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Written Submission from Paul Sedran

Mémoire de Paul Sedran

In the matter of the

À l’égard d’

Ontario Power Generation Inc.

Ontario Power Generation Inc.

Application to renew power reactor operating licence for the Darlington Nuclear Generating Station

Demande concernant le renouvellement du permis d’exploitation d’un réacteur de puissance pour la centrale nucléaire de Darlington

Commission Public Hearing Part-2

Audience publique de la Commission Partie-2

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Review of Fuel Channel Integrity and Comparison of Severe Accidents in a Darlington Reactor and for a Bruce Power Net Zero Vestas V80 Wind Turbine for the Darlington Relicensing Application

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Date: May 8th, 2025

1. Introduction

OPG's current power reactor operating licence for the Darlington Nuclear Generating Station (DNGS), consisting of Darlington Units 1 – 4, is valid until November 30th, 2025. OPG has applied to the CNSC, in Reference [1], ***the Darlington Nuclear Generating Station Power Reactor Operating Licence Renewal Application***, for a 30-year extension of the DNGS operating licence, to November 30th, 2055.

The current status of the four Darlington Reactors is as follows:

- Units 1, 2, and 3 were successfully refurbished and returned to service.
- Unit 4 is still undergoing refurbishment and will be returned to service by the end of 2026, respectively.

As part of the relicensing process, the CNSC has arranged for a public meeting, the second of two meetings, to be held on June 24–26, 2025, at which intervenors will provide their input regarding the application to extend the operating license for DNGS.

For the June public hearing, the CNSC has funded the author to perform a technical review of OPG's license renewal application for DNGS, from the perspective of his specialised experience, specifically on the topic of Fuel Channel Fitness-for-Service, under Contribution Agreement reference number: PFP 2023 DNNP-01. For the review, the author has:

1. Assessed the fitness-for-service of the DNGS Fuel Channels, as agreeed, and
2. In addition, estimated the probability of a fatality from a Worst-Case Accident (WCA) in DNGS compared to that for a WCA in in a particular Wind Turbine, installed at the Bruce Power Net Zero Wind Installation.

The probability estimates for Item 2 were undertaken as a rebuttal to the statement that wind turbines are safer than nuclear plants, which was stated by K. C. Johnston on January 13, 2025, at the CNSC public hearing on the license to construct the BWRX-300 at Darlington. Dr. Johnston's presentation was in support of CMD24-H3-79D.

Although CMD24-H3-79D was specifically submitted for the BXRX-300 public hearing, the general topic of wind turbine versus nuclear reactor safety directly applies to DNGS. Therefore, Item 2 was included in this intervention, with the expectation that related issues may be brought up by other intervenors at the public hearing.

It should be noted that OPG staff performed a high-level general review of this assessment and their comments were incorporated. However, although the numerical results presented are expected to be accurate, they were not subject to independent quality assurance verification, as required for official engineering calculations.

2. Review and Assessment of DNGS Fuel Channel Fitness-for-Service

For this assessment, the sections relevant to Fuel Channels in Reference [1], were reviewed by the author, drawing on extensive experience in fitness-for-service assessments for mechanical components.

The assessment is summarised below.

The design life of the original CANDU Fuel Channels in DNGS was 210 kEFPH (kilo Effective Full Power Hours) or 30 years, at a capacity factor of 80%, which was the case for all the original CANDU reactors.

In the refurbished Darlington reactors, the design life of the Fuel Channels was conservatively kept at 210 kEFPH, the same as the original Darlington Fuel Channels.

After 30 years of operation to the end of the requested licensing period in 2055, it is expected that the new Fuel Channels would have accumulated 235 kEFPH, which corresponds to 30 years of operation at a capacity factor of 90%.

For the new DNGS Fuel Channels, an operating life of 235 kEFPH is quite conservative based on:

1. The new Pressure Tubes feature material improvements; reductions in chemical impurity concentrations and refinements in microstructure.

2. The re-evaluation of the end-of-life of the Bruce B Fuel Channels to 300 kEFPH. Although the Darlington Fuel Channel operating conditions are slightly more severe than those in Bruce B, a FC life close to 300 kEFPH could be demonstrated for Darlington, should OPG decide to do the requisite work.

3. Empirical evidence of unacknowledged sources of conservatism in the Fuel Channel predictive models for:

   (a) DHC initiation from flaws in Pressure Tubes

   (b) Sag of the Fuel Channel as a single span beam

   (c) Sag of the Pressure Tube spans between the Spacers

   Regarding Point (a), the probabilistic models used to predict the frequencies of DHC initiation in Pressure Tubes factor into the probabilistic models for Loss-of-Coolant Accidents. These accidents are an important factor in the Reactor Probabilistic Safety Assessment.

   Table 1, below, presents predicted frequencies for through-wall crack penetration, originating from the expected population of axial flaws in the Pressure Tubes of various reactors.

Table 1 – Predicted Axial Through-Wall Crack Penetration Frequencies for the Pickering B, Bruce, and Darlington Reactors

Station	Reactor	Frequency of Axial Crack Penetration (Events/Year)	
		Mean	95% UB
Pickering B	Unit 7	0.116	0.119
Bruce A	Unit 4	1.73	1.74
Bruce B	Unit 7	0.114	0.117
Darlington	Unit 3	0.0302	0.0317

The predicted frequencies of axial through-wall crack penetration in Table 1 were taken from Figures 4-1 through 4-8 in Reference [2].

Through-wall crack penetration was never detected in any of the properly installed Pressure Tubes of Pickering Unit 7, Bruce Units 4 and 7, and in Darlington Unit 3, over the operating lives of the Pressure Tubes.

Therefore, the DHC initiation models are universally highly conservative and contribute conservative results to the Probabilistic Safety Assessments, including those for the Darlington Reactors.

To date, it is believed that OPG has not taken any credit for the conservatism in the predicted probabilities of through-wall crack penetration in any Probabilistic Safety Assessments.

