SHADOW FLICKER MODELING REPORT

Stark Wind Project
Herkimer County, New York

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1.0 EXECUTIVE SUMMARY

The Stark Wind Project (the Project) is a proposed wind power generation facility expected to consist of two (2) wind turbines in Herkimer County, New York. The Project is being developed by New Leaf Energy, Inc. (New Leaf). Epsilon Associates Inc. (Epsilon) has been retained by New Leaf to conduct a shadow flicker modeling study for this Project. This report presents results of the shadow flicker modeling of the proposed wind turbines in Herkimer County.

Shadow flicker modeling was conducted for three different scenarios: two (2) Vestas V150-4.3 wind turbines; two (2) Vestas V163-4.5 wind turbines; and two (2) GE 3.4-140 wind turbines. The purpose of this analysis is to predict the annual durations of wind turbine shadow flicker at nearby receptors.

For the Vestas V150-4.3 wind turbine, the maximum expected annual duration of shadow flicker at a modeling receptor is 36 hours, 40 minutes per year, this occurs at receptor #10. For the Vestas V163-4.5 wind turbine, the maximum expected annual duration of shadow flicker at a modeling receptor is 42 hours, 13 minutes per year, this occurs at receptor #10. For the GE 3.4-140 wind turbine, the maximum expected annual duration of shadow flicker at a modeling receptor is 33 hours, 7 minutes per year, this occurs at receptor #10. The modeling results are conservative in that modeling receptors were treated as “greenhouses” (i.e. having windows on all sides) and the surrounding area was assumed to be without vegetation or structures (“bare earth”).

2.0 INTRODUCTION

The proposed Project will consist of two (2) wind turbines. New Leaf is considering three different wind turbines: Vestas V150-4.3 units with a hub height of 120 meters, Vestas V163-4.5 units with a hub height of 113 meters, or GE 3.4-140 units with a hub height of 120 meters. Figure 2-1 shows the locations of the wind turbines in Herkimer County over aerial imagery.

Shadow flicker can be defined as an intermittent change in the intensity of light in a given area resulting from the operation of a wind turbine due to its interaction with the sun. An indoor observer experiences repeated changes in the brightness of the room as shadows cast from the wind turbine blades briefly pass by windows as the blades rotate. In order for this to occur, the wind turbine must be operating, the sun must be shining, and the window must be within the shadow region of the wind turbine, otherwise there is no shadow flicker. A stationary wind turbine only generates a stationary shadow similar to any other structure.

This report presents the findings of a shadow flicker modeling study for the Project. The wind turbines were modeled with the WindPRO software package using information provided by New Leaf. The expected annual duration of shadow flicker was calculated at modeling receptors. Shadow flicker isolines for the area surrounding the Project were generated. The results of the modeling are found within this report.

