCTION

Icing is an important issue when operating wind turbines in elevated or arctic areas as it can cause significant production losses and represent a safety risk [1]. In 2004, a 600 kW Enercon E-40 wind turbine with integrated blade heating was installed on Gütsch mountain, central Switzerland, at 2'300 m asl. Coincidentally, a fully equipped test station of the Swiss meteorological network SwissMetNet was installed about 200 m away from the wind turbine in 2003 (Fig. 1). The immediate proximity of the two facilities operating under icing conditions led to the launch of the research project "Alpine Test Site Gütsch: meteorological measurements and wind turbine performance analysis" [2] which is embedded in the European "COST Action 727: measuring and forecasting atmospheric icing on structures" [3].

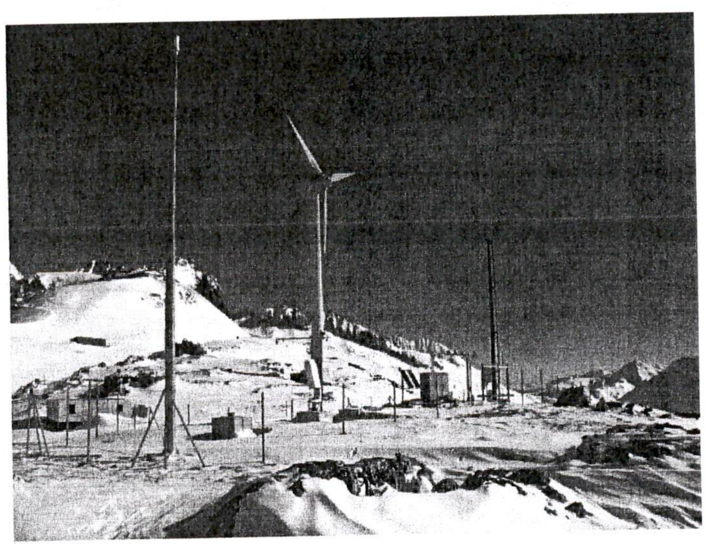

Figure 1: Alpine Test Site Gütsch.

## 2. SITE DESCRIPTION

The test site is located on a ridge in highly complex terrain in the midst of the Swiss alps at 2'300 m asl (Fig. 2). The prevailing wind directions are north and south (Foehn). Winds are very variable and during strong Foehn events, wind speeds can easily reach 120 km/h or more. The long term average monthly air temperature varies from -6.9°C in February to 7.3°C in July and drops below 0°C from November to April. The main icing periods are late autumn and early spring when the temperature often lies around 0°C. Icing can occur throughout the year. In mid winter the temperature can fall below -20°C.

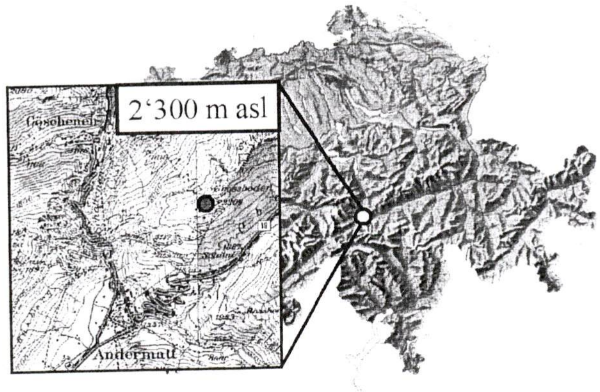


Figure 2: Location of the Alpine Test Site Gütsch.

## 3. METHOD

As the wind turbine is located close to ski slopes, ice throw is an important safety issue [4]. In order to achieve more information about the ice throw of the wind turbine, the area around the wind turbine was, if accessible, inspected after every icing event by a local person for ice fragments that had fallen off the blades. Distance from and direction relative to the turbine as well as size and weight of the recovered fragments were mapped and, together with photos (Fig. 3), collected in a data base. The following instrumentation was used for the documentation:

- Laser Distance Sensor (distance to wind turbine)
- Compass (angle relative to wind turbine)
- Spring balance (weight of ice fragment)
- Measuring stick (size of ice fragment)
- Digital camera (photos of the ice fragment)

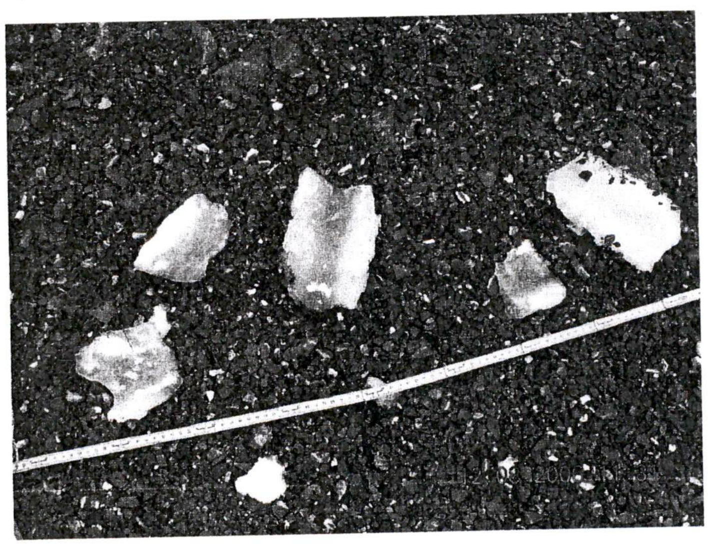

Figure 3: Photo of ice fragments

## 4. RESULTS

During the winters 2005/06 and 06/07, 121 ice fragments with a maximum length of more than 100 cm and a weight of up to 1'800 g could be recorded in distances of up to 92 m from the wind turbine. Due to the exceptionally warm weather, there were only few icing events on Gütsch during winter 2006/07 and therefore only 13 fragments could be found in this period. 94 fragments were recorded during winter 2005/06 whereas 14 fragments resulted from two icing events in August 2006. As the site was not accessible after every icing event, it has to be assumed that the number of collected ice fragments is lower than in reality.