With regard to Point (b), the sag of the entire FC has an effect on Calandria Tube (CT) integrity because sag of the FC can result in contact of the CT with the Liquid Injection Safety System Nozzle below it, leading to fretting of the CT.

As presented in Reference [3], ***Potential OPEX-Based Refinements to Fuel Channel Sag Models for Future Life Extensions*** there is evidence that the existing FC deformation models overestimate the sag of the FC. CT fretting is not an issue in Probabilistic Safety assessments. However, the overestimation of FC sag indicates that there are unexplored sources of conservatism in the FC deformation models.

Sag of the PT spans, from Point (c) above, is a significant safety-related factor since it determines the onset time of PT-CT contact and the probability of blister formation in the Pressure Tubes. The overall probability of PT rupture, used in the Probabilistic Safety Assessments, depends partially on the probability of blister formation.

Based on Reference [3], it can be shown the PT stiffness will increase with irradiation over time. The current PT-CT time-to-contact predictions do not take credit for irradiation-induced stiffening of the PT, and are, therefore, conservative. To date, OPG has not taken credit for irradiation stiffening of the Pressure Tubes in any Probabilistic Safety Assessments.

In summary, for the new Darlington Fuel Channels, a thirty year operating license (to 235 kEFPH) is reasonable. In the unlikely event that unexpected problems were to occur, they would be detected by PIP FC inspections and health monitoring measures in place at DNGS.

3. Probability of a Worst-Case Accident in a Reactor in DNGS

For this assessment, it is assumed that the most severe Beyond Design Basis Accident in Darlington would be a Station Blackout, (SBO) combined with a complete lack of action to restore cooling by the Reactor Operators and Station Operations Staff.

In the event of an SBO, severe overheating of the reactor core could lead to severe core damage, which could lead to the release of radioactive materials into the environment, all of which would definitely be prevented by various Operator actions to re-establish cooling of the fuel.

For Darlington, the probability of a Station Blackout was determined to be 1 event in 10^7 years, for a frequency of $1x10^{-7}$ events per year from Reference [4], which also categorised the lack of response by the operators to restore cooling as an incredible event. Regarding operator inaction, in discussions with OPG. It was noted that the operators are trained to restore cooling in the event of an SBO, so the assumption of operator inaction is excessively conservative and is not used in the Darlington Probabilistic Safety Assessment.

The probability of Operator inaction following an SBO is not known, but an upper-bound estimate is proposed, as follows.

For the sake of argument, Operator inaction could occur if the reactor operators and station staff were all incapacitated by poisoning, as an example.

Assuming, very conservatively that one such event occurred at one of the Darlington reactors at the end of 2024, the frequency of Operator inaction would then be given as one event over the number of reactor operating years for DNGS.

From the DNGS reactor history Table of Appendix 1, the station had accumulated 117.6 reactor years of operation as of the end of 2024.

Assuming one incident of Operator inaction within 117.6 reactor years of operation, the frequency of Operator inaction would be 0.008 events per year.

Therefore, the predicted frequency of an SBO combined with operator inaction that would result in an atmospheric release would be:

$$0.008 \times 1\text{x}10^{-7} = 8.50\text{x}10^{-10} \text{ events per year.}$$

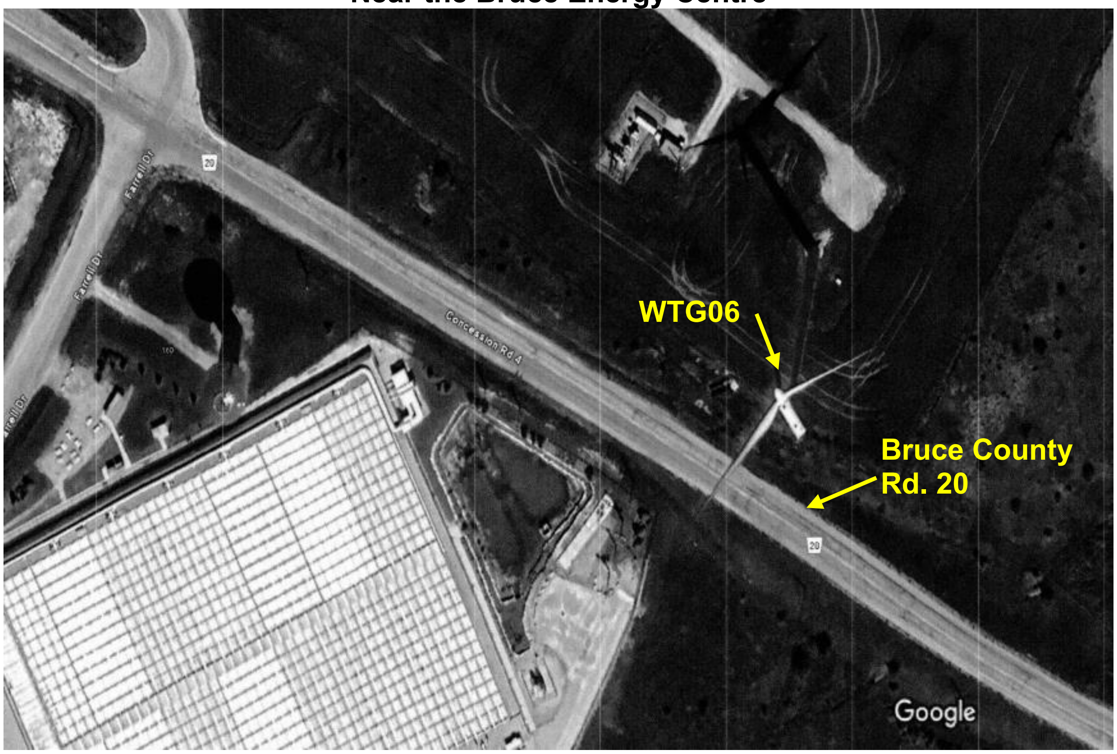
4. Probability of a Worst-Case Accident for a Huron Wind Veras V80 1.8 MW Wind Turbine

4.1 Description of the Wind Turbine Selected for Assessment

The accident probability assessment was performed specifically for one of the Vestas V80 1.8 MW Wind Turbines Installed at the Bruce Power Net Zero (Formerly Huron Wind) Facility near Tiverton, Ontario. The specific Wind Turbine in question is located adjacent to Bruce County Road 20 (Concession Road 4), about 200 m South-East of the Bruce Power Visitor's Centre.