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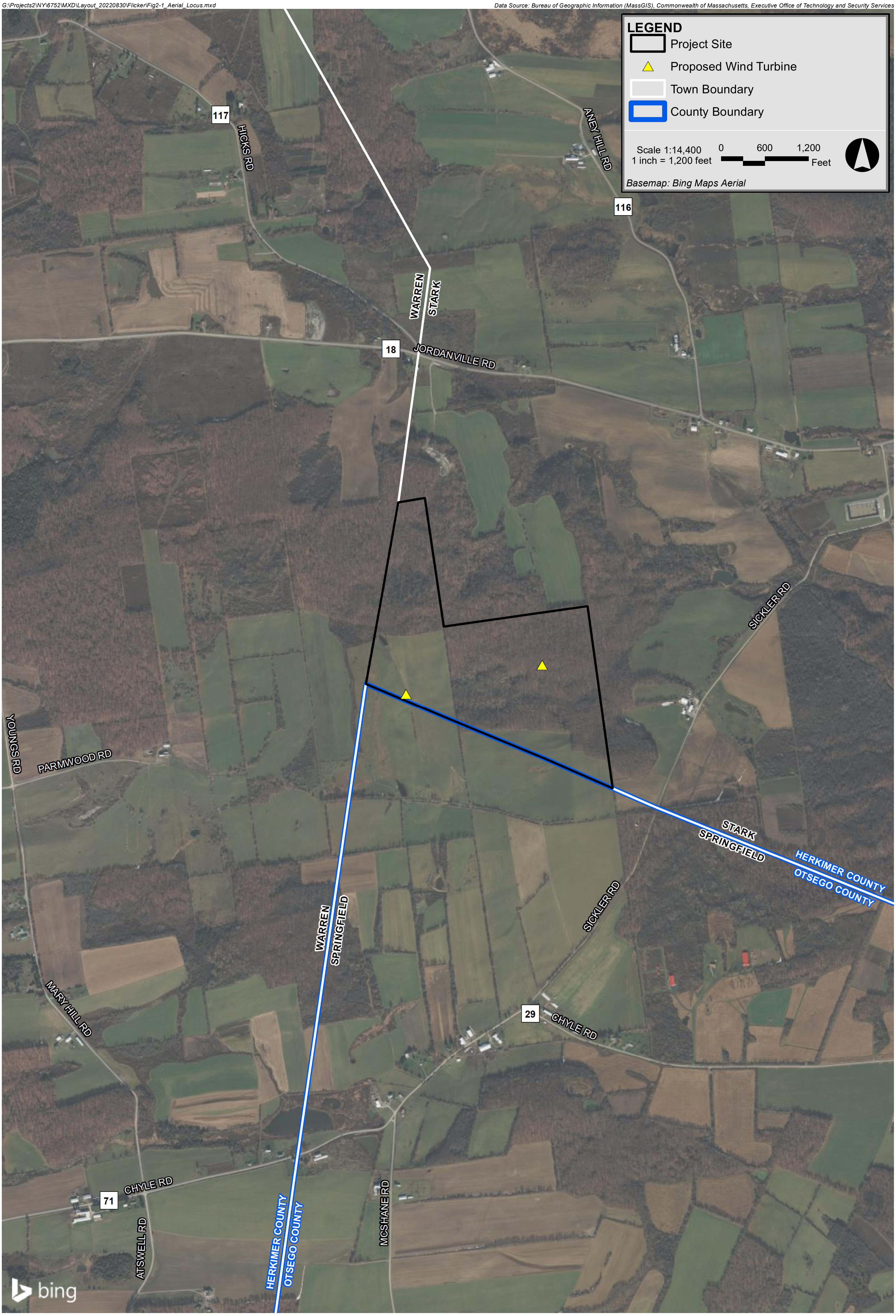
Data Source: Bureau of Geographic Information (MassGIS), Commonwealth of Massachusetts, Executive Office of Technology and Security Services



Stark Wind Stark, New York

Figure 2-1
Aerial Locus

3.0 SHADOW FLICKER MODELING

3.1 Modeling Methodology

Shadow flicker was modeled using a software package, WindPRO version 3.5. WindPRO is a software suite developed by EMD International A/S and is used for assessing potential environmental impacts from wind turbines. Using the Shadow module within WindPRO, worst-case shadow flicker in the area surrounding the wind turbines was calculated based on data inputs including: location of the wind turbines, location of discrete receptor points, wind turbine dimensions, flicker calculation limits, and terrain data. Based on these data, the model was able to incorporate the appropriate sun angle and maximum daily sunlight for this latitude into the calculations. The resulting worst-case calculations assume that the sun is always shining during daylight hours and that the wind turbine is always operating. The WindPRO Shadow module can be further refined by incorporating sunshine probabilities and wind turbine operational estimates by wind direction over the course of a year. The values produced by this further refinement are known as the “expected” shadow flicker. Expected annual shadow flicker durations are presented in this section.

This analysis is for the wind turbine array dated August 30, 2022. The location of the wind turbines is shown in Figure 3-1 and the coordinates are provided in Appendix A. The wind turbine will either be a Vestas V150-4.3 unit with a 150-meter rotor diameter and a hub height of 120 meters, a Vestas V163-4.5 unit with a 163-meter rotor diameter and a hub height of 113 meters, or a GE 3.4-140 unit with a 140-meter rotor diameter and a hub height of 120 meters. The wind turbines have the following characteristics based on the technical data provided by New Leaf:

		V150-4.3	V163-4.5	GE 3.4-140
♦ Rated Power	=	4,300 kW	4,500 kW	3,400 kW
♦ Hub Height	=	120 meters	113 meters	120 meters
♦ Rotor Diameter	=	150 meters	163 meters	140 meters
♦ Cut-in Wind Speed	=	3 m/s	3 m/s	3 m/s
♦ Cut-out Wind Speed	=	24.5 m/s	24 m/s	26 m/s[1]

To-date, there are no federal, state, or local regulations regarding the maximum radial distance from a wind turbine to which shadow flicker should be analyzed applicable to this Project. In the United States, shadow flicker is commonly evaluated out to a distance of ten times the rotor diameter. According to the Massachusetts Model Bylaw for wind energy facilities, shadow flicker impacts are minimal at and beyond a distance of ten rotor diameters.[2] Defining the shadow flicker calculation area has also been addressed in Europe where the ten times rotor diameter approach