Figure 4 shows the distribution of the recorded fragments around the wind turbine. It is obvious that most of the ice fragments come to land South of the wind turbine. This seems plausible as icing most likely occurs during situations with winds from the North whereas air from the South is often dried out by the Foehn effect and therefore only rarely causes any icing.

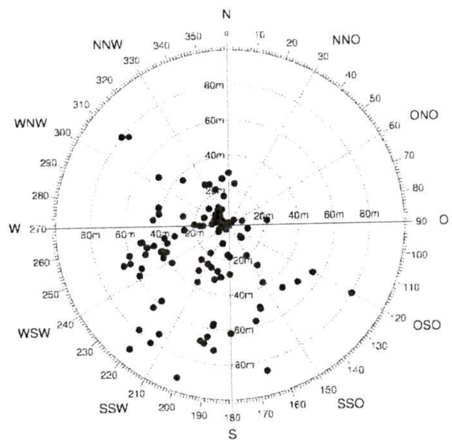


Figure 4: Distribution of ice throw relative to the wind turbine.

Figure 5 shows the frequency of found fragments for different distance classes. It can be seen, that almost 40% of the ice was found within a distance of 20 m (length of the rotor blade) or less around the wind turbine. The maximum throwing distance was 92m.

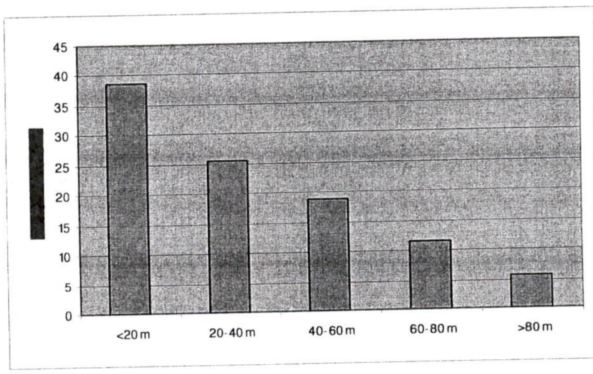


Figure 5: Frequency distribution of ice throw for different throwing distance classes.

The maximum throwing distance of $d$ = 135 m according to the simplified empirical equation by [4]

$$d = (D+H)\cdot 1.5$$

$D$ = rotor diameter [Gütsch: 40 m]
$H$ = hub height [Gütsch: 50m]

was not reached during this study so far.

The maximum weight of an ice fragment was 1'800 g. When an ice fragment was broken into pieces on ground, all parts were weighted together. Figure 6 shows the frequency of ice throw for different weight classes. Almost 50% of the found fragments had a weight of 50g or less.

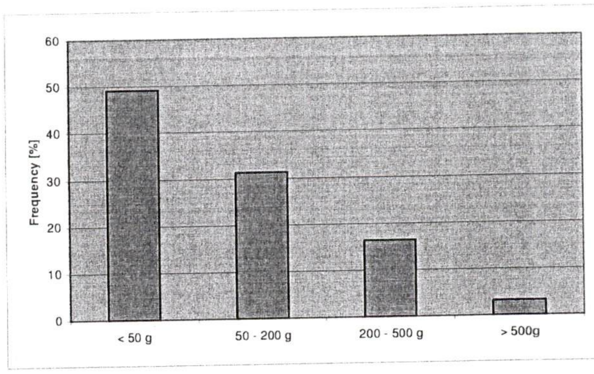


Figure 6: Frequency distribution of ice throw for different weight classes.

Figure 7 shows the relationship between weight and distance of the ice fragments. It can be clearly seen, that the throwing distance is independent of the ice fragment's weight.

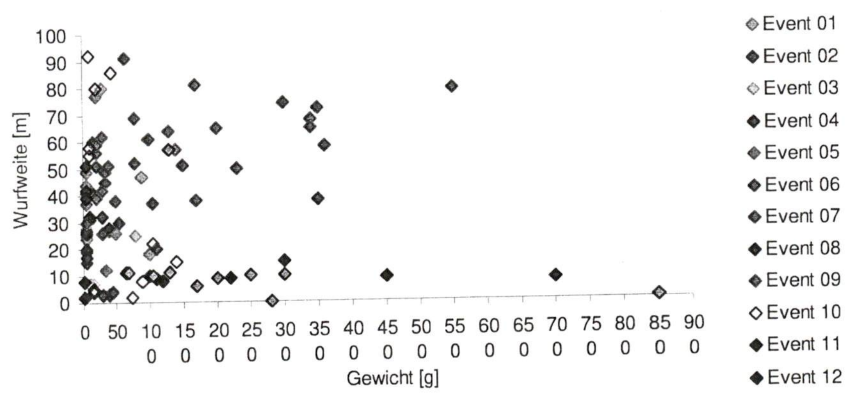


Figure 7: Ice fragment's weight versus throwing distance.

