Shadow Flicker Report

Cassadaga Wind Project

Towns of Arkwright, Charlotte, Cherry Creek, and Stockton, Chautauqua County, New York

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1.0 PROJECT OVERVIEW

Cassadaga Wind LLC (the Applicant), a subsidiary of EverPower Wind Holdings, Inc. is proposing to construct a wind energy generation facility and associated necessary Project infrastructure in the Towns of Arkwright, Charlotte, Cherry Creek, and Stockton in Chautauqua County, New York (hereafter referred to as the Project)(see Figure 1). The proposed Project will consist of up to 58 turbines for a total anticipated nameplate generating capacity of 126 MW. The actual number of turbines constructed will depend on the capacity of the turbine model selected, in order to reach a total generating capacity of up to 126 MW. However, no more than 58 turbines will be built and therefore this maximum number of turbines is assumed for this evaluation. The purpose of this report is to provide an assessment of the potential shadow flicker that could be experienced at sensitive receptors located in the vicinity of the proposed Project. Sensitive receptors include any known residential structures (both participating and non-participating), schools, office buildings, store fronts, or high-use public recreation areas that are located within the Study Area. An exhaustive search was performed by the Applicant to locate and identify these receptors. The procedure entailed mapping the study area and overlaying the area projected to be impacted by shadow flicker. The entire identified area was ground proofed in person on Tuesday March 29, 2016. All of the roads were driven and specific points that met the criteria were marked with a GPS point and photograph.

Several wind turbine generators are being considered for this Project, however the model with the largest rotor diameter is the Vestas V136-3.45 MW wind turbines. Each wind turbine consists of three major mechanical components: the tower, nacelle, and rotor. Assuming use of the Vestas V136 turbines or equivalent, the anticipated tower height or "hub height" (height from foundation to the center of the rotor), for each turbine is approximately 82 meters (269 feet). The V136 has a rotor diameter of 136 meters (446 feet), resulting in a total maximum height of 150 meters (492 feet). The current Project turbine layout is depicted in Figure 2.

The Project is located in Chautauqua County, New York approximately 18 miles north of the Pennsylvania border, 15 miles east of Lake Erie, and approximately 9 miles south of the City of Dunkirk. The Project is located within the Allegheny Plateau physiographic province of New York State. Elevations in the area range from between 1,200 feet above mean sea level (AMSL) in eastern Chautauqua County to 1,900 feet AMSL in the western portion of the county. Land cover within the Project area is dominated by active agriculture and forest land, with widely scattered farms and single family residences generally occurring along the road frontage.

2.0 INTRODUCTION

Shadow flicker refers to the moving shadows that an operating wind turbine casts at times of the day when the turbine rotor is between the sun and a receptor's position. Shadow flicker is most pronounced in northern latitudes during winter months because of the lower angle of the sun in the winter sky. However, it is possible to encounter shadow flicker anywhere for brief periods before sunset and after sunrise (U.S. Department of the Interior, 2005). During intervals of sunshine, wind turbine generators will cast a shadow on surrounding areas as the rotor blades pass in front of the sun, causing a flickering effect while the rotor is in motion. Shadow flicker does not occur when fog or clouds obscure the sun, or when turbines are not operating.

The distance between a wind turbine and a potential shadow-flicker receptor affects the intensity of the shadows cast by the blades, and therefore the intensity of flickering. Shadows cast close to a turbine will be more intense, distinct, and focused. This is because a greater proportion of the sun's disc is intermittently blocked by the turbine (BERR, 2009). Obstacles such as terrain, vegetation, and/or buildings occurring between receptors and wind turbines may significantly reduce or eliminate shadow-flicker effects. At distances beyond roughly 10 rotor diameters (approximately 1,360 meters based on the Vestas V136 turbine model used in this case) shadow-flicker effects are generally considered negligible (BERR, 2009; DECC, 2011; DOER, 2011).

