Grover Hill Wind, LLC
Case No. 20-417-EL-BGN

Exhibit U
Ice Throw Risk Assessment
Westwood
April 2021

DICKINSON WRIGHT PLLC

ICE THROW RISK ASSESSMENT

Grover Hill Wind Farm

Paulding County, Ohio

APRIL 2021

PREPARED FOR:

STARWOOD ENERGY GROUP

PREPARED BY:

Westwood

Ice Throw Risk Assessment

Grover Hill Wind Farm

Paulding County, Ohio

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Report Update

Westwood Professional Services bears no responsibility to update this report for any changes occurring subsequent to the final issuance of this report.

Revision History

Revision No.	Revision Purpose	Date	Revised By
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1.0 Introduction

Westwood Professional Services was hired by Starwood Energy Group Global, Inc. to perform an ice-throw risk assessment for the proposed Grover Hills wind farm located in north west Ohio near the town of Grover Hill. The risk assessment involves estimating the risk of ice fragments being thrown from wind turbine blades and striking members of the general public that may be in the vicinity of the wind turbine.

The regulations for the state of Ohio require that:

- The risk of ice throw be reported at the property boundary and public road that are nearest to a wind turbine.
- The probability of a 1-kg fragment of ice landing beyond the statutory property line setback (turbine blade length plus 1,125 ft which equals 1,391 ft or 424 m) for each turbine location is less than one per cent per year.

2.0 Wind Turbine Icing

For the purposes of this study, it was assumed that the wind farm site is classified as IEA Icing Class 2, [1] which produces approximately 2,000 1-kg ice fragments per year, and that there are approximately 8 icing days per year. The wind distribution associated with the icing periods (wind speed and direction) was extracted from the wind data set supplied by the Client and was used in the analysis. Icing periods were considered to be from October 1 through March 31.

3.0 Ice Throw Risk Assessment Methodology

The methodology used in this study is based on the recommendations and guidelines which were developed in conjunction with the project "Wind Energy in Cold Climates" (WECO) which was partially funded under contract JOR3-CT95-0014 of the Non-Nuclear Energy Program managed by the European Commission, DGXII, and by the UK Department of Trade and Industry. The project was coordinated by the Finnish Meteorological Institute. The general approach is as follows:

- Determine the periods when icing may occur based on historical climatic data.
- Within those icing periods, determine the corresponding wind distribution.
- Within the resultant wind distribution, exclude those periods when the wind turbines will be shut down automatically by the wind turbine control system or by remote operators.[1]
- Based on the number of icing days determined from the analysis of the historical climatic data, use the WECO guidelines to arrive at the probability of fragments landing at the various distances from the turbines which are of interest.

[1] Not considered in this risk assessment.

- Estimate the probability of members of the general public being present within the distances from the turbine which are of interest or concern.
- Estimate the combined probability of members of the general public being hit by ice fragments.
- Compare that probability to a suitable benchmark risk, such as the risk of being struck by lightning.

4.0 WECO Guidelines

The WECO guidelines were based on a combination of numerical modeling and physical observations. The details of the guidelines were published in a series of conference papers [2, 3, 4]. Westwood Professional Services has developed a numerical model incorporating the methodology, recommendations and modeling assumptions from the WECO guidelines. This numerical model was used to estimate the probability of an ice fragment landing in any particular square meter of ground area in the vicinity of a wind turbine of interest for the Grover Hills project.

The following assumptions were used:

- The ice fragment is equally likely to become detached at any blade azimuth angle.
- The probability of ice detaching at the blade tip is three times greater than the probability of ice detaching at the hub. Linear interpolation is used for intermediate radial positions.
- Ice fragments have mass of either 1 kg or 0.5 kg and both have a frontal area 0.01 m^2.
- The wind speed distribution is extracted from the historical climatic data.
- The wind directional distribution is extracted from the historical climatic data.
- There is no correlation between the wind speed and the wind direction.
- There is no correlation between wind speed or direction and the occurrence of icing conditions.
- The wind turbine is always aligned with the wind.
- The wind turbine rotor is stationary when the wind speed is outside the operation wind speed range of the wind turbine.

With regard to the size of ice fragments, based on the results of the WECO project, it was determined that most ice fragments observed were in the range of 0.1 kg to 1.0 kg. Based on these findings, the guidelines recommend simulating ice throw fragments with a mass of 0.5 kg and 1.0 kg.