In order to get information about the relation between wind speed and distance of some of the ice throw cases, the average wind speed during the period where the ice fragment could be fallen off the blade (most likely during or shortly after a blade heating sequence) was estimated and plotted against the throwing distance. The result is illustrated in Figure 8 and shows a clear correlation between wind speed and distance of the ice throw (dashed line).

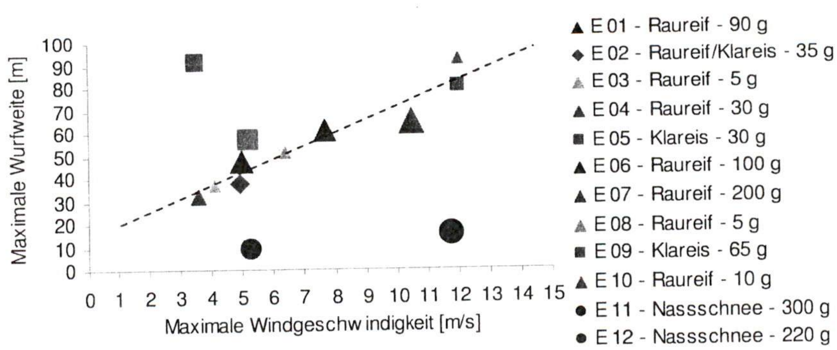


Figure 8: Wind speed versus throwing distance.

When mapping the ice fragments on site, the attempt was made to classify the type of ice into rime ice, clear ice or wet snow. Figure 9 shows the distribution of the different ice types around the wind turbine. It can be seen, that rime ice was found only on the southern side of the wind turbine whereas clear ice also appeared on the northern side of the wind turbine. Wet snow fragments were only found in the immediate proximity of the wind turbine.

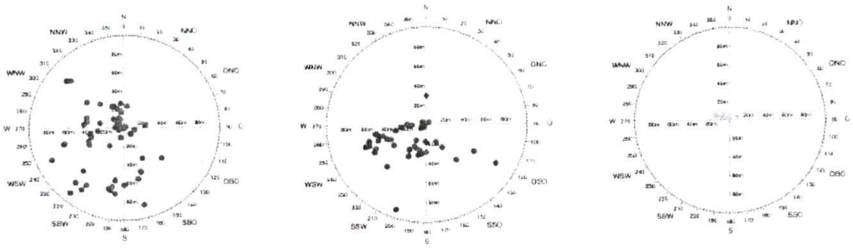

Figure 9: Distribution of ice throw around the wind turbine for clear ice (left, red), rime ice (middle, blue) and wet snow (right, green).

## 5. CONCLUSIONS

- Ice throw from the wind turbine occurs regularly during icing events at the Gütsch site.
- Ice throw can happen at any time of the year, even in summer.
- Most of the ice throw occurs underneath the blades of the wind turbine. This is therefore the most dangerous area.
- The maximum throwing distance given by the empirical formula [4] was not reached on Gütsch so far.
- Most of the ice fragments have a rather small weight. Nevertheless, the ice fragments can have weights up to 1.8 kg.
- There is no relationship between the weight of the ice fragment and the throwing distance.
- The throwing distance is dependent from the wind speed when the ice falls of the blade.
- Ice throw is a significant safety risk at the Gütsch site. Therefore warning signs have been installed and a nearby winter walking trail was placed further away from the wind turbine.

The study will be continued during the last project winter 2007/08.

## 6. ACKNOWLEDGEMENTS

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# RISK ANALYSIS OF ICE THROW FROM WIND TURBINES

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## 1. Introduction

Wind turbines are normally erected far away from houses, industry, etc., as the wind conditions are not favourable in the vicinity of large obstacles. Furthermore, with regard to acoustic noise emission and shadow flicker certain distances are required by national regulations, when wind farms are planned in the neighbourhood of residential areas. Thus, wind turbines should not cause risks as far as ice throw is concerned. However, the turbines are erected close to roads or agricultural infrastructure in order to avoid long and expensive access roads for erection and maintenance. This induces a risk for persons passing by the wind turbines, cars passing the streets if ice fragments fall down from a turbine.

Especially in the mountainous sites or in the northern areas icing may occur frequently and any exposed structure - also wind turbines - will be covered by ice under special meteorological conditions. This is also true if today's Multi Megawatt turbines with heights from ground to the top rotor blade tip of more than 150 m can easily reach lower clouds with supercooled rain in the cold season, causing icing if it hits the leading edge.

