WCO | WIND CONCERNS ONTARIO REPORT

Mechanical failure behind crash of Ontario wind turbine experiment

A device developed as part of a $4.9-million experiment to improve wind turbine efficiency and reduce noise failed — but questions remain unanswered.

October 2024

On June 30th, 2021, there was an incident involving a single wind turbine in an industrial wind power site operated by Capstone Infrastructure Corporation, in the company's Skyway 8 project, located in Southgate Township.

A device added to the wind turbine and one of the turbine blades failed, with the result that the large blade crashed to the ground. According to a report in the *Toronto Star* and the *Dundalk Herald*, the wind turbines were halted and roads nearby were closed for several days, to ensure public safety.

Wind Concerns Ontario, a collation of community groups and individuals across Ontario concerned about the impact of industrial wind power sites filed a Freedom of Information request with the Ontario Ministry of Environment, Conservation and Parks (MECP) in 2023. The request was made because there had been no public reports of an investigation into the incident, by either the operator, the Government of Ontario as provincial regulator for wind turbines, or the National Research Council, which funded the pilot project.

The request was filed in 2023, given the file number A-2023-07092. A response was received in July 2024. The fulfillment of the request cost approximately $120.[1]

[1] Wind Concerns Ontario is a federally incorporated not-for-profit organization, supported by membership fees and donations.

Skyway 8 wind turbine showing blade remnants, partial PowerCone device, and debris. [Photo: M.L. Morfitt]

What was the "PowerCone®"?

According to a Noise Engineering Assessment completed by the MECP, the "PowerCone Technology is described in Biome Renewable Inc's 2018 Technical Brochure entitled PowerCone TM. The PowerCone is a helical drag-based power producing device located at the center of the turbine upstream from the hub. It redirects wind away from the central region of the rotor, creating torque, before channeling this flow onto the leading edge of outbound sections of the rotor blade."[2]

[2] Ministry of Environment, Conservation and Parks, Noise Engineering Assessment, Denton Miller, ND. FOI A-2023-07092, page 00004.

The wind turbine used for testing was subject to the terms of a Renewable Energy Approval or REA granted to the project operator.

In a letter to the Environmental Permissions Branch of the MECP, Capstone describes the process by which the PowerCone test project was to occur. It was planned to be installed in December 2019, but installation was delayed due to the need for "important components" to be re-fabricated "due to manufacturing errors made by our suppliers," and delays due to the COVID pandemic. [3]

According to letters from the MECP, the PowerCone was to be removed by June 20, 2021. In fact, the device was not installed until March 19, 2021.[4] Testing was to start May 30, 2021, to conclude no later than May 30, 2022.

It did not get that far.

The PowerCone device failed on June 30th, 2021, after less than eight weeks from installation.

The "investigation"

Documents provided to Wind Concerns Ontario included emails between the wind power project operator Capstone and the environment ministry MECP.

On September 29, Capstone replied to a query from the MECP as to whether the recommissioning of the damaged turbine would include re-installation of the test device.

Capstone's Corporate Communications Manager replied:

> "No, we are not installing another PowerCone nor are we contemplating any further testing until the full results of the investigation are complete."

Other documents relate to acoustics audits to be performed on the wind turbine with the test device to verify compliance with noise limit regulations but, as it happened, the device was not in operation long enough for these audits to be performed.

According to a letter from Capstone to Cara Salustro, an Environmental Compliance Officer in the Owen Sound District office of the MECP, dated October 11, 2022:

> "…there was a turbine incident involving the turbine that was hosting the PowerCone®. One turbine blade and one PowerCone® blade suffered significant structural damage and the Alpha PowerCone® test was halted. An independent investigation was launched in Q3 2021 and completed in Q4 2021.The site has been completely rehabilitated and the PowerCone® has been safely removed from the turbine and all debris removed from the site and safely disposed of.

[3] Letter Patrick Veith, Capstone VP Operations to Miroslav Ubovic, MECP, May 5, 2021.
[4] Ibid.

> "A root cause analysis was conducted by an independent third party, Complete Wind Corporation, with input from independent investigators representing the turbine OWM (Vestas) and the insurance company (FM Global). We are unable to share the full reports due to confidentiality agreements, however, an excerpt of their report is attached."[5]
>
> Capstone then goes on to report to the MECP that the Root Cause Analysis revealed that "**hardware used to secure the PowerCone® to the hub of the turbine failed in operation due to fatigue loads** and as a result the PowerCone® became loose. Once a number of bolts failed under fatigue loads, there was insufficient carrying capacity in the remaining bolts." [Emphasis ours]

Once that happened, Capstone said, the blades and brackets for the device being tested struck one of the turbine blades, which led to imbalance in operation.