5.0 Candidate Wind Turbines

Starwood Energy Group Global, Inc. is considering three different turbine models for the Grover Hills project, the GE 1.6-100 with a 100 m hub height, the Vestas V100 with a 95 m hub height, and the Siemens 2.3-101 with an 80 m hub height. Based on an analysis of the hub height, rotor diameter and nominal rotor speed during operation, it was determined that the Vestas V162-6.0-

119 turbine had the highest tip speed and potential for the farthest ice throw and so was used for this study. The specifications for the Vestas V162-6.0-119 are as follows:

Rated Power:	6 MW
Rotor Diameter:	162 m (532 ft)
Hub Height:	119 m (390 ft)
Cut-in Wind Speed:	3 m/s (6.7 mph)
Cut-out Wind Speed:	24 m/s (53.7 mph)
Nominal RPM:	10.9 rpm
Tip Speed:	92.5 m/s (207 mph)

Monte Carlo simulations involving 1,000,000 iterations were performed for four different scenarios; an ice fragment with a mass of 1.0 kg either being thrown or dropped, and an ice fragment with a mass of 0.5 kg either being thrown or dropped.

The simulations involved randomly choosing a wind speed and wind direction from the representative distributions, the radial position along the blade length at which the ice fragment detaches, and the angular position of the blade relative to the ground (azimuth angle).

Based on the four input parameters, the trajectory of the ice fragment is calculated from the instant it leaves the blade until it hits the ground. For each iteration, the landing position of the ice fragment is recorded. The landing positions are then binned based on distance and direction in order to obtain the landing probability distribution per square meter in the immediate vicinity of the wind turbine.

6.0 Results

The results of the Monte Carlo simulations for all directions are shown in Figure 1 below. *These results are based on the assumption that the wind turbine is in operation during an icing event*. The figure shows the estimated probability of an ice fragment landing in a 1 m^2 area of ground as a function of distance and all directions from the turbine.

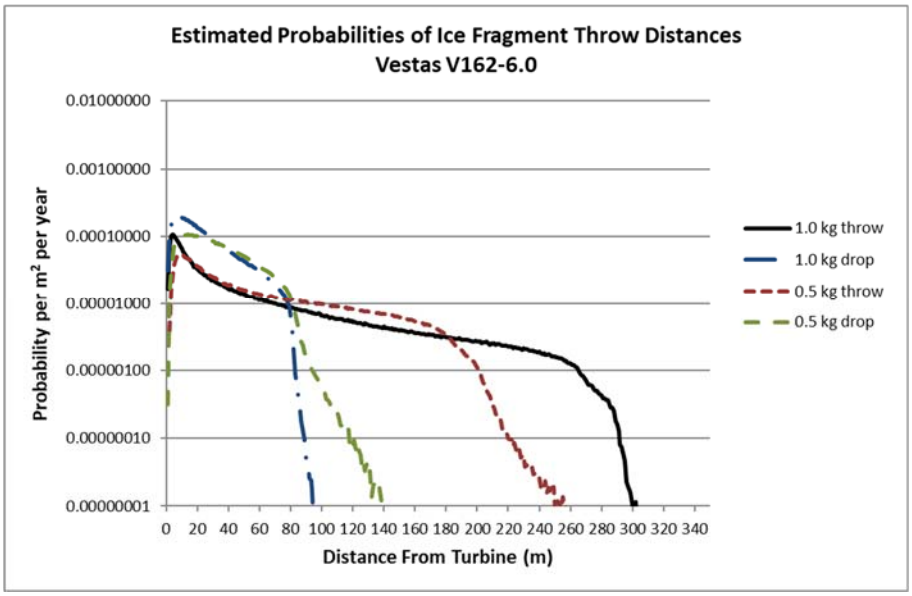

Figure 1: Estimated Probabilities of Throw and Drop Distances

As can be seen from the probability distributions shown in Figure 1, it is unlikely that an ice fragment would travel farther than approximately 320 meters (1,050 ft). Therefore, the probability of a 1-kg fragment of ice being thrown a distance of 1,391 ft is zero, which is less than the compliance criteria of one percent per year as per the Ohio state regulations.

For the largest turbine being considered for the project (Vestas V162-6.0-119), the distance to the nearest public road is 222 m (727 ft). The nearest public road is Township Highway T18 running east-west which is south of turbine T38. The probability of a 1-kg ice fragment landing on the public road is 0.0003 % or once in 333,333 years.

The nearest participating property boundary is the boundary between land parcels 130-P and 143-P, which is 6 m (19.3 ft) north of turbine T25. The probability of a 1-kg ice fragment landing at that location is 0.0116% or once in 8,621years.