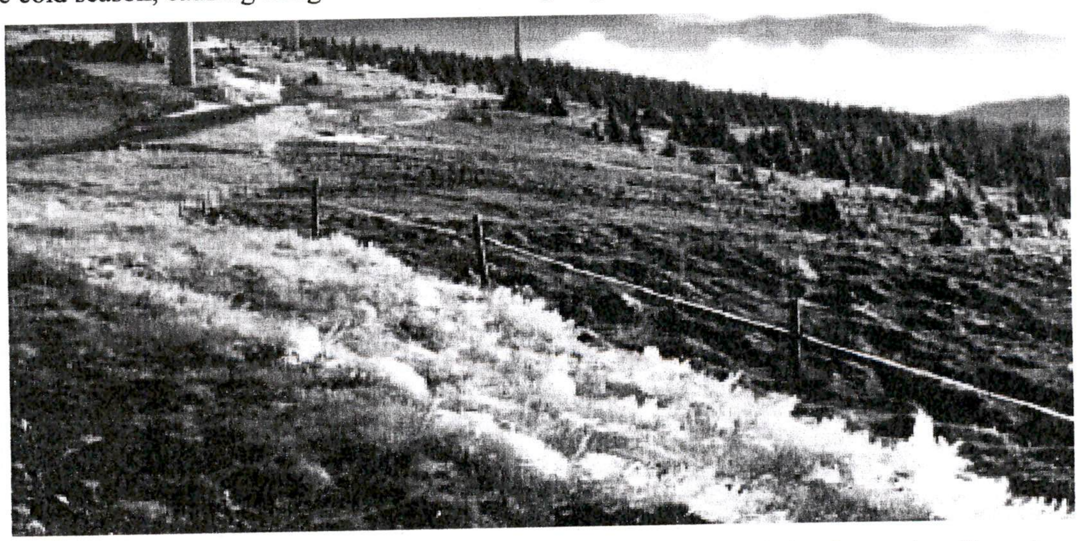

Figure 1 Nice view, but the rime ice accretion on the grass and the fence signalises danger of ice throw in the neighbourhood of the wind turbines.

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[*)] former affiliation: TÜV-Nord Gruppe, Hamburg



Paper presented at BOREAS 6, 9 to 11 April 2003, Pyhä, Finland

If a wind turbine operates in icing conditions which are described in [1], two types of risks may occur if the rotor blades collect ice. The fragments from the rotor are thrown off from the operating turbine due to aerodynamic and centrifugal forces or they fall down from the turbine when it is shut down or idling without power production. It depends upon the weather and especially the wind conditions, on the instrumentation of the wind turbine's control system, and on the strategy of the control system itself.

In the IEC Standard [2] icing is defined as an extreme external condition. Following the philosophy of this Standard a design load case, combining external and operation conditions, never combines extreme external conditions with faults. Regarding icing as an extreme external condition, only situations at normal operation are to be considered. This is important for the assumption how the control system is reacting under icing conditions.

## 2. Icing during operation

When the turbine is operating it is assumed that the leading edge of the rotor blade collects ice and drops it off regularly, due to aerodynamic and centrifugal forces [3]. Depending on the rotor azimuth, the rotor speed, the local radius, and the wind speed, the throwing distance of the ice fragments varies. Also, the geometry of the ice fragments and its mass will affect the flight trajectory. Typical ice fragments have been investigated in a wind tunnel in order to assess the aerodynamic properties of such a body [4]. Taking into account the experience gained from the research project WECO, Wind Energy production in COld climate [1] and the wind tunnel tests [4] typical ice accretion at the rotor blade's leading edge can be estimated and its flight trajectory calculated. The results of the calculations have been validated against the results of an inquiry among operators of wind turbines where the masses and throwing distances of ice fragments in wind farms have been investigated. The comparison proved the calculation to be conservative.

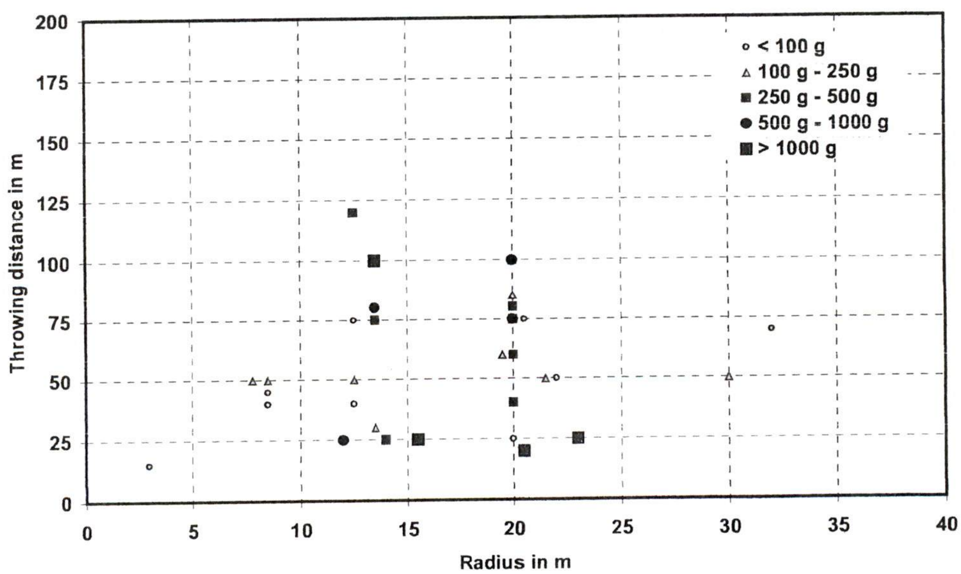


Figure 2 Observed ice fragments from the WECO data base [1] and own additional data.

The calculation needs the following inputs, which are partly known exactly, but some of them still have to be estimated on the knowledge available at present. Input parameters from the wind turbine are the rotor diameter, the hub height and the blade shape - most important the chord length at the tip of the blade - and the rotor speed range.