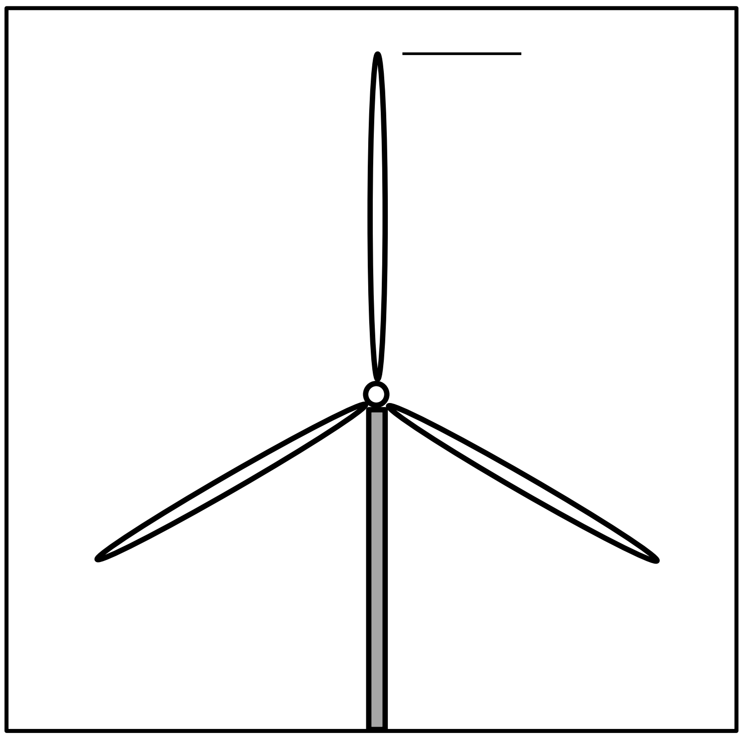
There are six Wind Turbines at the Bruce Power Net Zero side, accidents for each of which could have been considered. The particular Wind Turbine, Unit WTG06, was chosen for analysis because the tower is located approximately a few hundred m from Bruce County Road 20. As seen in the Google Maps photograph of Figure 1, below, the WTG06 Turbine Blades extend out over the road. In the event of a blade root failure in which the blade is ejected, it would be quite possible that the blade would land on the road. In the case of Unit WTG06, this is easily demonstrable. For the other four Wind Turbines, more detailed ballistics analyses would be required to calculate the probabilities of an ejected blade landing on the road, which were not pursued.

Figure 1
Google Maps Photo Depicting WTG06 Adjacent to Bruce County Road 20
Near the Bruce Energy Centre



The geometry of the Vestas V80 1.8 MW Wind Turbine is shown in Figure 2.
The three blades are mounted on a hub with a 2 m diameter hub cover. The blades have a length of 39 m and each blade weights 9 tons. The rotor diameter is 80 m. The height of the tower, measured as the height of the hub, varies from 60 to 78 m.

Figure 2
Configuration of the Vestas V80 1.8 MW Wind Turbine



The operating rotational speed of the rotor is 18.75 rpm.

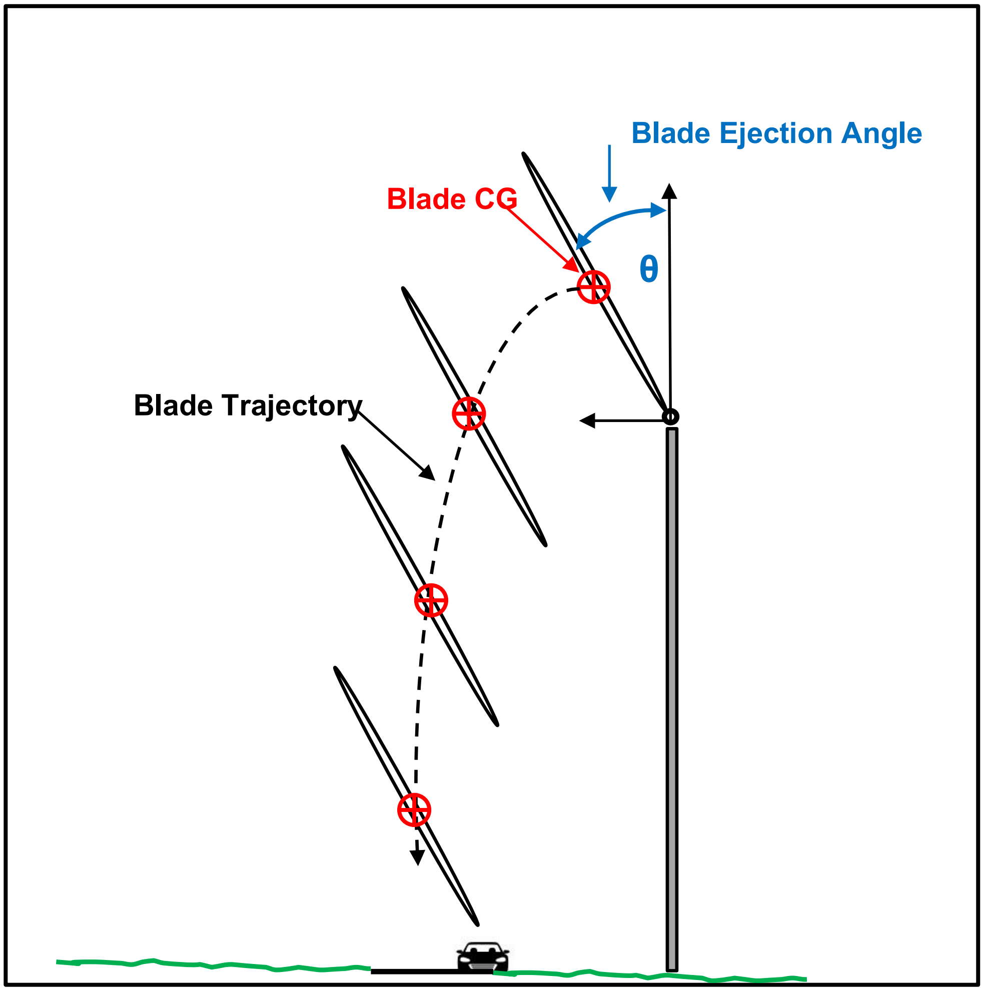
Figure 3 illustrates the trajectory of the blade centre of gravity should the blade fail while located at a particular angular orientation, at an angle θ, while over the road.