They do not describe the extent of the failure which was that a large portion of turbine blade was thrown to the ground and lodged in the earth, resembling a huge sword. (See photo.)

The actual report prepared by Complete Wind was not provided in response to the FOI request but an Executive Summary was provided, in the tranche of documents.[6] The Summary offers a little more detail, describing the event as bolts failing "in an instantaneous manner…and while failing it impacted initially with the LE [leading edge] of the rotor blade, resulting in catastrophic impact."[7]

Wind Concerns Ontario was not the only party interested in the results of the investigation. An email was sent from Richard Ford, senior policy advisor in the Ontario energy ministry, on November 22, 2021, to Cara Salustro in the environment ministry, with this request.

> "I am looking for some information on the recent turbine failure at the Skyway 8 project near Dundalk and I understand you may be the Environmental Officer for that area. In addition to understanding what led to the turbine failure, I am particularly interested to understand whether the Biome Renewables equipment that was under test was implicated in any way. My team at the Ministry of Energy has been considering the potential for turbine enhancements that may help increase energy yield and improve wind power economics." [8]

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[5] FOI request A-2023-07092 page 000026, letter from Capstone to Ministry of Environment, Conservation and Parks

[6] FOI op cit, pages 000027-000028

[7] FOI op cit, page 000028, Rotor Blade Failure Review by Chris Wraith, "engineering manger [sic], Complete Wind Corporation, January 23, 2022.

[8] Richard Ford email to Cara Salustra, November 22, 2021, FOI p. 000021.

Engineering and the report

As part of our review of the documents, Wind Concerns Ontario consulted with Vern Martin, a mechanical engineering specialist in the field of rotating machinery and principal with FlowCare Engineering Inc. He had a number of comments regarding the PowerCone event, and the investigation notes provided.

- The report is bereft of any detail. At the outset, Megan Hunter of Capstone says in her email of Oct. 11, 2022 that a 'root cause analysis' was done by an 'independent third party, Complete Wind Corporation with independent investigators representing the turbine OEM (Vestas) and the insurance company (FM Global)'... but the full report can't be shared because of confidentiality agreements. Obviously, this makes it very difficult to provide any comments since details have not been provided to examine. Along these same lines, no details have been expressed concerning the confidentiality agreements or what the basis is for having them.
- In the aforementioned document from Capstone to the MECP, further confusion is created (perhaps inadvertently) when the words ‘hardware’ and ‘bolts’ seem to have been used interchangeably. However, it is surmised that it was the ‘bolts’ that initially failed as opposed to ‘brackets’ or some other type of hardware type etc.
- The 'report' has a date of January 23, 2022, on it so the process took from then to October for it to get submitted to the MECP.
- The 'report' does not call itself an RCA [Root Cause Analysis] even though Capstone refer to it as such. The title on the 'report' says it is a 'Rotor Blade Failure Review'. Although there may not be precise definitions for what constitutes an ‘analysis’ or a ‘review,’ it is likely that most professional engineers would treat these words quite differently as far as what they mean to the level of investigation that is being referred to. At the outset, it could be inferred from the report title that the 'terms of reference' for the work weren't to investigate why the 'PowerCone' failed but why the main blades failed... since words matter and have to be weighed carefully to understand the intent, this is a distinct but important difference. A review of the scope of work that defined exactly what Complete Wind Corporation was expected to provide would have been very helpful. Based on these documents, the reader is left in the dark not only as to the results of what was investigated but even what was requested from those investigating the failure. This is a similar question that arises in engineering offices on a regular basis where a detailed description of what is required by a client needs to be scrutinized. For example, there is a vast difference between a ‘detailed engineering design analysis’ and a ‘cursory overview of a design.’

  For the record, the following description of ‘fatigue’ and ‘fatigue failure’ is provided for context to this discussion:

In materials science, fatigue is the initiation and propagation of cracks in a material due to cyclic loading. Once a fatigue crack has initiated, it grows a small amount with each loading cycle, typically producing striations on some parts of the fracture surface. The crack will continue to grow until it reaches a critical size, which occurs when the stress intensity factor of the crack exceeds the fracture toughness of the material, producing rapid propagation and typically complete fracture of the structure.

Fatigue failure is classically defined as the initiation and propagation of cracks in a material due to cyclic loading. This type of failure occurs even when the applied stress is well below the material's static strength.