Although shadow flicker has been alleged to cause or contribute to health effects, blade pass frequencies for modern commercial scale wind turbines are very low. According to the Epilepsy Society (2012), approximately five percent of individuals with epilepsy have sensitivity to light. Most people with photosensitive epilepsy are sensitive to flickering around 16-25 Hz (Hertz or Hz = 1 flash per second), although some people may be sensitive to rates as low as 3 Hz and as high as 60 Hz. Modern wind turbines (including the proposed Vestas V136) typically operate at a frequency of 1 Hz or less, and there is no evidence that wind turbines can trigger seizures (British Epilepsy Association, 2007; Ellenbogen et al., 2012; Parsons Brinckerhoff, 2011; NHMRC, 2010). The primary concern with shadow flicker is the annoyance it can cause for adjacent homeowners. Annoyance can trigger physiological reactions of the autonomic nervous and/or endocrine systems that increase the risk of cardiovascular disorders. However, it is important to note that annoyance is not a disease or physical illness in of itself; rather it is a variable and subjective response to stimuli that can include many other things besides shadow flicker.

The location and duration of shadow flicker can be predicted using computer modeling programs and input data regarding turbine characteristics and weather conditions. A "worst-case" shadow-flicker scenario could be predicted based on the assumptions that there are no clouds or fog, wind conditions allow continuous turbine operation, the turbine rotor is continuously perpendicular to the sun, and the turbine rotor is positioned between the receptor and the sun. However, this "worst–case" scenario is not what would actually occur because turbines do not operate continuously, are not always aligned perpendicular to the sun, and are not always positioned between the receptor and the sun. In addition, sunlight intensity and duration vary daily and seasonally, and obstacles that block shadows (terrain, vegetation, and buildings) exist in the landscape.

3.0 METHODS

3.1 Shadow Flicker Analysis

This shadow flicker analysis evaluated the potential impact of 58 Vestas V136 turbines, each with a rotor diameter of 136 meters and a hub height of 82 meters. Prior to conducting the shadow-flicker analysis, the Applicant identified potential receptors in the vicinity of the Project. A study area of 10 rotor diameters is typical for analysis of shadow-flicker effects. In the case of Vestas V136 turbine used in this analysis, 10 rotor diameters equals 1,360 meters (4,462 feet). A maximum distance of potential effect of 1,360 meters was used for this analysis to ensure that all potentially impacted receptors were identified and assessed.

The shadow flicker analysis for the proposed Project used *WindPRO 2.9.285* software and associated Shadow module. *WindPRO* is a widely accepted modeling software package developed specifically for the design and evaluation of wind power projects. Input variables and assumptions used for shadow flicker modeling calculations for the proposed Project include:

- Latitude and longitude coordinates of 58 proposed wind turbine sites (provided by the Applicant).
- Latitude and longitude coordinates for 522 potential receptors located in the 10 rotor diameter (1,360 meters) Study Area (provided by the Applicant).
- USGS 1:24,000 topographic mapping and USGS 10-meter resolution digital elevation model (DEM) data.
- The rotor diameter (136 meters) and hub height (82 meters) for the Vestas V136.
- Annual wind rose data (provided by the Applicant), which is depicted in Table A1 of Attachment A (to determine the approximate directional frequency of rotor orientation throughout the year).
- To account for the occurrence of cloudy conditions, the average monthly percent of available sunshine for the nearest NOAA weather station in Buffalo, New York was used. Data was obtained from NOAA's "Comparative Climatic Data for the United States through 2012" (see Table A2 of Attachment A) (http://www.ncdc.noaa.gov).
- No allowance was made for wind being below or above generation speeds. Blades are assumed to be moving during all daylight hours when the sun's elevation is more than 3 degrees above the horizon. Shadow flicker is generally considered imperceptible when the sun is less than 3 degrees above the horizon (due to the scattering effect of the atmosphere on low angle sunlight) (States Committee for Pollution Control, 2002).
- The possible screening effect of all existing trees and buildings adjacent to the receptors was not taken into consideration in the modeling. In addition, the number and/or orientation of windows in residential structures were not considered in the analysis.

Shadow-flicker effects on receptors are expressed in terms of predicted frequency (hours per year). Shadow isolines (i.e., contours indicating total number of hours of shadowing per average year) were calculated based on the data and assumptions outlined above. These isolines define the theoretical number of hours per year that shadow flicker would occur at any given location within a 1,360-meter radius of all proposed and alternate turbines (see Figure 3).

The model calculations include the cumulative sum of shadow hours for all Project turbines. This omni-directional approach reports total shadow flicker results at a receptor regardless of the presence or orientation of windows at that particular residence (i.e., it assumes shadows from all directions can be perceived at a residence, which may or may not be true). A receptor in this “greenhouse” model is defined as a one square meter area located one meter above ground; actual house dimensions are not taken into consideration.