1 Identified as “preliminary” by GE.

2 Massachusetts Department of Energy Resources, “Model As-of-Right Zoning Ordinance or Bylaw: Allowing Use of Wind Energy Facilities” 2009.

has been accepted in multiple European countries.[3] Some jurisdictions conservatively require a larger calculation area. The New Hampshire Site Evaluation Committee through rulemaking docket 2014-04 adopted rules on December 15, 2015 outlining application requirements and criteria for energy facilities, including wind energy facilities. As part of these revised regulations, Site 301.08(a)(2) requires an evaluation distance of at least 1 mile from a wind turbine.[4] Section 16-50j-94, part (g), of the Regulations of Connecticut State Agencies identifies the components required in a shadow flicker evaluation report which includes the calculation of shadow flicker from each proposed wind turbine to any off-site occupied structure within a 1.25 mile radius.[5] For this Project, ten times the largest rotor diameter of the proposed wind turbines corresponds to a distance of 1.01 miles (1,630 m). Conservatively, this analysis includes shadow flicker calculations out to 1.25 miles (2,012 m) from each wind turbine in the model for the proposed layout.

Epsilon generated a modeling receptor dataset consisting of 25 receptors via desktop analysis. The dataset is representative of residential buildings within the vicinity of the project. Each modeling point was assumed to have a window facing all directions ("greenhouse" mode) which yields conservative results. All modeling receptors are identified in Figure 3-1. The model was set to limit calculations to 2,012 meters from a wind turbine, the equivalent of 1.25 miles. Consequently, shadow flicker at any of the 25 modeling receptors greater than the corresponding limitation distance from a wind turbine was zero. In addition to modeling discrete points, shadow flicker was calculated at grid points in the area surrounding the modeled wind turbines to generate flicker isolines. A 20-meter spacing was used for this grid as shown in Figure 3-2, Figure 3-3, and Figure 3-4.

The terrain height contour elevations for the modeling domain were generated from elevation information derived from the National Elevation Dataset (NED) developed by the U.S. Geological Survey. Conservatively, obstacles, i.e. buildings and vegetation, were excluded from the analysis. This is effectively a "bare earth" scenario which is conservative. When accounted for in the shadow flicker calculations, such obstacles may significantly mitigate or eliminate the flicker effect depending on their size, type, and location. In addition, shadow flicker durations were calculated only when the angle of the sun was at least 3° above the horizon.

Monthly sunshine probability values were input for each month from January to December. These numbers were obtained from a publicly available historical dataset for Syracuse, New York from the National Oceanic and Atmospheric Administration's (NOAA) National Centers for

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3 Parsons Brinckerhoff, "Update of UK Shadow Flicker Evidence Base" Prepared for Department of Energy and Climate Change, 2011.

4 State of New Hampshire Site Evaluation Committee Site 300 Rules (2015), available at http://www.gencourt.state.nh.us/rules/state_agencies/site100-300.html Accessed in September 2022.

5 State of Connecticut CSC Wind Regulations (2014), available at https://eregulations.ct.gov/eRegsPortal/Browse/RCSA?id=Title_16Subtitle_16-50jSection_16-50j-94&content=shadow%20flicker/ Accessed in September 2022.

Environmental Information (NCEI).[6] Table 3-1 shows the percentage of sunshine hours by month used in the shadow flicker modeling. These values are the percentages that the sun is expected to be shining during daylight hours.

The number of hours the wind turbine is expected to operate for the 16 cardinal wind directions was input into the model. An hourly dataset for a one year period of wind directions and scaled wind speed was provided by New Leaf for a height of 120 meters. Epsilon used this data to calculate the typical annual number of operational hours per wind direction sector. These hours per wind direction sector are used by WindPRO to estimate the "wind direction" and "operation time" reduction factors. Based on this dataset, the wind turbine would operate 89% of the year. Table 3-2 shows the distribution of operational hours for the 16 wind directions.