The primary aspects of fatigue failure are:

- *It is caused by repeated or fluctuating stresses.*
- *The failure can occur at stress levels significantly lower than the material's tensile strength.*
- *It involves a progressive process of crack initiation and growth.*

Here are some basic questions that arise from a cursory review of the documents that were provided:

- The statement "hardware used to secure the PowerCone® to the hub of the turbine failed in operation due to fatigue loads" needs to be questioned since there is no exact definition of what a 'fatigue load' is. The occurrence of fatigue as outlined in the foregoing combines the concepts of stress and number of cycles. (For simplicity, this ignores the further complications of full and part load stress cycles.) As such, a 'fatigue failure' can result from an infinite number of combinations of stress levels and cycles where the 'endurance limit' of the material is exceeded. In other words, a 'fatigue failure' can be avoided as long as the combination of stress levels and cycles stays <u>below</u> the material endurance limit. So, in view of this understanding, what is meant by **'failed in operation due to fatigue loads'**? Does the writer simply mean that the bolts failed as a result of a 'fatigue mechanism'?
- If the bolts failed from a fatigue mechanism, how was this determined? Was a fatigue analysis conducted on the bolts? This would assume that a thorough stress and natural frequency analysis was conducted on the complete assembly using finite element analysis? Was that done? Or was a review done of the original Biome finite element analysis and it was found to be deficient? Was any laboratory testing done to physically establish (or confirm) how many cycles a bolt could be subjected to at a particular load before a fatigue failure occurred?

- What metallurgical examination of the bolts was conducted? Was metallurgical material testing done? Was it established that the bolt material used was in accordance with what was specified?
- Were the failed bolts examined under some type of high-resolution method such as a scanning electron microscope?
- Did the stress analysis conclude that the number of bolts was insufficient and/or that they should have been larger, different material type or grade, etc.? In other words, is it just as accurate to say that the bolts were severely loaded to the extent that they failed at a very low number of cycles as it is to say they failed from a fatigue mechanism?
- Did the fatigue analysis conclude that the number of cycles that it failed at was consistent with what was predictable for the failure? What fatigue analysis method/code was used?
- What is the nature of the cycles that the bolts were subjected to? Is this simply referring to the change in loads due to the rotation of the rotor?
- **It should be recognized that it was not the PowerCone device that failed, and neither was it the wind turbine that failed**…. it was the combination of the PowerCone and the wind turbine. With this in mind, was the original wind turbine manufacturer involved in the failure analysis? Were they involved in the original application of the PowerCone device to their turbine to ensure that some predetermined threshold of stresses would not be exceeded by the device? If they were not, does this mean that Biome conducted a 'reverse engineering process' to the wind turbine to establish whether or not its design was sufficient for carrying the additional loads imposed by the PowerCone device? Assuming the original equipment manufacturer was not involved, was any of the subsequent stress analysis work conducted by rotating equipment engineering specialists?

There are many questions such as these that should be part of the due diligence steps for conducting a failure analysis. These are just some immediate ones that become evident from briefly considering this application.

- Basically, it seems that what the summary is saying is the following as far as the sequence of events with the actual failure:
  - The bolts used for attaching the PowerCone device failed in a fatigue mode.
  - Once a sufficient number of the bolts had separated, the device came loose from the rest of the rotor during normal rotation. (It is assumed that 'coming loose' is synonymous with 'separating so that it is no longer attached'.)
  - As the device separated from where it had been attached, the device (or remnants of it) came in contact with one of the three IWT blades and in the process, the blade was severely damaged and broke apart.

However, this is just the Executive Summary and there is no evidence presented that confirms that this is the failure mode and/or how it was arrived at.

- Given how quickly the failure occurred after the 'PowerCone' was installed, it would seem that a reader could rightly be skeptical of that conclusion of the failure being fatigue. Since the complete report wasn't provided, a whole host of important details (such as how highly stressed everything was) aren't known and if those details were known, it may be found that metal fatigue just played a minor role in the overall failure mechanism.
- On the Complete Wind Corporation report, it did not appear that any of the three names had a 'P.Eng.' behind them *[P.Eng means "professional engineer" and is a professional designation meaning the individual has completed the requirements of the professional regulatory body, and is subject to rules and code of conduct etc.]*

Safety concerns

In 2022, the Multi Municipal Energy Working Group, an association of Ontario municipalities working on energy issues, prepared a report on the "catastrophic failures" (an engineering term) of wind turbines in Ontario to date.