Because the shadow flicker analysis conducted for the proposed Project was based on the conservative assumptions that 1) all 58 turbines will be built, 2) the turbines are in continuous operation during daylight hours, and 3) that shadow flicker can be perceived at a receptor structure regardless of the presence or orientation of windows or the screening effects of all surrounding trees and buildings, the analysis presented herein is a conservative projection of the shadow-flicker effects at ground level.

3.2 Viewshed Analysis

In addition to the shadow flicker analysis described above, a viewshed map was created using ArcGIS modeling to define areas of potential Project visibility within the study area. The viewshed map identified areas within the study area that could have an unobstructed line of sight to any portion of one or more of the proposed turbines. This map was prepared using 10-meter resolution USGS DEM data, the 2011 USGS National Land Cover Dataset (NLCD), the location and height of all proposed turbines, and ESRI ArcGIS® software with the Spatial Analyst extension. Based on standard visual assessment practice, the locations of forest land within the study area, as mapped by the NLCD, was assigned an assumed height of 40 feet and added to the DEM. Once the viewshed analysis was completed, the areas covered by the mapped forest vegetation layer were designated as “not visible” on the resulting data layer. In most forested areas, views will be well screened by the overhead tree canopy. During the growing season the forest canopy will fully block views of the proposed turbines, and such views will typically be almost completely obscured, or at least significantly screened by tree trunks and branches, even under “leaf-off” conditions. It is worth noting that forest vegetation within the study area is generally greater than 40 feet in height, and areas of forest vegetation mapped by the NLCD do not include the locations of hedgerows, street trees, yard vegetation, and other vegetation or structures in the landscape that may provide visual screening. Therefore, as previously stated the screening effect of all existing trees is not accounted for.

3.3 Shadow Flicker Threshold

No consistent national, state, county, or local standards exist for allowable frequency or duration of shadow flicker from wind turbines at the proposed Project site. In general, quantified limits on shadow flicker are uncommon in the United States because studies have not shown it to be a significant issue (USDOE, 2008, 2012; NRC, 2007). However, standards developed by some states and countries provide guidance in this regard. The New Hampshire Office of Energy and Planning (2008) issued a model ordinance for small wind energy systems (<100 kW) that defines significant shadow flicker impacts as more than 30 hours per year on abutting occupied buildings. A model wind ordinance prepared by the North Carolina Wind Working Group in 2008 suggests a limit of 30 hours per year (generally less than 1% of annual daylight hours) at any occupied building on a non-participating landowner's property (NCWWG, 2008). The Wisconsin Administrative Code (WAC) specifies a limit of 30 hours per year at any non-participating residence or occupied community building (Wisconsin Public Service Commission, 2012). The WAC also requires mitigation for non-participating residences or occupied community buildings experiencing 20 hours or more per year of shadow flicker. The Ohio Power Siting Board uses 30 annual hours of shadow flicker as a threshold of acceptability in certifying commercial wind power projects (OPSB, 2011a, 2011b, 2012, 2013, 2014). Additionally, international guidelines from Europe and Australia have suggested 30 hours of shadow flicker per year as the threshold of significant impact, or the point at which shadow flicker is commonly perceived as an annoyance (NRC, 2007; DECC, 2011; DPCD, 2012). Accordingly, a threshold of 30 shadow flicker hours per year was applied to the analysis of the proposed Project to identify any potentially significant impacts on identified non-participating receptors.

4.0 RESULTS

Output from the model includes the following information:

- Calculated shadow-flicker time (days per year, maximum hours per day, and total hours per year when shadow flicker is expected) at each of the 519 receptors located in the Study Area.
- Tabulated and plotted time of day that structures are predicted to receive shadow flicker.
- Shadow isolines, which are used to create maps showing turbine locations, receptors, and projected shadow-flicker duration (hours per year) without taking into consideration the effect of screening provided by vegetation and structures (see Figure 3).

These data are presented in the tables and calendars included in Attachment B.

A summary of the projected shadow flicker at each of the 519 receptors is presented below:

- 147 (28%) of the receptors are not expected to experience any shadow flicker,
- 10 (2%) of the receptors may be affected 0-1 hour/year,
- 167 (32%) of the receptors may be affected 1-10 hours/year,
- 95 (18%) of the receptors may be affected 10-20 hours/year,
- 45 (9%) of the receptors may be affected 20-30 hours/year,
- 55 (11%) of the receptors may be affected for more than 30 hours/year.