6 NCEI (formerly NCDC), https://www1.ncdc.noaa.gov/pub/data/ccd-data/pctpos20.dat. Accessed in September 2022.

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Data Source: Bureau of Geographic Information (MassGIS), Commonwealth of Massachusetts, Executive Office of Technology and Security Services

Stark Wind **Stark, New York**

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Figure 3-1

Shadow Flicker Modeling Locations

Table 3-1 Monthly Percent of Possible Sunshine

Month	Possible Sunshine
January	46%
February	52%
March	51%
April	55%
May	53%
June	55%
July	62%
August	58%
September	54%
October	46%
November	33%
December	36%

Table 3-2 Operational Hours per Wind Direction Sector

Wind Sector	Operational Hours
N	112
NNE	70
NE	90
ENE	207
E	509
ESE	358
SE	211
SSE	196
S	259
SSW	426
SW	730
WSW	566
W	1197
WNW	1785
NW	812
NNW	271
Annual	7799

3.2 Shadow Flicker Modeling Results

Following the modeling methodology outlined in Section 3.1, WindPRO was used to calculate shadow flicker at the 25 discrete modeling receptor points. In addition to the discrete modeling points, shadow flicker isolines were generated based on the grid calculations for the Project.

3.2.1 Shadow Flicker Modeling Results – V150-4.3

Table B-1 in Appendix B presents the modeling results. Expected values are presented.

The predicted expected annual shadow flicker duration ranged from 0 hours, 0 minutes per year to 36 hours, 40 minutes per year for all 25 receptors. The maximum expected flicker modeled occurs at receptor #10. 16 of the 25 receptors were predicted to experience no annual shadow flicker. 8 receptors were predicted to experience some shadow flicker but less than 10 hours per year. The modeling results showed that zero (0) receptors would be expected to have between 10 hours and 30 hours of shadow flicker per year. One (1) receptor is expected to have over 30 hours of flicker per year. Figure 3-2 displays the modeled flicker isolines (expected hours per year) over aerial imagery in relation to the modeled wind turbine and modeling receptors.

3.2.2 Shadow Flicker Modeling Results – V163-4.5

Table B-2 in Appendix B presents the modeling results. Expected values are presented.

The predicted expected annual shadow flicker duration ranged from 0 hours, 0 minutes per year to 42 hours, 13 minutes per year for all 25 receptors. The maximum expected flicker modeled occurs at receptor #10. 16 of the 25 receptors were predicted to experience no annual shadow flicker. 8 receptors were predicted to experience some shadow flicker but less than 10 hours per year. The modeling results showed that zero (0) receptors would be expected to have between 10 hours and 30 hours of shadow flicker per year. One (1) receptor is expected to have over 30 hours of flicker per year. Figure 3-3 displays the modeled flicker isolines (expected hours per year) over aerial imagery in relation to the modeled wind turbine and modeling receptors.

3.2.3 Shadow Flicker Modeling Results – GE 3.4-140

Table B-3 in Appendix B presents the modeling results. Expected values are presented.

The predicted expected annual shadow flicker duration ranged from 0 hours, 0 minutes per year to 33 hours, 7 minutes per year for all 25 receptors. The maximum expected flicker modeled occurs at receptor #10. 18 of the 25 receptors were predicted to experience no annual shadow flicker. 6 receptors were predicted to experience some shadow flicker but less than 10 hours per year. The modeling results showed that zero (0) receptors would be expected to have between 10 hours and 30 hours of shadow flicker per year. One (1) receptor is expected to have over 30 hours of flicker per year. Figure 3-4 displays the modeled flicker isolines (expected hours per year) over aerial imagery in relation to the modeled wind turbine and modeling receptors.

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Data Source: Bureau of Geographic Information (MassGIS), Commonwealth of Massachusetts, Executive Office of Technology and Security Services

Stark Wind Stark, New York

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Figure 3-2

Shadow Flicker Modeling Results – Vestas V150-4.3

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Data Source: Bureau of Geographic Information (MassGIS), Commonwealth of Massachusetts, Executive Office of Technology and Security Services

Stark Wind Stark, New York

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Figure 3-3

Shadow Flicker Modeling Results – Vestas V163-4.5

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Data Source: Bureau of Geographic Information (MassGIS), Commonwealth of Massachusetts, Executive Office of Technology and Security Services

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Figure 3-4
Shadow Flicker Modeling Results – GE 3.4-140

Appendix A

Wind Turbine Coordinates

Table A-1.1: Wind Turbine Coordinates - V150

Wind Turbine ID	Wind Turbine Type	Hub Height (m)	Coordinates NAD83 UTM Zone 18N (meters)	
			X (Easting)	Y (Northing)
1	Vestas V150-4.3	120	510066.90	4749510.03
2	Vestas V150-4.3	120	510635.55	4749631.03

Table A-1.2: Wind Turbine Coordinates - V163

Wind Turbine ID	Wind Turbine Type	Hub Height (m)	Coordinates NAD83 UTM Zone 18N (meters)	
			X (Easting)	Y (Northing)
1	Vestas V163-4.5	113	510066.90	4749510.03
2	Vestas V163-4.5	113	510635.55	4749631.03