In the example trajectory shown in Figure 3, will come to rest on Bruce County Road, resulting in the risk of striking a vehicle on the road.

4.2 Prediction of the Blade Trajectories in the Event of a Blade Ejection

For this assessment, it is assumed that, in the event of a Blade root failure, the blade can be at any angular position during the operation of the Rotor.
In Figure 3, with Bruce County Road 20 to the left of the Wind Turbine, the greatest risk of the Blade landing on the road would result from the Blade ejection occurring with the Blade at an angle ranging from 0 to 180°.

Figure 3
Illustration of Blade Trajectory Following Ejection



Therefore, Blade Trajectories, relative to Bruce County Road 20, were calculated for various Blade angles at ejection.

The trajectories were determined by calculating the locations of the Blade Centre of Gravity (CG) starting with the Blade ejection and ending with the Blade resting on the ground.

The calculations were performed along the following steps:

1. For the given Blade angle at ejection, the x and y coordinates of the Blade CG were found. Note that x is tangential distance from the centre of the Rotor and y is the height above the ground.
2. Knowing the angular velocity and position of the Blade CG at ejection, the instantaneous x and y velocities at ejection were found.
3. Assuming that the blade would fall without spinning about the CG, the Blade would strike the ground before the CG. In this case, the time of flight is defined as the time interval from the ejection of the Blade to when the tip of the Blade strikes the ground. The y distance that the CG would travel during the time of flight was found and was used to calculate the Blade time of flight
4. Using the Blade time of flight and the x velocity component of the CG from Step 2, the x distance covered by the Blade CG during the time of flight was found.
5. Knowing the length of the Blade, the ejection angle, the x distance of the CG at ejection, and the x distance covered by the CG during the time of flight, the x coordinate of the Blade tip upon contact with the ground was found.
6. Finally, to find the resting position of the Blade on the ground, it was assumed that the Blade would fall over tangentially after contact of the tip with the ground and would come to rest with the leading Blade tip on the ground, at the same position where the Blade tip struck the ground.

In the CG trajectory calculations, gravity was the only force assumed to act on the Blade, with no air resistance accounted for.

Results for a typical Blade trajectory calculation are presented in Table 2, below.

Table 2
Summary of Blade Trajectory Calculations for θ = 67.5°

Basic Data

h_{Hub}	θ		Δh_{CG}	d
(m)	(°)	(rad)	(m)	(m)
68	67.5	1.178	7.7	68.0

Find Ground Contact Time

ω		r_{CG}	v_0	v_{0y}	a	t	d_y
(rpm)	(rad/s)	(m)	(m s^{-1})	(m s^{-1})	(m s^{-2})	(s)	(m)
16.8	1.759	20	35.2	32.5	9.81	1.454	68

Find Horizontal distance travelled by the CG

v_0	v_{0x}	t	d_x	Δx_{CG}	x_{CG}
(m s^{-1})	(m s^{-1})	(s)	(m)	(m)	(m)
35.2	13.5	1.454	19.6	18.5	38.1

Find the Location of Fallen Blade wrt the Road

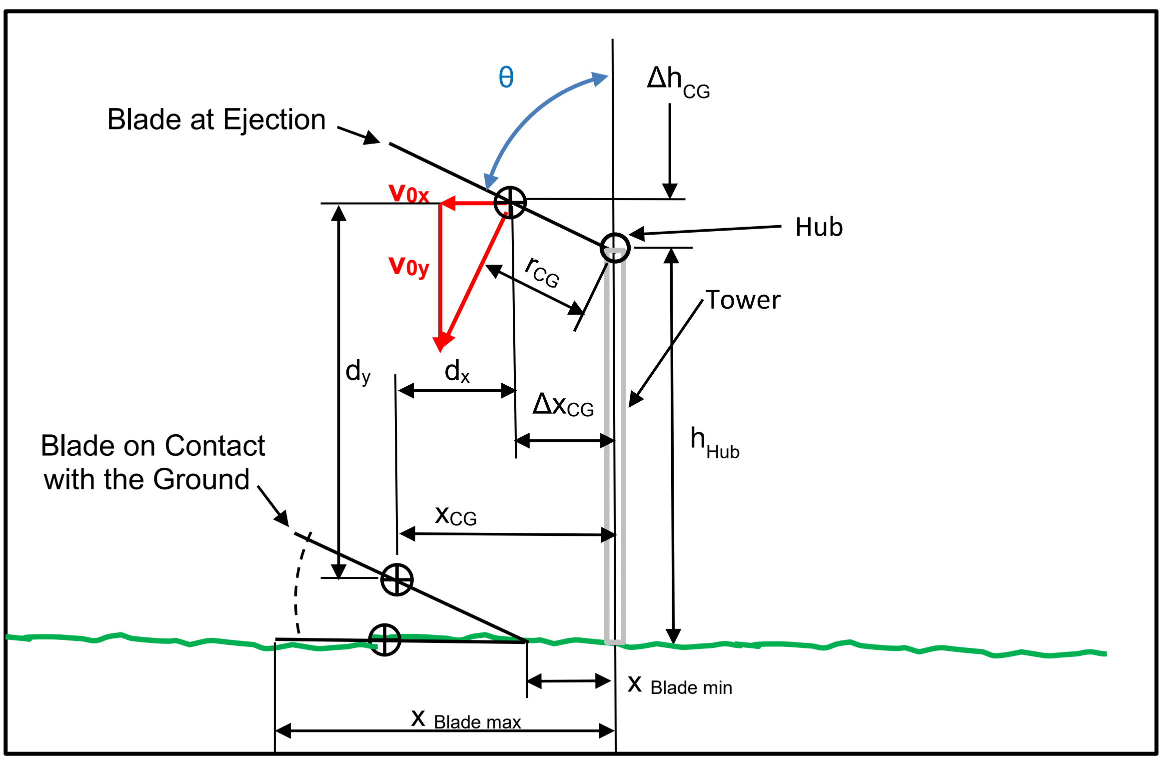
x_{CG}	Δx_{CG}	$x_{Blade\ max}$	$x_{Blade\ min}$
(m)	(m)	(m)	(m)
38.1	18.5	59.6	19.6