As these results indicate, 89% of the receptors are predicted to receive less than 30 hours of shadow flicker per year, with 62% of the receptors predicted to receive less than 10 hours of shadow flicker per year. At most receptor locations shadow flicker will occur primarily in the early morning or late afternoon and will generally last less than 1 hour per day. The maximum daily duration of shadow flicker predicted at any receptor is 2 hours and 6 minutes (at receptor 3229, see Attachment B).

Attachment B provides the results of the predicted shadow flicker at each structure calculated to experience more than 30 hours of shadow flicker per year. The times of day and duration of shadow flicker experienced by each structure will vary throughout the calendar year based on the position of the sun in the sky and the direction of prevailing winds. See Attachment B for a table indicating the amount of shadow flicker expected at each receptor over 30 hours and for detailed calendars that illustrate the specific times of year and day that shadow flicker may occur.

5.0 DISCUSSION

5.1 Receptors Predicted to Receive Over 30 Hours of Shadow Flicker

As indicated above, results of the shadow flicker analysis for the Cassadaga Wind Project indicate that up to 55 receptors could exceed the 30-hour threshold. However, 32 of these receptors (58%) are located on properties owned by Project participants. The details regarding anticipated shadow flicker at all structures predicted to receive in excess of 30 hours are summarized below in Table 1.

Table 1. Receptors Predicted to Exceed 30 Hours of Shadow Flicker

Receptor ID	Receptor Type[1]	Project Status	Predicted Shadow Flicker (days/year)	Predicted Annual Shadow Flicker (hh:mm/year)	Predicted Max Daily Shadow Flicker (hh:mm/day)
3740	Residential	Non-Participating	171	30:10	0:59
2774	Residential	Non-Participating	175	30:16	0:53

Receptor ID	Receptor Type[1]	Project Status	Predicted Shadow Flicker (days/year)	Predicted Annual Shadow Flicker (hh:mm/year)	Predicted Max Daily Shadow Flicker (hh:mm/day)
3304	Residential	Non-Participating	186	30:23	0:56
1554	Residential	Non-Participating	213	30:31	0:44
3739	Residential	Non-Participating	173	31:10	1:01
1464	Unknown[2]	Non-Participating	113	32:42	1:08
3083	Residential	Non-Participating	152	32:53	0:51
2735	Residential	Non-Participating	171	33:13	0:55
1461	Unknown[2]	Non-Participating	117	33:47	1:08
1589	Residential	Non-Participating	172	34:24	0:46
2734	Unknown[2]	Non-Participating	175	34:27	0:56
2730	Unknown[2]	Non-Participating	177	35:41	0:56
675	Residential	Non-Participating	142	35:56	1:05
2718	Unknown[2]	Non-Participating	179	36:31	0:59
3737	Residential	Non-Participating	181	39:27	1:08
720	Residential	Non-Participating	186	40:19	1:11
703	Residential	Non-Participating	171	40:22	1:13
2036	Unknown[2]	Non-Participating	118	41:38	1:03
2405	Residential	Non-Participating	168	42:07	1:10
1603	Residential	Non-Participating	234	44:05	1:02
2750	Residential	Non-Participating	219	46:04	1:08
2422	Residential	Non-Participating	247	58:55	1:04
3710	Unknown[2]	Non-Participating	295	70:07	1:11
2245	Residential	Participating	107	30:03	1:18
743	Unknown[2]	Participating	185	30:19	0:50
3337	Residential	Participating	196	30:31	0:53
1831	Unknown[2]	Participating	133	33:00	1:15
747	Residential	Participating	203	33:50	0:48
3154	Residential	Participating	147	34:02	0:44
1824	Unknown[2]	Participating	139	35:00	1:17
742	Residential	Participating	204	35:06	0:52
3016	Residential	Participating	163	36:29	1:24
3576	Residential	Participating	89	36:32	1:11
3319	Residential	Participating	237	37:50	0:52
2600	Unknown[2]	Participating	156	38:04	1:00
1606	Residential	Participating	199	39:15	0:51
2597	Unknown[2]	Participating	160	40:26	1:01