The nearest non-participating property boundary is the boundary between land parcels 73-P and 94-NP, which is 425 m (1,394 ft) southwest of turbine T13. The probability of a 1-kg ice fragment landing at that location is zero since it is beyond the maximum throw distance of 320 m (1,050 ft).

7.0 Control and Mitigation Strategies

There are a number of different ice sensors available in the marketplace. It is well known that none of them are reliable 100% of the time. For this reason, it is common to use more than one type of sensor or a combination of methods to monitor for and predict icing conditions. The most common methods currently used to detect icing include weather monitoring, using two

anemometers (one heated and one not), ultrasonic sensors, video cameras, and blade vibration sensors.

Weather monitoring is commonly the only method employed on a number of existing single-turbine projects, with no incidents of ice fragment strikes being reported. Although the safety record of these single-turbine projects is good, it would still be advisable on a larger wind farm project to employ weather monitoring in conjunction with other sensors to curtail the wind turbines during times of potential icing.

Using two anemometers mounted on the nacelle, the wind speed difference between the heated and unheated anemometers will become greater as ice accretes on the unheated anemometer. If, at the same time, the ratio between the wind turbines power output and the expected power output is greater than some threshold value, the wind turbine controller then shuts down the turbine.

Ultrasonic sensors are mounted on the nacelle and vibrate at a known frequency, usually in the range of 40 to 70 kHz. The sensors frequency changes as ice accretes on the probe. These sensors typically have a heating element that is used to melt the ice from the sensor in order to monitor the rate of ice accretion. This signal is monitored by the controller and the turbine is automatically shut down when a pre-determined threshold is reached.

Using a video camera mounted in the hub and positioned to monitor the pressure side of the blade has also been used to detect the accumulation of ice. This method requires continuous monitoring and good visibility at night which can be expensive and could also cause problems with the additional nighttime visibility of the turbines.

All modern wind turbines have vibration sensors that are used to detect rotor imbalance which can be harmful to the machine. Oftentimes the rotor will become unbalanced due to uneven buildup of ice on the blades, which will then trigger an automatic shutdown of the turbine. Sometimes however the ice buildup will be uniform so that the rotor imbalance is not significant enough to trigger a shutdown.

The subject of ice sensors is an active area of continued research and new sensors and methods are still emerging so that it would be advisable to survey the current marketplace before making a final decision regarding the combination of strategies to be employed at the Back Fork site.

8.0 Other Considerations

This risk assessment does not take into account the following:

- The implementation of ice sensors and control strategies are not considered. Ice sensors and control strategies are planned to be implemented which will greatly reduce the probabilities from those estimated in this report. This risk assessment assumes that the wind turbine is in operation while ice has accumulated on the blades.
- The presence of trees or other structures that could provide coverage are not considered. Blockage or coverage by trees or structures from ice fragment throws would further reduce the probabilities of a strike to an ever-present individual or a passing vehicle.

- Terrain or topography are not considered. The model assumes flat terrain. The presence of significantly elevated terrain or hills would impact the results. A turbine situated on a steep hill would potentially throw ice fragments further, whereas the presence of a hill between the wind turbine and a potential landing point could intercept the trajectory of the fragment. There are no such steep hills or terrain within the Grover Hills project area.

9.0 Conclusions and Recommendations

There are no buildings that are within the potential strike zone of ice-throw fragments. The maximum throw distance of a 1-kg ice fragment is approximately 320 m (1,050 ft) and the probability that the fragment throw distance would be greater than the statutory property line setback of 1,391 ft is less than one percent per year (in fact it is zero) which is in compliance with the Ohio state regulation requirement.

Theses probabilities do not take into account the fact that ice sensors and other ice-throw mitigation strategies will be used to avoid ice-throws altogether. This risk assessment assumes that the turbine is in operation during an icing event. When control strategies are factored in, the probabilities of an ice fragment strike becomes even lower, since it will be highly unlikely that the turbines will actually be in operation during the times when icing is occurring.

Even though the risk of an ice strike is remote, it is still recommended that a combination of ice sensors, weather monitoring, and control algorithms be used to curtail the wind turbines during times of potential or actual icing conditions. In addition, warning signs should be posted at various locations to warn of the potential hazard.

10.0 References

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Rissanen, S. and Lehtomaki, V. 2016. Wind Power Icing Atlas – WIceAtlas, VTT. Available at: http:///www.vtt.fi/sites/wiceatlas. [4]

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