The symbols in Table 2 are defined in Table 3. Figure 4 provide a graphical description of the variables in Table 2.

Table 3
Definition of Symbols in Table 2

h_{Hub}	Height of the Rotor Hub above the Ground
θ	Orientation Angle of the Blade
Δh_{CG}	Height of the Blade CG above the Hub
d_y	Vertical Distance Travelled by the CG in t
ω	Rotational Speed of the Blade
r_{CG}	Radial Distance of the CG wrt the Centre of the Rotor
v_0	Velocity of the Blade CG
v_{0y}	y (Vertical) Component of the Velocity of the Blade CG
a	Acceleration due to Gravity
t	Time from the Ejection of the Blade to Contact with the Ground
v_{0x}	X (Horizontal) Component of the Velocity of the Blade CG
d_x	x-Distance Travelled by the Blade CG in t
Δx_{CG}	x-Distance from the Origin to the Blade CG at Blade Ejection
x_{CG}	x Coordinate of the Blade CG at Contact with the Ground
$x_{Blade\ max}$	x Coordinate of the Blade Tip
$x_{Blade\ min}$	x Coordinate of the Blade Root

Figure 4
Illustration of the Variables in Table 3



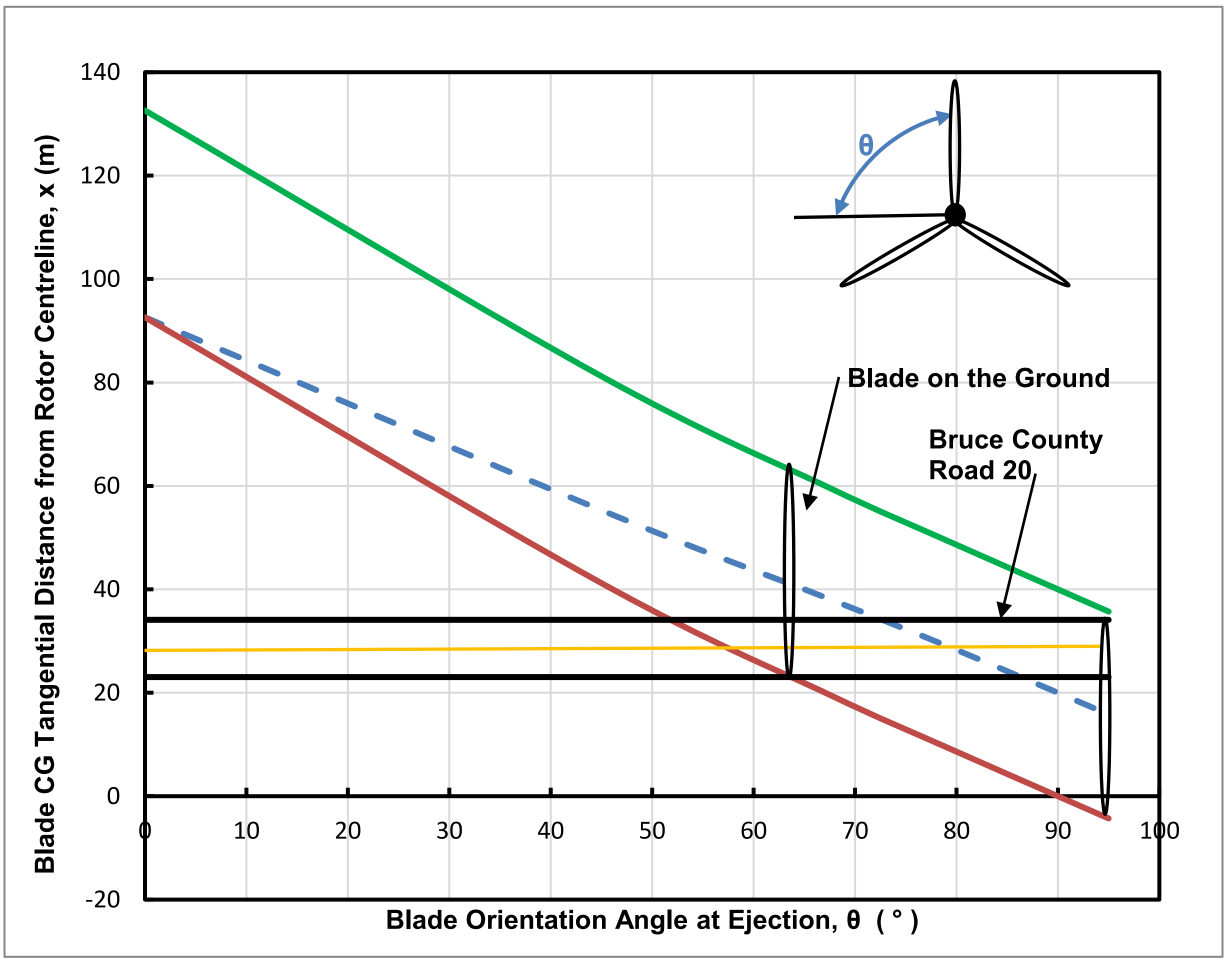
From Table 2, after the Blade is ejected, the CG of the blade would fall a distance of 68 m upon striking the ground. For a rotational speed of 16.8 rpm, the CG would have a velocity of 32.5 m/s with a vertical component of 32.5 m/s, downward upon ejection. Under free fall due to gravity, the Blade would strike the ground 1.454 s after ejection. During the fall of the blade, the CG would travel 19.5 m in the horizontal direction at a velocity of 13.5 m/s.