They wrote:

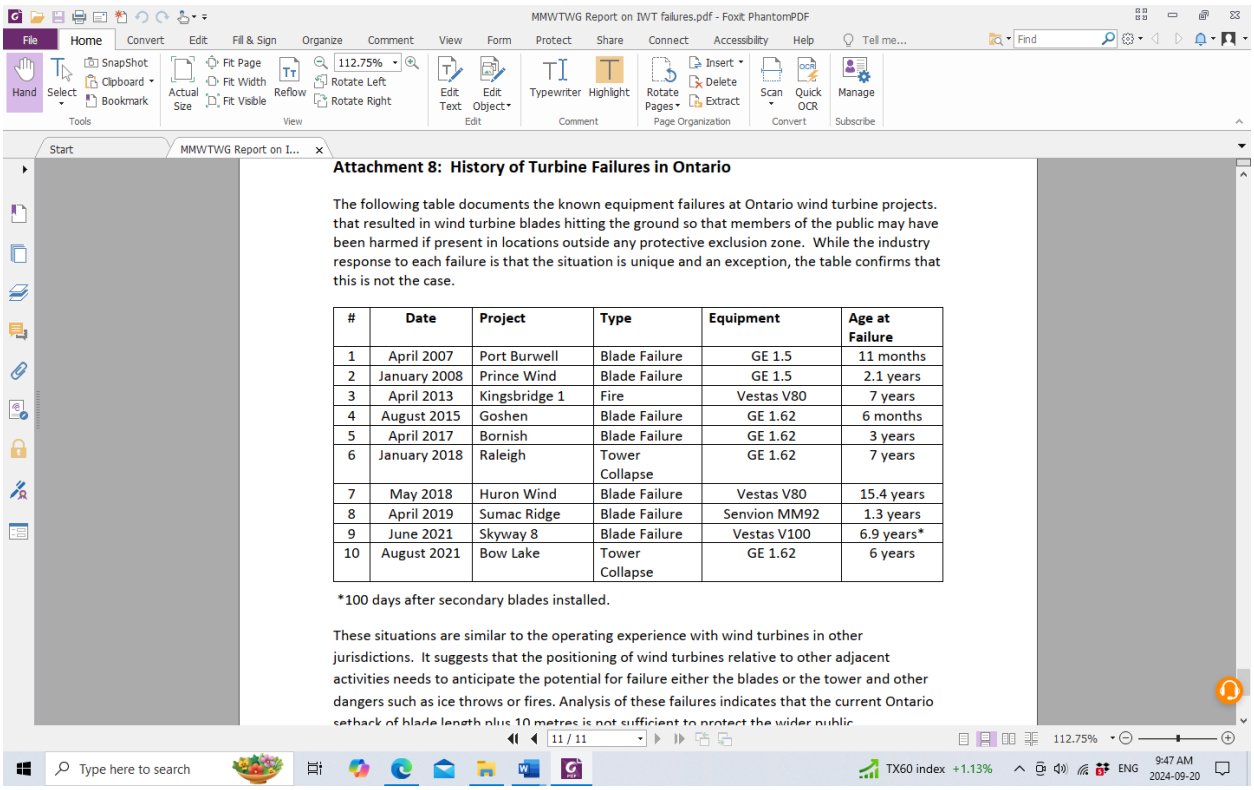
> "Based on the number of catastrophic wind turbine failures, the Multi Municipal Wind Turbine Working Group (MMWTWG)[9] is deeply concerned about the associated implications. While the wind power industry reports that each is an isolated incident, there are now too many incidents for this response to be credible. At least 10 known turbines failures have happened in Ontario since 2007. Each of these resulted in significant portions of blades or the tower hitting the ground at some distance from the turbine base.
> At the same time, there has been no public response from the provincial government that indicates these potentially serious incidents are being investigated either in the context of public and/or workplace safety. To date, there has been no information shared with MMWTWG member municipalities."

In the report is a list of known wind turbine failures, including the PowerCone incident at Skyway 8, with this introduction:

> "The following table documents the known equipment failures at Ontario wind turbine projects that resulted in wind turbine blades hitting the ground so that members of the public may have been harmed if present in locations outside any protective exclusion

[9] The Group changed its name in 2023.

zone. While the industry response to each failure is that the situation is unique and an exception, the table confirms that this is not the case."



Attachment 8: History of Turbine Failures in Ontario

The following table documents the known equipment failures at Ontario wind turbine projects. that resulted in wind turbine blades hitting the ground so that members of the public may have been harmed if present in locations outside any protective exclusion zone. While the industry response to each failure is that the situation is unique and an exception, the table confirms that this is not the case.