Table A-1.3: Wind Turbine Coordinates - GE 3.4-140

Wind Turbine ID	Wind Turbine Type	Hub Height (m)	Coordinates NAD83 UTM Zone 18N (meters)	
			X (Easting)	Y (Northing)
1	GE 3.4-140	120	510066.90	4749510.03
2	GE 3.4-140	120	510635.55	4749631.03

Appendix B

Shadow Flicker Modeling Results: Modeling Receptors

Table B-1: Shadow Flicker Modeling Results at Discrete Points - Sorted by Receptor ID - V150

Receptor ID	Coordinates UTM NAD83 Zone 18N (meters)		Expected Shadow Flicker Hours per Year
	X (Easting)	Y (Northing)	(HH:MM/year)
1	509197.47	4751051.79	0:00
2	510076.60	4750909.69	0:00
3	510580.35	4750877.12	0:00
4	511248.38	4750922.84	0:00
5	511293.16	4750644.94	0:08
6	511384.60	4750644.73	1:46
7	511506.61	4750614.60	3:47
8	511702.33	4750509.17	7:41
9	512006.72	4750524.79	3:16
10	511244.08	4749405.28	36:40
11	511031.70	4748960.72	4:48
12	508444.60	4748644.52	4:37
13	508462.85	4748519.47	0:04
14	508509.56	4748291.42	0:00
15	508660.65	4748239.10	0:00
16	509491.44	4747601.00	0:00
17	509628.50	4747553.11	0:00
18	510001.15	4747829.23	0:00
19	510148.07	4747972.39	0:00
20	510448.11	4748066.93	0:00
21	510601.15	4748207.84	0:00
22	510776.39	4748097.01	0:00
23	510929.80	4748072.64	0:00
24	511002.82	4748043.00	0:00
25	511349.45	4748375.62	0:00

Table B-2: Shadow Flicker Modeling Results at Discrete Points - Sorted by Receptor ID - V163

Receptor ID	Coordinates UTM NAD83 Zone 18N (meters)		Expected Shadow Flicker Hours per Year
	X (Easting)	Y (Northing)	(HH:MM/year)
1	509197.47	4751051.79	0:00
2	510076.60	4750909.69	0:00
3	510580.35	4750877.12	0:00
4	511248.38	4750922.84	0:00
5	511293.16	4750644.94	0:11
6	511384.60	4750644.73	1:56
7	511506.61	4750614.60	3:59
8	511702.33	4750509.17	8:21
9	512006.72	4750524.79	3:36
10	511244.08	4749405.28	42:13
11	511031.70	4748960.72	5:23
12	508444.60	4748644.52	4:46
13	508462.85	4748519.47	0:14
14	508509.56	4748291.42	0:00
15	508660.65	4748239.10	0:00
16	509491.44	4747601.00	0:00
17	509628.50	4747553.11	0:00
18	510001.15	4747829.23	0:00
19	510148.07	4747972.39	0:00
20	510448.11	4748066.93	0:00
21	510601.15	4748207.84	0:00
22	510776.39	4748097.01	0:00
23	510929.80	4748072.64	0:00
24	511002.82	4748043.00	0:00
25	511349.45	4748375.62	0:00

Table B-3: Shadow Flicker Modeling Results at Discrete Points - Sorted by Receptor ID - GE 3.4-140

Receptor ID	Coordinates UTM NAD83 Zone 18N (meters)		Expected Shadow Flicker Hours per Year
	X (Easting)	Y (Northing)	(HH:MM/year)
1	509197.47	4751051.79	0:00
2	510076.60	4750909.69	0:00
3	510580.35	4750877.12	0:00
4	511248.38	4750922.84	0:00
5	511293.16	4750644.94	0:00
6	511384.60	4750644.73	1:27
7	511506.61	4750614.60	3:28
8	511702.33	4750509.17	6:56
9	512006.72	4750524.79	2:53
10	511244.08	4749405.28	33:07
11	511031.70	4748960.72	4:15
12	508444.60	4748644.52	4:21
13	508462.85	4748519.47	0:00
14	508509.56	4748291.42	0:00
15	508660.65	4748239.10	0:00
16	509491.44	4747601.00	0:00
17	509628.50	4747553.11	0:00
18	510001.15	4747829.23	0:00
19	510148.07	4747972.39	0:00
20	510448.11	4748066.93	0:00
21	510601.15	4748207.84	0:00
22	510776.39	4748097.01	0:00
23	510929.80	4748072.64	0:00
24	511002.82	4748043.00	0:00
25	511349.45	4748375.62	0:00