The size of the ice fragments is estimated according to the recommendations given in [1,4]. Observations show that the ice fragments don't hit the ground as long slender parts but break off immediately after detaching from the blade into small fragments. For the worst case scenario several assumptions can be made in order to reduce the extent of calculations. Smaller ice fragments or the smaller area produce less aerodynamic drag and thus increase the throwing distance. Large or long ice fragments experience more aerodynamic drag and will hit the ground in a closer radius around the turbine. The wind tunnel test showed a typical drag coefficient of $c_d = 1.2$. In the throw calculations $c_d = 1.0$ has been chosen for conservative assumptions. Possible lift of the fragments has been neglected. For the calculation of the ice fragment's mass the ice density given in [5] with 700 kg/m³ has been used. The steps of rotor azimuth were chosen to two degrees. The air density is automatically corrected according to the ICAO atmosphere to the altitude of the site plus hub height at an ambient air temperature of 0°C. Higher temperatures will increase the throwing width, but no icing will occur at temperatures with more than a few degrees above the freezing point. Wind gradients have been neglected.

The result of such a typical ice throw calculation for an operating turbine is a table of numbers and for better understanding a graphic has been plotted directly on the topographical map of the site concerned. Ellipsoidal curves representing the possible hits on the ground in steps of wind speed demonstrate the risk area on the map.

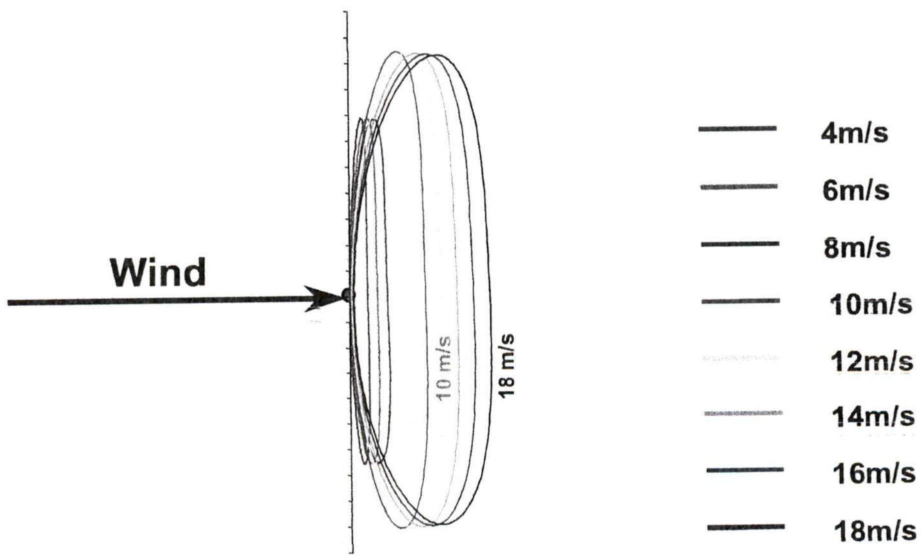


Figure 3 Result of the ice throw calculation. The curves represent the worst case width per wind speed.

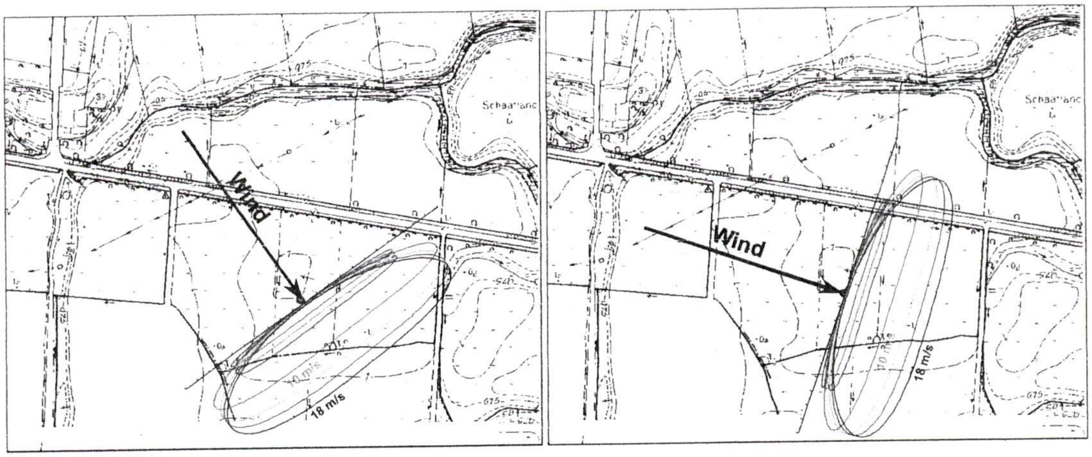


Figure 4 Combination of the ice throw calculation and the topographical map. In the right side the wind direction causes risky operation during icing conditions for the road, whereas the situation in the left side is not critical.

What can be done with the result of such a calculation? If the wind speed and direction is known at the specific site as shown for example in Figure 4 the control system of the turbine can decide whether the turbine has to be shut down or keep in operation. The control system should base its decision upon the icing conditions, the wind speed and direction and the rotor speed. An unnecessary risk can be avoided in that way. Alternatively, a big circle around the turbine representing the overall risk area can be drawn. However, this will need much more space within the wind farms.

A simplified empirical equation has been introduced in [1] representing such a "risk circle" without detailed calculations.

$$d = (D + H) \cdot 1.5$$

$d$ = maximum throwing distance in m

$D$ = rotor diameter in m

$H$ = hub height in m

This empirical and simplified equation can only be a "rough guess" and a help for a first shot in planning the position of a wind turbine close to streets or other objects, involving a certain risk. A more detailed calculation is recommended.