Receptor ID	Receptor Type[1]	Project Status	Predicted Shadow Flicker (days/year)	Predicted Annual Shadow Flicker (hh:mm/year)	Predicted Max Daily Shadow Flicker (hh:mm/day)
3170	Residential	Participating	184	40:27	1:15
3392	Residential	Participating	159	46:30	1:02
3589	Residential	Participating	109	47:31	1:24
2622	Residential	Participating	126	51:31	1:17
3380	Residential	Participating	181	51:41	1:48
2779	Unknown[2]	Participating	173	51:51	1:23
2623	Unknown[2]	Participating	124	56:04	1:22
1185	Residential	Participating	198	58:29	1:10
1379	Residential	Participating	238	61:18	1:10
2463	Residential	Participating	182	62:39	1:15
3265	Residential	Participating	274	62:49	1:20
1315	Unknown[2]	Participating	254	74:02	1:14
3318	Residential	Participating	274	79:13	1:26
1087	Residential	Participating	130	82:52	2:00
2276	Residential	Participating	249	100:44	2:02
2461	Residential	Participating	323	107:50	1:41
1199	Residential	Participating	311	113:07	1:41
3229	Residential	Participating	343	116:34	2:06

[1] There were no identified Schools, Office Buildings, or Storefronts within the Study Area.
[2] Structures in rural settings that are usually associated with agriculture or maintenance buildings.

Although shadow flicker at these receptors exceeds the 30-hour per year threshold, these calculations do not take into account the actual location and orientation of windows, or the screening effects associated with existing, site-specific conditions and obstacles such as trees (i.e., does not take into account the results of the viewshed analysis) and/or buildings. Further, this analysis assumes turbine rotors are continuously in motion. Given these assumptions, the predicted shadow-flicker frequency represents a conservative scenario, and almost certainly overstates the actual frequency of shadow flicker that would be experienced at any given receptor location. In addition, many of the modeled shadow flicker hours are expected to be low intensity because they would occur during the early morning or late afternoon hours when the sun is low in the sky. As the sun sinks below the horizon, more of its light is scattered by the atmosphere, which has the effect of dampening its brightness and therefore reducing its ability to cast dark shadows (EMD, 2013). As stated previously 58% of these receptors are on parcels owned by Project participants. Details regarding shadow flicker effects predicted at the remaining non-participant receptors are presented in Table 2. Results of predicted shadow flicker at each receptor is provided in Attachment B.

To provide a more realistic prediction of where shadow flicker will actually be perceived, *WindPRO* model results were compared to the results of the viewshed analysis conducted for the Project. As described in Section 3.2, the viewshed analysis takes into consideration the screening effect of mapped forest vegetation with an assumed average height of 40 feet (EDR, 2016). The viewshed analysis indicates that 11 of the 23 non-participant receptors predicted to experience over 30 hours of shadow flicker will not have views of the Project due to screening provided by mapped topography and vegetation (see Table 2 and Figure 4).

Table 2. Daily Effect to Non-Participating Receptors Predicted to Exceed 30 Hours of Shadow Flicker

Receptor ID	Project Status	Predicted Annual Shadow Flicker (hh:mm/year)	Turbines Contributing Shadow Flicker	Approximate Times of Day Receptor Potentially Affected by Flicker[1]	Vegetation Viewshed Analysis Results
675	Non - Participant	35:56	1, 2, 22	6:00PM - 8:00PM	Turbine Screened
703	Non - Participant	40:22	1, 2, 9, 22	5:30PM - 7:45PM 8:00PM - 8:15PM	Turbine Screened
720	Non - Participant	35:56	1, 2, 9, 22	4:30PM - 8:15PM	Turbine Visible
1461	Non - Participant	33:47	50	6:30PM - 8:00PM	Turbine Visible
1464	Non - Participant	32:41	50	6:30PM - 8:00PM	Turbine Visible
1554	Non - Participant	30:31	28, 33, 38, 43	6:00AM - 7:00AM 7:15AM - 8:00AM	Turbine Visible
1589	Non - Participant	34:24	33, 38, 43	6:00AM - 7:00AM 7:15AM - 8:30AM	Turbine Visible
1603	Non - Participant	44:05	33, 38, 43	2:45PM - 4:00PM 5:45PM - 7:00PM 7:30PM - 8:30PM	Turbine Visible
2036	Non - Participant	41:38	31	6:15AM - 7:30AM	Turbine Visible
2405	Non - Participant	42:07	41, 54	6:15AM - 7:30AM 2:30PM - 4:00PM	Turbine Screened
2422	Non - Participant	58:55	26, 32, 34, 40	6:00AM - 8:30AM	Turbine Screened
2718	Non - Participant	36:31	5, 14, 17	5:00PM - 8:30PM	Turbine Screened
2730	Non - Participant	35:41	5, 14, 17	4:30PM - 8:15PM	Turbine Screened
2734	Non - Participant	34:27	5, 14, 17	4:30PM - 8:15PM	Turbine Visible