Once the x coordinate of the CG at the time of contact with the ground was established, the x coordinate of the end of the blade striking the ground was found. To find the resting position of the blade on the ground, it was assumed that the blade would fall over in a simple manner. The x position of the end of the Blade striking the ground first was assumed to be the same, before and after the blade falling over.

As shown in Table 2, for a Blade ejection at a Blade orientation angle of 67.5°, the root of the Blade would be at x = 19.6 m and the tip would be at x = 59.6 m. Figure 5, below, shows that inside edge of Bruce County Road 20 is at x = 23 m and the outside edge is at x = 45 m, so that the Blade would come to rest on the ground, completely blocking the road.

Using the Blade resting positions predicted for each trajectory in Step 6, each one calculated as shown in Table 2, a plot of tangential Blade resting distance (which is in the x direction), versus θ, was generated and is presented in Figure 5.

Figure 5
Plot of Blade Tangential Resting Distance Relative to Bruce County Road 20



The blue dashed line represents the predicted x distance of the Blade CG when the Blade tip first contacts the ground. The red line represents the x distance, versus θ, of the Blade tip closest to the Wind Turbine with the Blade resting on the ground. Similarly, the green line is a plot of the x distance versus θ for the blade tip furthest from the Wind Turbine, with the blade resting on the ground.

The centreline of Bruce County Road 20 is depicted as the yellow horizontal line at a tangential distance of 28 m. The two parallel thick black lines represent the two edges of Bruce County Road 20.

As seen in Figure 4, for lower values of θ, it is predicted that the ejected blade would be thrown clear of the road. For θ = 53°, it is predicted that the blade would land with the closest Blade tip on the edge of the road. The critical result in Figure 4 is that the Blade, in its resting position, would completely cover the road for a range of Blade orientation angles from θ = 63° to 95°.

From this result, it is possible that, given the right timing, a vehicle could crash into the fallen blade.

4.3 Definition of the Worst-Case Accident

With the possibility of the ejected blade landing on Bruce County Road 20, as illustrated in Figure 5, two types of accidents are envisioned:

1. The blade landing on a passing vehicle
2. The blade landing across the road as depicted in Figure 5, an instant before a passing vehicle reaches the blade, resulting in a full-speed frontal collision with the blade.

For this assessment, only the Type 2 Accident was considered and so the worst-case accident was taken to be a frontal collision with the Blade resting on the road.

For the Type 1 accident, the probability would be considerably lower than the Type 2 Accident and more difficult to access.

The worst-case accident details are as follows.

A serious frontal collision would only take place if the Blade were to land a short distance in front of the approaching vehicle. For the worst-case accident, it was assumed that there would be insufficient time for the driver to apply the brakes so that the vehicle would crash into the Blade with no reduction in speed.

The speed limit on Bruce County Road 20 adjacent to the Wind Turbine is 80 km/h and it was assumed that the vehicles passing by the Wind Turbine would be travelling at a speed of 80 km/h. Based on personal experience, 80 km/h is somewhat of an underestimate of the typical speed of vehicles on Bruce County Road 20.

4.4 Probability of a Worst-Case Accident for the Wind Turbine

In order for the Worst-Case accident to occur, there are three conditions to be met:

1. There must be a Blade structural failure that results in the Blade being ejected from the rotor. The probability of Blade ejection is covered in Section 4.4.1

2. The Blade must be ejected with a Blade orientation angle ranging from from 63° to 95°, from Section 4.2, as detailed in Section 4.4.2.

3. At the time of the Blade ejection, there must be a vehicle driving by the Wind Turbine, in a location that would expose the vehicle to crashing into the fallen Blade, as outlined in Section 4.4.3.

In Section 4.4.4 the Probability of a Worst-Case Accident is determined from the combined probability of events 1, 2, and 3.

4.4.1 Probability of a Blade Ejection

Based on data compiled in 2023 by the renewable energy insurance underwriter GCube, wind turbine blades failed at a rate of roughly 3,800 per year in a population estimated at 700,000 blades worldwide.

For the V80 Wind Turbine, the average resultant probability of blade ejection was determined to be 0.016 events per year.

4.4.2 Probability of a Blade Landing on Bruce County Road 20

In Section 4.2, it was found that if the Blade were ejected at an orientation angle ranging from 63° to 95°, then the Blade would completely cover the road upon landing.

The probability of the Blade landing so as to cover the road completely works out to be

$$P_{Angle} = (95° - 63°)/360° = 0.089 \text{ events per Blade ejection.}$$

4.4.3 Probability of an Exposure of a Vehicle to a Blade on the Road

From a traffic survey, the average daily traffic on Bruce County Road 20 is 3969 vehicles per day.