## 3. Ice fall from a wind turbine at standstill

Only the icing of the rotor blade is discussed here. During winter time it may occur that - depending on the shape of the nacelle housing - snow and ice adds up on the top. Due to the heating of generator and gearbox, the ice on the surface melts and results in a water film enabling the amount of ice or snow to slip down. As the rotor blade always represents the higher position, for the worst case scenario, ice from tower or nacelle can be neglected. However, close to the turbine the high masses of possibly falling large and heavy ice fragments may be extremely dangerous for maintenance staff. Precaution is necessary to avoid accidents resulting from that.

In principle, a shut down wind turbine does not differ from other structures like towers, antenna masts, masts of power lines, etc. concerning ice accretion. Depending on the rotor position of the braked or idling rotor different fall widths along the prevailing wind will result at the end of the icing event and increasing temperatures. The size, the mass and the aerodynamic properties are estimated in the same way as for operating turbines. It is recommended that - if operation during icing conditions is excluded - that the turbines shuts down if only a slight ice accretion builds up at the rotor's leading edge. Once the turbine is stopped, it may not restart automatically if it is not guaranteed that all ice is melted or removed from the surface. This is not necessary if the turbine can be started manually and it is sure that any risk for persons or objects in the vicinity of the turbine can be excluded.

For automatically detecting ice on the rotor blades, several methods can be recommended. However, at present all these methods or instruments have to be improved and further validated. At first, the power curve and the ambient air temperature should be checked continuously. If a defined deviation is detected which can be related to a beginning rotor blade icing, the turbine should be shut down. The rotor blades use highly sophisticated aerodynamics and thus will react rather sensitively to small roughnesses at the leading edge like ice. If the temperature is low as well, a drop in the power signal at a certain wind speed - even if related to the affected hub anemometer - can be an indicator for icing. An ice free anemometer is required as well as a heated wind vane in order to avoid an oblique inflow, which would increase the fatigue loads and decrease the power. A heated shaft of the anemometer alone cannot be recommended.

Observations reported in [1] show that an amount of ice accretion in the order of up to 40 per cent of the chord length leads to a throw-off situation during operation. However, the power loss caused by a much smaller amount of ice will indicate icing much earlier. If the turbine is shut down, the ice built up during idling or standstill as described in [3] has to be considered.

The fragments falling down - released during the dewing period - will only be accelerated by the wind speed. The rotor is assumed to be positioned in the typical stand still or parked situation. The maximum wind speed has to be predicted according to the site specific report, connected additionally to the temperature.

For the calculations the following data are required: The altitude of the site, the hub height and the rotor blade radius of the turbine and the rotor blade geometry. The last one is needed for the estimation of the ice fragment's size.

Observation showed that ice fragments which fall from a stopped rotor break into smaller parts on the way down to the ground. In the worst case - large ice fragments reach longer distances from the still standing rotor - two meter long fragments have been investigated. The other dimensions of the ice fragments depend on the geometry of rotor blade. For the calculations it is assumed that the fragments start at the blade tip. The volume of the ice piece multiplied with the ice density from [5] results in the fragment's mass. Contrary to the rotating rotor the drag coefficient of the ice fragment from the stopped rotor is assumed to be 1.2, as this produces greater falling distances and is thus a conservative assumption. The air density is gained from the site altitude plus hub height at an air temperature of 0° C which also leads to conservative results.

The overall falling trajectories for different ice fragment's masses, wind speeds and rotor positions is demonstrated in Figure 5.

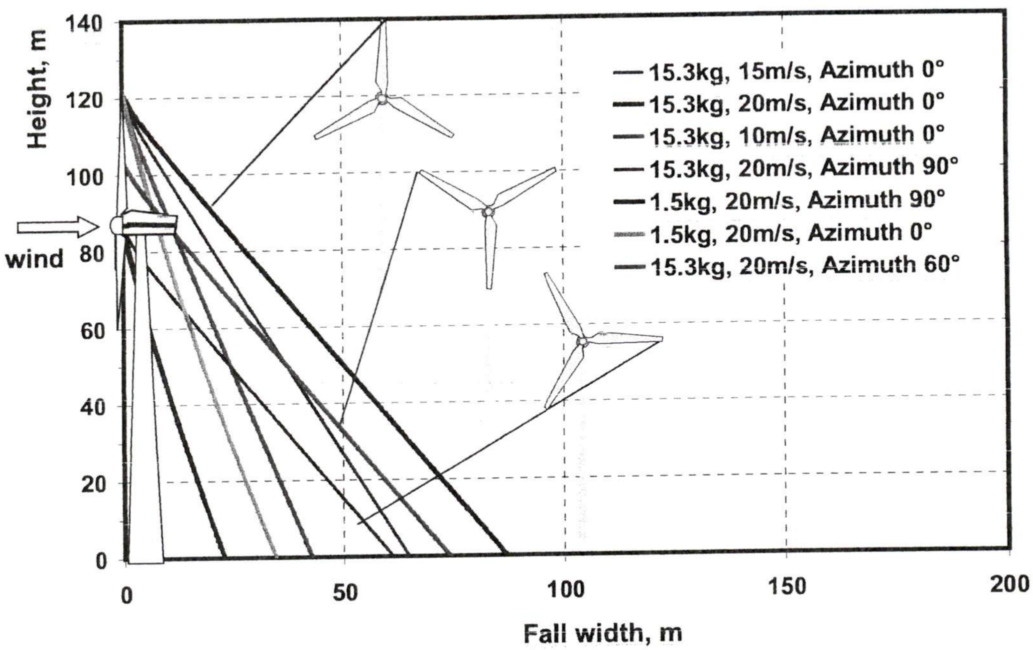


Figure 5 Typical result of an ice fall width calculation for a turbine at standstill. Parameters: Wind speed, rotor position and size of ice fragments.