Receptor ID	Project Status	Predicted Annual Shadow Flicker (hh:mm/year)	Turbines Contributing Shadow Flicker	Approximate Times of Day Receptor Potentially Affected by Flicker[1]	Vegetation Viewshed Analysis Results
2735	Non - Participant	33:13	5, 14, 17	4:30PM - 8:15PM	Turbine Visible
2750	Non - Participant	46:04	5, 14, 17	3:30PM - 8:15PM	Turbine Visible
2774	Non - Participant	30:16	5, 14, 17	3:45PM - 8:15PM	Turbine Screened
3083	Non - Participant	32:53	36, 48	6:30AM - 7:45AM 7:15PM - 7:45PM	Turbine Visible
3304	Non - Participant	30:23	49, 51, 55	3:00PM - 4:15PM 5:00PM - 7:45PM	Turbine Visible
3710	Non - Participant	70:07	3, 7, 11	3:00PM - 5:00PM 6:30PM - 8:30PM	Turbine Screened
3737	Non - Participant	39:27	3, 7, 11	2:30PM - 3:15PM 4:30PM - 8:00PM	Turbine Screened
3739	Non - Participant	31:10	7, 11	3:30PM - 5:00PM 5:15PM - 7:00PM	Turbine Screened
3740	Non - Participant	30:10	7, 11	3:30PM - 5:00PM 5:15PM - 7:00PM	Turbine Screened
742	Participant	35:06	1, 2, 9, 22	3:30PM - 8:00PM	Turbine Visible
743	Participant	30:19	1, 2, 9, 22	3:30PM - 8:00PM	Turbine Visible
747	Participant	33:50	1, 2, 9, 22	3:30PM - 8:00PM	Turbine Visible
1087	Participant	82:52	44, 45, 46	6:15PM - 8:00PM	Turbine Visible
1185	Participant	58:29	28, 44, 46	5:00PM - 7:45PM	Turbine Visible
1199	Participant	113:07	28, 44, 45, 46	6:45AM - 8:30AM 1:30PM - 3:00PM 5:00PM - 7:45PM	Turbine Visible
1315	Participant	74:02	28, 33, 44	3:30PM - 4:45PM 6:00PM - 7:00PM	Turbine Screened
1379	Participant	61:18	28, 33, 43	3:00PM - 3:45PM 4:30PM - 6:30PM 7:00PM - 7:45PM	Turbine Screened
1606	Participant	39:15	28, 33, 38, 43	6:00AM - 8:45AM	Turbine Visible
1824	Participant	35:00	50, 52	7:15AM - 9:30AM	Turbine Screened
1831	Participant	33:00	50, 52	7:15AM - 9:30AM	Turbine Screened
2245	Participant	30:03	31	7:00AM - 9:00AM	Turbine Visible
2276	Participant	100:44	31, 34, 40	7:15AM - 9:30AM	Turbine Visible