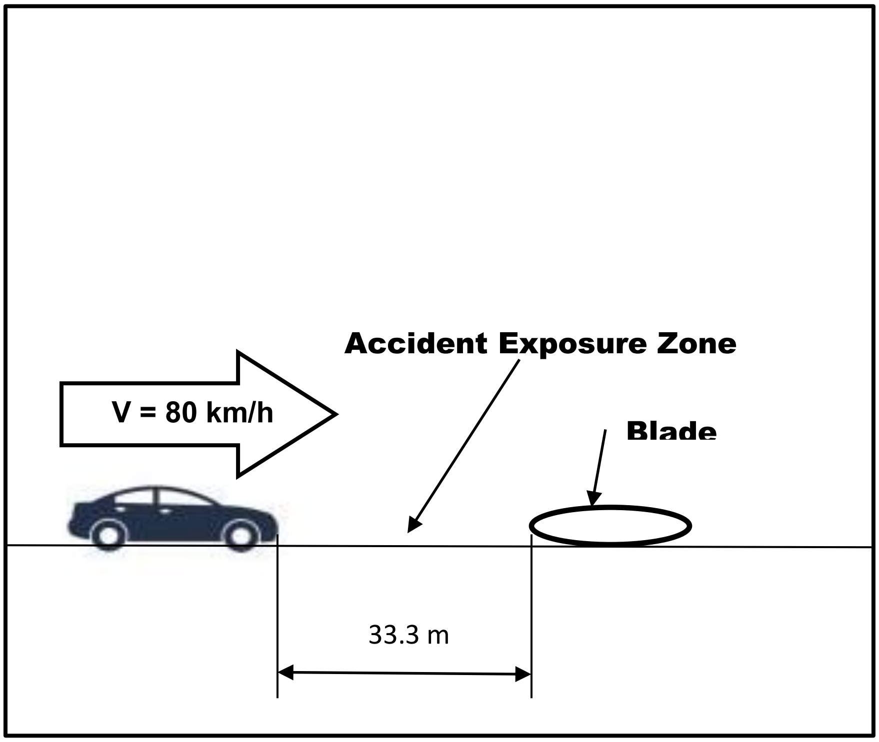
In the event of a blade ejection, every vehicle passing by the Wind Turbine on Bruce Country Road 20 would potentially be exposed to Accident Type 2, a collision with the ejected blade, resting on Bruce Country Road 20. The exposure time was calculated as follows.

Assuming a reaction time of 1.5 s for the driver to apply the brakes in response to the Blade falling across the road in front of the vehicle, with 3969 exposures per day, the total exposure time per year for a vehicle passing by the Wind Turbine would be 2.17×10^6 s. For a speed of 80 km/h or 22.2 m/s a full-speed crash would occur if the blade were to land a distance of 33.3 m in front of the vehicle or less.

Figure 6 illustrates the scenario required for the occurrence of the Worst-Case Accident on Bruce Road County Road 20 at WTG06 and depicts the 33.3 m accident exposure zone that would exist in front of the fallen Blade.

For a total of 3.20×10^7 s in a year, the probability of a vehicle being exposed to a fallen Blade on Bruce County Road 20, was found to be 0.069. As a clarification, a probability of 0.069 of exposure means that within an average 24 hour period, 1.65 hours is the time period in which a vehicle would residing within the “danger zone”.

Figure 6
Scenario for the Worst-Case Accident on Bruce County Road 20 at WTG02



4.4.4 Probability of a Worst-Case Accident

The probability of a Worst Case Accident is given by the product of three probability terms:

$$P_{WCA} = P_{Failure} \times P_{Angle} \times P_{Exposure}$$

Where P_{WCA} is the probability of the Worst-Case Accident,

$P_{Failure}$ is the probability of a Blade failure,

P_{Angle} is the probability of the Blade being ejected at the angle required for it to land on the road,

and $P_{Exposure}$ is the probability of a vehicle driving towards the Wind Turbine, being exposed to a frontal collision with a Blade by being within 33.3 m of the Blade when it falls.

For $P_{Failure}$ = 0.016 events per year,

P_{Angle} = 0.089 events per failure, and for

P_E = 0.069 events per year,

P_{WCA} would equal 9.98 x 10^{-5} events per year.

5. Comparison of the Probabilities of Worst-Case Accidents for a Darlington Reactor and the Bruce Power Net Zero Vestas V80 1.8 MW Wind Turbine (WTG02)

From Section 4.4.4, the probability of a worst-case accident resulting from Blade failure in the WTG06 was predicted to be 9.98 x 10^{-5} events per year. It is reasonable to assume 1 fatality per event, considering that in some events, one or more passengers could be in the vehicle.

From Section 3, 8.50x10^{-10} events per year was the predicted probability of the worst-case accident for a Darlington reactor, resulting in the release of radioactivity into the environment.

Therefore, the probability of a worst-case accident resulting from a Blade failure in the WTG06 Wind Turbine is predicted to be 9.98 x 10^{-5}/ 8.50x10^{-10} or 1.17 x 10^{5} times greater than a worst-case accident in one of the Darlington reactors.

A complication in properly and fairly assessing the consequences of the Darlington Worst-Case-Accident and those for the Wind Turbine Worst-Case-Accident is that different numbers of people would be involved in the two Worst-Case-Accidents.

Consequently, the number of people potentially affected by the Worst-Case-Accidents need to be factored into the Worst-Case-Accident Probabilities in order to determine and to compare the overall severity of the Accidents, expressed as fatalities per year, which is done in Section 6.0

6. Comparison of the Consequences of the Worst-Case-Accidents

In this section, the consequences of the Worst-Case Accidents are expressed in terms of fatalities per year, derived as (events/ year) times (fatalities/event).

For the WCA in WTG06, the frequency was determined to be 9.98 x 10^{-5} events per year. Conservatively assuming one fatality per event, the fatality rate would be 9.98 x 10^{-5} fatalities per year for the worst-case accident in WTG06.

For the WCA at Darlington, with a frequency of 8.50x10^{-10} events per year, it is necessary to estimate how many people would be affected by the accident.

An estimate of the number of people affected was performed using Table 6.4 of ***Study of Consequences of a Hypothetical Severe Nuclear Accident and Effectiveness of Mitigation Measures***, Reference [4]. A condensed version of Table 6.4 from Reference [4] is presented in Table 4, below.

The Table gives the expected number of excess future cases of childhood thyroid cancer that would result from the WCA in a Darlington Reactor. For childhood thyroid cancer, the baseline number of cases is 1,078 in a population of 100,000. The number of excess future cases represents the number of cases in a population of 100,000 resulting from the Darlington WCA, that would be additional to the baseline number of cases. Childhood thyroid cancer was chosen as a measure of the consequence of a WCA at Darlington since it is the most likely of all ill health effects. The 24-01 scenario assumes radiation release 24 hours after the SB0.