As mentioned before, icing is defined as an extreme external condition and - according to the design standard's philosophy - must not be combined with a faulty control system. In the example shown in Figure 5 the turbine always heads towards the wind without yaw error.

A parameter calculation has been performed and as a result a simplified empirical equation developed for a stillstanding turbine:

$$d = v\frac{D/2+H}{15}$$ with

$v$ = wind speed at hub height in m/s

$d$ = maximum falling distance in m

$D$ = rotor diameter in m

$H$ = hub height in m.

However, it is recommended to calculate more in detail. For a quick shot and rough estimation it may be sufficient to use the simple equation for a turbine iced at standstill.

## 4. Risk analysis

The two situations described above show the worst case scenario during icing conditions for an operating and an idling turbine, respectively. In fact, reality shows a few days of icing per year only. During these icing days only situations with a proper wind speed and wind direction in combination with detachment of ice fragments at the right time and right location will cause a hit at a certain spot at the ground. Provided that a person stays exactly at that time on that location an incident or accident occurs. The risk analysis aims at this probability and figures the quantity.

The following input data are needed in order to assess the risk for a person or an object in the neighbourhood of a wind turbine under icing conditions:

§ The number of icing events per year. This information cannot be found in the standard meteorological weather reports or the sit evaluation reports. If wind measurements are available and the anemometers are not cup and shaft heated, the number of occurrences in the bin around 0 m/s in the wind speed frequency distribution is unexpectedly high in winter time and shows a normal "Weibull-like" shape in summer time, this is an indication for icing. If two anemometers, one heated and one non-heated are used, the number of icing days can roughly be estimated as shown in Figure 6. The effect of snow and low temperatures on the anemometers as shown in the Figure is discussed in [3].

§ The wind direction and wind speed frequency distribution in combination with either information of icing events (see above) or in combination with the air temperature. This can also be an icing excluding parameter.

§ The location, number and mass of the individual ice fragments thrown off or falling from the wind turbine.

§ The number of persons passing the risk area per year

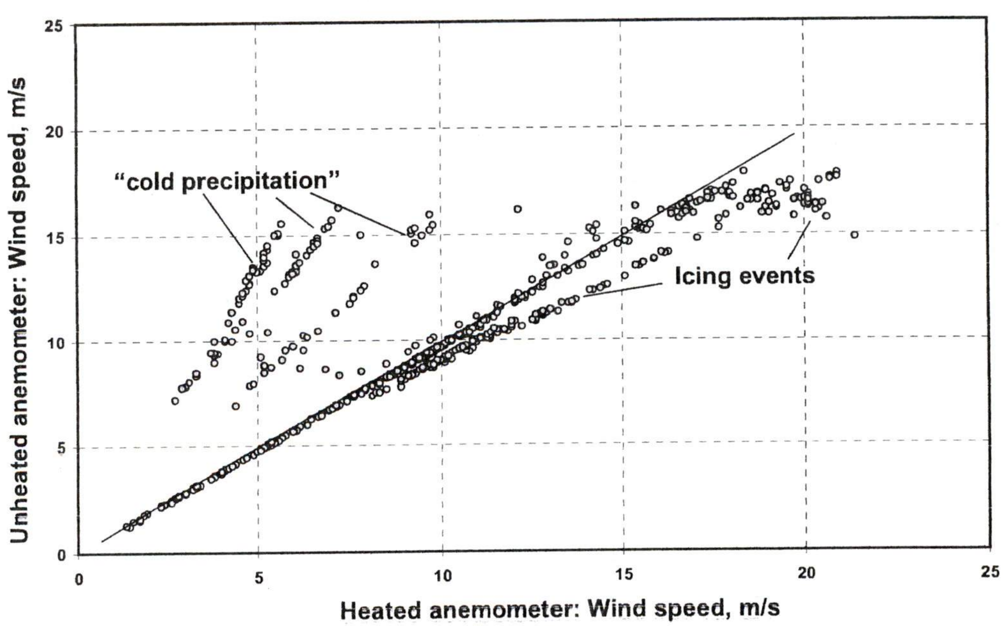


Figure 6 Measurement during icing conditions at a meteorological mast. Unheated versus heated anemometer.