Receptor ID	Project Status	Predicted Annual Shadow Flicker (hh:mm/year)	Turbines Contributing Shadow Flicker	Approximate Times of Day Receptor Potentially Affected by Flicker[1]	Vegetation Viewshed Analysis Results
				6:15PM - 8:30PM	
2461	Participant	107:50	26, 32, 34, 40	6:30AM - 9:15AM	Turbine Visible
2463	Participant	62:39	41, 54	6:45AM - 8:15AM 3:00PM - 3:30PM	Turbine Screened
2597	Participant	40:26	54, 58	7:00AM - 9:00AM	Turbine Screened
2600	Participant	38:04	54, 58	7:00AM - 9:00AM	Turbine Screened
2622	Participant	51:31	5, 14	6:45PM - 8:45PM	Turbine Screened
2623	Participant	56:04	5, 14	6:45PM - 8:45PM	Turbine Screened
2779	Participant	51:31	5, 14, 17, 42	6:30AM - 9:00AM 8:00PM - 8:30PM	Turbine Screened
3016	Participant	36:29	17, 23, 42	7:15AM - 9:15AM 6:45PM - 7:30PM	Turbine Visible
3154	Participant	34:02	21, 36	6:15AM - 8:15AM	Turbine Screened
3170	Participant	40:27	13, 23, 49, 55	8:45AM - 10:00AM 7:15PM - 8:30PM	Turbine Visible
3229	Participant	116:34	13, 23, 49, 55	7:00AM - 10:00AM 3:15PM - 8:15PM	Turbine Screened
3265	Participant	62:49	13, 49, 51, 55	8:15AM - 10:00AM 4:00PM - 5:45PM 6:45PM - 8:30PM	Turbine Visible
3318	Participant	79:13	19, 20, 57	6:00AM - 9:00AM	Turbine Visible
3319	Participant	37:50	19, 20, 21, 57	6:30AM - 9:00AM	Turbine Screened
3337	Participant	30:31	19, 20, 21, 57	7:00AM - 8:45AM	Turbine Visible
3380	Participant	51:41	53, 56, 57	8:30AM - 9:15AM 4:00PM - 6:45PM	Turbine Visible
3392	Participant	46:30	4, 56	6:30AM - 8:00AM 5:45PM - 6:00PM 6:15PM - 7:00PM	Turbine Screened
3576	Participant	36:32	3	6:00AM - 7:45AM	Turbine Screened
3589	Participant	47:31	3	7:00PM - 8:45PM	Turbine Visible

[1]The times of day presented in Table 2 represent the range of times during which each structure could potentially experience shadow flicker throughout the year; however, no structures will experience shadow flicker every day during all those hours. See Attachment B for detailed calendars that illustrate the specific times of year and day that each structure may experience shadow flicker.

5.2 Potential Impacts on Recreational Areas

A qualitative review of the potential impact from shadow flicker on recreational areas was also assessed. Recreational resources (parks, trails, campgrounds) were mapped in relation to the shadow flicker model results/isolines (see Figure 4). The Earl Cardot Eastside Overland Trail, the Equestrian Trail, the regional Snowmobile Trails, and the Boutwell Hill State Forest are located within the Study Area, and portions of these recreational areas will experience shadow flicker. In general however, the Project will have minimal impact on recreational areas because viewers will not be subject to shadow flicker for extended periods of time. In addition, based on the viewshed analysis, a large portion of the recreational resources that are within the Study Area are anticipated to have limited to no views of Project turbines, therefore, limiting and/or eliminating shadow flicker from these areas. Figure 4 depicts the results of the shadow flicker modeling in relation to the viewshed analysis and recreational areas.

5.3 Potential Cumulative Impacts

The shadow flicker Study Area for the proposed Project is not located within 10 rotor diameters of another proposed, permitted, or built wind farm. The nearest such project is the Arkwright Summit Wind Farm, which was recently issued permits by the Town of Arkwright Town Board, and is located 2.5 miles north of the Cassadaga Project (as measured to the nearest turbine). Therefore, the Arkwright project does not have the potential to cause cumulative impacts on the receptors within the Study Area.

6.0 CONCLUSIONS

In summary, *WindPRO* predicted that 55 receptors will receive more than 30 hours/year of shadow flicker from the Project wind turbines. Thirty two (32) of these receptors are located on properties owned by Project participants, while the remaining 23 receptors are non-participating. Additional evaluation through viewshed analysis was conducted for all receptors predicted to receive more than 30 hours of flicker per year. This analysis revealed that 26 receptors are not anticipated to receive any shadow flicker due to the extent of screening by intervening vegetation not included in the *WindPRO* software, leaving 29 receptors predicted to receive more than 30 hours per year. Of these, 17 receptors are Project participants. Depending on the final turbine layout and model selected, there may be no non-participating receptors that are predicted to receive more than 30 hours/year of shadow flicker, the proposed threshold for which mitigation will be performed as discussed below. If, based on the final turbine layout and model selected, there are non-participating receptors predicted to receive more than 30 hours/year of shadow flicker, the Applicant may pursue neighbor agreements with the owners of those receptors. Alternatively, the Applicant may perform a receptor specific shadow flicker model taking into account the actual location and orientation of windows, or the screening effects associated with existing, turbine operational data, site-specific conditions and obstacles such as trees (i.e., does not take into account the results of the viewshed analysis) and/or buildings to demonstrate that shadow flicker will not be greater than 30 hours/year in a more realistic shadow flicker model before considering mitigation options discussed below.