#	Date	Project	Type	Equipment	Age at Failure
1	April 2007	Port Burwell	Blade Failure	GE 1.5	11 months
2	January 2008	Prince Wind	Blade Failure	GE 1.5	2.1 years
3	April 2013	Kingsbridge 1	Fire	Vestas V80	7 years
4	August 2015	Goshen	Blade Failure	GE 1.62	6 months
5	April 2017	Bornish	Blade Failure	GE 1.62	3 years
6	January 2018	Raleigh	Tower Collapse	GE 1.62	7 years
7	May 2018	Huron Wind	Blade Failure	Vestas V80	15.4 years
8	April 2019	Sumac Ridge	Blade Failure	Senvion MM92	1.3 years
9	June 2021	Skyway 8	Blade Failure	Vestas V100	6.9 years*
10	August 2021	Bow Lake	Tower Collapse	GE 1.62	6 years

*100 days after secondary blades installed.

These situations are similar to the operating experience with wind turbines in other jurisdictions. It suggests that the positioning of wind turbines relative to other adjacent activities needs to anticipate the potential for failure either the blades or the tower and other dangers such as ice throws or fires. Analysis of these failures indicates that the current Ontario

Cost to taxpayers

The National Research Council of Canada (NRC) was the lead on the PowerCone project, which according to the NRC website was funded at least in part by Canada's Energy Innovation Program. Other funders were involved so that the total amount for the project, now marked as "completed", was $4.9 million.

According to the NRC, all was not lost:

> "PowerCone® demonstration ended early due to a mechanical failure. Preliminary results were positive but were inconclusive due to the length of the demonstration period."

Although the website states it was last updated in 2020, and the project is marked "completed," it also states that more PowerCone testing is ongoing at the University of British Columbia.

> "Computational fluid dynamics (CFD) simulation of the impact of the PowerCone® technology at a windfarm level in partnership with a research team at UBC is currently underway. This will help to build support for the wind farm level benefits of the PowerCone® technology."

The last word: unanswered questions

The decision to develop a device such as the PowerCone and carry out a test confirms several concerns about industrial wind turbines: first, they are not very efficient at generating power, especially in Ontario, so operators are looking for help; and second, noise, as reported by people forced to live near turbines, is recognized as a problem that needs to be resolved.

Other questions persist:

Community safety: what guarantees for citizens and municipal governments have that safety and communications protocols are in place and will be followed? In the case of Skyway 8, the municipality was not informed of the event, as far as is known, and had to inquire about it. Roadways were closed for several days, at a cost and inconvenience to residents.

Landowner safety: this is not known as contracts between wind power site operators and landowners leasing land are confidential, but landowners would be advised to ensure there are communication and safety protocols for them, too. The Skyway 8 event took place on a working farm where it is possible people could have been in the field on that day.

Transparency: As the Multi Municipal Energy Working Group described in its report, wind turbine safety is an important issue. There should be communication about the event immediately, as noted above, but also afterward. The regulator, currently named the Ministry of Environment, Conservation and Parks, has a duty to inform the municipality and its citizens of the results of an investigation.

Professional oversight: the lack of professionally certified engineers in the authorship of this report is worrying, and may be of interest to the regulatory body, the Professional Engineers of Ontario. As noted by our consulting engineer, the diagnosis of "fatigue" after a mere 100 days of operation is not satisfactory.

Cost to taxpayers and social benefit: the almost $5-million price tag for this adventure seems inappropriate, particularly as it would contribute to the financial success of both the technology inventor and the wind power industry as a whole. By comparison, the Canadian Institutes of Health Research administered funding in the amount of $4.3 million for a five-year research study on the origins of respiratory disease in Canada, and included a team of multiple medical researchers working through the Canadian Respiratory Research Network and the Canadian Lung Association. The goal of that study was "to understand the full burden of chronic airway diseases in Canada (both diagnosed and undiagnosed) and to generate new knowledge that will inform public policy and lead to interventions to reduce the burden of asthma and COPD."

Wind power has been fraught with problems since the Ontario government passed the Green Energy and Green Economy Act in 2009 to propel the wind power industry forward. Many analysts have commented on the lack of cost-benefit-analysis, and Ontario communities have had to live with the noise pollution introduced by industrial-scale wind turbines, with inadequate enforcement of regulations by the environment ministry. The goal of the PowerCone device confirms those concerns as its intent was to boost productivity (and profits) while reducing environmental noise.

The PowerCone event underlines concerns about community safety. While often portrayed as benign structures, wind turbines are in fact wind power generators and are industrial-scale machinery. Ontario's citizens deserve assurance as to safety of these machines, and any experimental alterations, going forward.

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