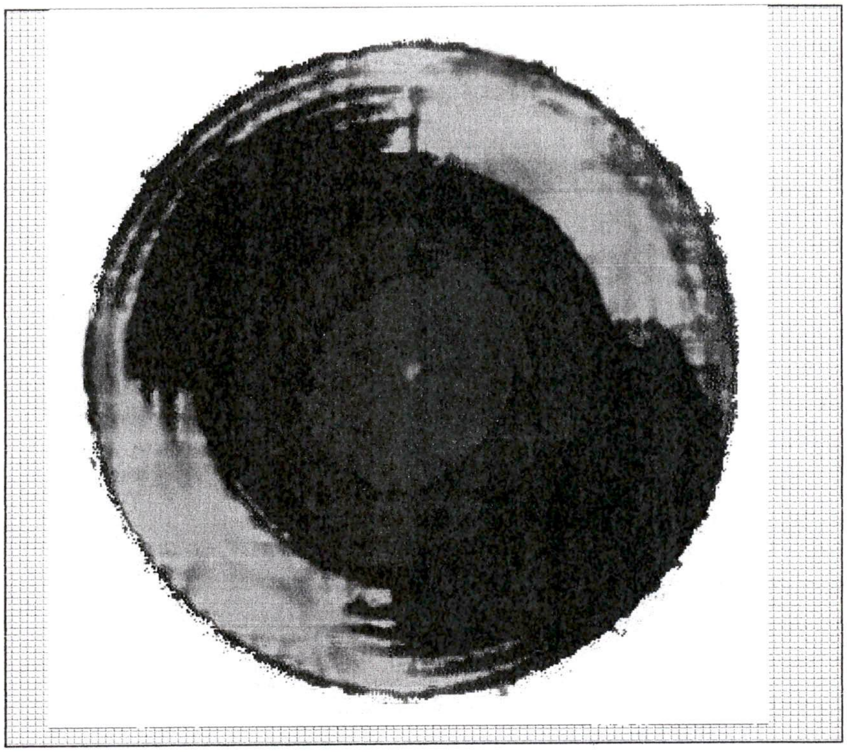

Figure 7 Principle sketch of the probability of hits per m² and year. The colours indicate the numbers of hits. The influence of the wind direction evident.

Additionally, some principal assumptions related to the site have to be taken into account before summarising the overall risk which is shown in Figure 7 which shows the principle sketch of the probability of hits per m² and year. The colours indicate the numbers of hits. The influence of the wind direction evident. This type of result can be interpreted for example for a road as follows: If 15,000 persons pass the road close to the wind turbine per year there might be one accident in 300 years. This result is normally compared against the general risk for life in a country. The requirement is that the introduction of a new technology such as a wind turbine at ice endangered sites must not increase this general risk in a given range.

## 5. Conclusion

The experience and the results of many calculations show that during operation small fragments are hitting the ground in a larger distance than those with a big area whereas from stopped turbines the larger pieces can be transported wider than small ones. However, provided that the turbine is operating the area of risk is larger than at standstill. In both cases the wind direction is an important parameter for the assessment of possible risk and an important parameter for the control systems concerning its behaviour during icing events. Ice sensors and also ice detection by using power curve plausibilisation or two anemometers - one heated, one unheated - is not reliable enough at the moment and needs to be improved.

There is still a lot of information required from operators after icing events in their wind farms. Observation of the turbines and especially the blades by web cameras proved to be a suited, but time consuming method in the Tauernwind project. The calculation methods as well as the assumptions made for the ice fragments have to be improved and validated against observation, if available. Bench mark tests or round robin actions, respectively, have to be carried out for various computer codes, calculating the ice throw trajectories. Furthermore, after the validation of the models, parameter studies have to be performed in order to improve simplified assumptions for international Standards and recommendations.

In Germany and Austria ice throw/fall prediction reports are required by the building authorities of some districts, especially in the inland and mountainous regions. Together with the increasing number of wind turbines at these sites the number of ice throw reports for building permission increases. It is to be expected that in connection with this, the number of experts and competing companies will increase as well and will improve the knowledge.

As a general recommendation it can be stated that wind farm developers should be very careful at ice endangered sites in the planning phase and take ice throw into account as a safety issue. Each incident or accident caused by ice throw is an unnecessary event and will decrease the public acceptance of wind energy.

## 6. References

[1] Bengt Tammelin, Massimo Cavaliere, Hannele Holtinnen, Colin Morgan, Henry Seifert, Kristiina Säntti; Wind Energy in Cold Climate, Final Report WECO (JOR3-CT95-0014), ISBN 951-679-518-6, Finnish Meteorological Institute, Helsinki, Finland, February 2000.

[2] Standard of the International Electrotechnical Commission; IEC 61400 - 1 ed 2 wind turbine generator systems: Safety requirements.

[3] Seifert, H.; Technical Requirements for Rotor Blades Operating in Cold Climate; BOREAS VI, 9 to 11 April 2003, Pyhä, Finland

[4] Seifert, H., Richert, F.; Aerodynamics of Iced Airfoils and Their Influence on Loads and Power Production; Presentation at the EWEC '97 held in Dublin, Ireland, 6-9 Oct. 1997.

[5] DIBt Richtlinie für Windkraftanlagen, Deutsches Institut für Bautechnik, Fassung 1993, Kap. 6.7

"Please provide a description of what efforts Just Wind will take to minimize any risk of ice throws."

When wind turbine blades experience icing, blade efficiency decreases. Ice impairs the air flow over the wing surface making the airfoil less aerodynamic. This reduction in efficiency is indicated by a SCADA monitoring system. In such an event, an inspection of the turbine blades would be conducted. An assessment would then be made to determine the possible thickness of ice on the surface of the blades.

If the ice is found to be excessive, the turbines can be remotely shut down and restarted several times to try and shake the ice loose from the blades. If the ice does not shed from the blades, Just Wind can elect to leave the turbine in a state referred to as "Idle Stop". In the idle stop position the blades are feathered into the stopped position. The turbine's rotors rotate very slowly, as to not damage the internal gear box causing stand still marks on the internal gears. This can weaken the teeth within the gear box and can cause premature failure of the gear box itself. Any ice present will not be propelled as there will be no centrifugal force. The Idle Stop state can be maintained indefinitely until the ice has been shed from the blades.

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