Table 4
Excess future risk of childhood thyroid cancer (in 100,000) for the 24-01 Scenario

Distance from DNGS (km)	Excess Future Cases (in 100,000)
20	720
36	287
50	114

Figure 7, is a plot of excess future cases of childhood thyroid cancer in the event of a WCA in DNGS, versus distance from DNGS. The blue curve is a power function curve fit to the data points in Table 4, including a number of extrapolated points. The power function curve intercepts the x axis at 76.6 km.

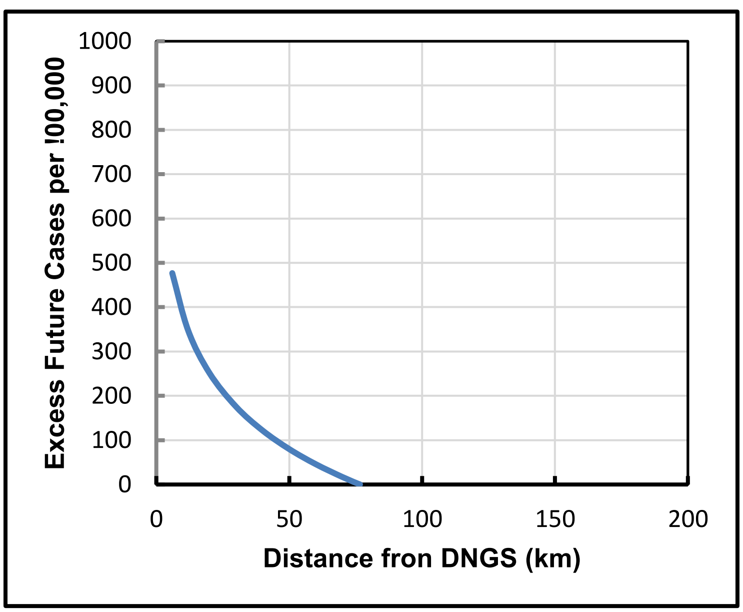
From Figure 7, it was found that a total of 1515 excess cases of childhood thyroid cancer would occur within a radius of 76.6 km, per 100,000 children for the WCA in Darlington.

The current population within a 76.6 km radius of DNGS, was estimated to be 6,644,218 people. Currently, 15.8 per cent of the population of Ontario consists of children, under age 14. Based on this ratio, a total of 1,049,786 children reside within a distance of 76.6 km of DNGS.

Therefore, based on 1515 excess cases of childhood thyroid cancer per 100,000 children, there would be 15904 excess cases within the population of children that reside within a distance of 76.6 km of DNGS.

Assuming a fatality rate of 10%, 1,590 excess fatalities in children would occur as a result of a WCA in Darlington.

Figure 7
Plot of Excess Future Cases of Childhood Leukemia vs Distance from DNGS



Therefore, the complete risk scenario for the Darlington WCA is given by:

1590 (fatalities/event) x 8.50×10^{-10} events / year = 1.35×10^{-6} fatalities per year.

Therefore, comparing 9.98×10^{-5} fatalities per year for the WCA in WTG02 with 1.35×10^{-6} fatalities per year for the WCA in Darlington, this assessment shows that the consequences of a WCA would be 74 times greater for WTG02 than for a Darlington Reactor.

7. Discussion of Results

Various simplifications were employed in the calculations, in Section 4.2, of the Blade CG trajectories following the failure of the Blade. The main simplifications were that the Blade would not spin about its CG and that there would be no aerodynamic forces on the blade that would effect the Blade free fall to the ground. Should the root of the Blade not break cleanly, leaving a ligament of the Blade attached to the rotor, spinning of the Blade would result during the free fall. The resulting analysis of the fall of the Blade to the ground would be more complicated, but the results are expected to be similar since the centre of gravity trajectories would be the same, with and without spinning of the ejected blade.

The overall scope of this assessment is very limited since the fatalities per year were estimated only for a particular Wind Turbine and only for the case of blade ejection. Other modes of failure, such as tower collapse, were not considered. The assessment would be more comprehensive if more Wind Turbines were considered. For example, fatality per year estimates could be generated for Worst-Case Accidents for all the Wind Turbines in Ontario, for comparison with the fatalities per year for Worst-Case Accidents in all of the Reactors in Ontario.

Another point made by OPG is that in the Probabilistic Safety Assessment, risk is determined as an aggregate of all possible accidents, not just the most severe accident as was done in this assessment. Although a comparison of aggregate risk for all accidents for DNGS and for WTG02 would have been more comprehensive, it was agreed that the comparison of the worst-case accidents was valid, for the purposes of this submission.

Should all Wind Turbines in Ontario be considered, the fatality rate would increase significantly over 9.98×10^{-5} fatalities per year for the WCA in WTG06. If all Ontario Reactors were considered, the estimated fatality rate from a WCA would also increase from the 1.35×10^{-6} fatalities per year estimate. However, it is expected that the increase in fatality rates for all Ontario Wind Turbines, relative to that for WTG06, would be greater than the increase in fatality rates, relative to that for one Reactor in Darlington.

It should be clearly noted that the health consequence predictions of Section 6 were not reviewed by health physics professionals and were not subject to QA verification. As such, the accuracy of the predictions can't be assured by the author, but are considered to be reasonable for the purposes of this submission.

8. Conclusions

1. The probability of a Worst-Case Accident in one of the DNGS reactors is a small fraction (0.00001) of that for a Worst-Case Accident in WTG06, located adjacent to Bruce County Road 20.

2. The predicted consequences of the Worst-Case Accidents for a Darlington Reactor and for WTG02, expressed as fatalities per year, compare as follows:

   Darlington Reactor WCA – 1.35×10^{-6} fatalities per year

   WTG02 WCA – 9.98×10^{-5} fatalities per year.

3. Although the assessment is highly limited, it refutes the blanket statement the CANDU reactor is unsafe in comparison with Wind Turbines.

4. The methods demonstrated in this assessment can be refined and be used in a more comprehensive province-wide analysis to compare the safety risks of Nuclear Reactors and Wind Turbines, expected to show that CANDU Reactors pose less of a risk to public safety than Wind Turbines, as indicated here.

9. References

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