As stated earlier, the number of turbines proposed for the Project will be dependent on the model chosen. This will provide additional opportunities for minimizing shadow-flicker effects. If a turbine model with a larger generating capacity is ultimately used for this Project, less than 58 turbines would be constructed. In addition, if a turbine model with a smaller rotor diameter is ultimately used (i.e., 120 meters) the modeled shadow flicker is expected to be less than that which is currently modeled. However, because the final turbine model is not known, and to provide a conservative, worst-case analysis, this study evaluates the potential impact of 58 turbines with the largest rotor diameter.

Many of the modeled shadow flicker hours are expected to be of low intensity, as they will occur during the early morning or late afternoon hours when the sun is low in the sky. When the sun sinks low on the horizon, more of its light is scattered by the atmosphere, which has the effect of dampening its brightness and therefore reducing its ability to cast dark shadows. Where shadow flicker does occur from the Project wind turbines, it is anticipated that it can be readily mitigated by planting of trees to screen the affected windows from the sun, or by the installing blinds or curtains. These mitigation options can be easily implemented even after the Facility has been constructed. Closing blinds or curtains on windows that face the turbine(s) during periods of shadow flicker effectively mitigates shadow flicker impacts. For example, the maximum daily shadow flicker received at any receptor in the study is 2:06 hours/day at receptor 3229. As shown in the graphical calendar in Attachment B, shadow flicker of this duration would only occur in mid to late March and mid to late September, when turbine 13 east of receptor 3229 would create shadow flicker in the morning (8:00 to 9:30 AM), while turbine 49 west of the receptor would create shadow flicker in the evening (5:45 to 7:30 PM). At other times of year, receptor 176 will receive less shadow flicker or potentially none at all.

7.0 REFERENCES

British Epilepsy Association. 2007. *Photosensitive Epilepsy.* Epilepsy Action, Yeadon Leeds, UK.

Business Enterprise & Regulatory Reform (BERR). 2009. *Onshore Wind: Shadow Flicker* [website]. Available at: http://webarchive.nationalarchives.gov.uk/20081013085503/http:/www.berr.gov.uk/whatwedo/energy/sources/renewables/planning/onshore-wind/shadow-flicker/page18736.html (Accessed February, 2016). United Kingdom Department for Business Enterprise and Regulatory Reform.

Department of Energy and Climate Change (DECC). 2011. *Update of UK Shadow Flicker Evidence Base: Final Report.* Parsons Brinckerhoff, London, UK, p. 5.

Massachusetts Department of Energy Resources (DOER). 2011. Model Amendment to a Zoning Ordinance or By-law: Allowing Conditional Use of Wind Energy Facilities. Available at: http://www.mass.gov/eea/docs/doer/gca/wind-not-by-right-bylaw-june13-2011.pdf (Accessed February, 2016).

Department of Planning and Community Development (DPCD). 2012. *Policy Planning and Guidelines for Development of Wind Energy Facilities in Victoria.* The State of Victoria, Department of Planning and Community Development, Melbourne, Australia.

Ellenbogen, J. M., S. Grace, W. J. Heigher-Bernays, J. F. Manwell, D. A. Mills, K. A. Sullivan, M. G. Weisskopf. 2012. *Wind Turbine Health Impact Study: Report of Independent Expert Panel*. January 2012. Prepared for Massachusetts Deparment of Environmental Protection and Massachusetts Department of Public Health. Available at: http://www.mass.gov/eea/docs/dep/energy/wind/turbine-impact-study.pdf (Accessed February, 2016).

EMD. 2013. *WindPRO 2.8 User Manual*. Available at: http://help.emd.dk/knowledgebase/ (Accessed February, 2016).

Epilepsy Society. 2012. *Wind Turbines and Photosensitive Epilepsy*. Available at: http://www.epilepsysociety.org.uk/AboutEpilepsy/Whatisepilepsy/Triggers/Photosensitiveepilepsy/windturbines (Accessed February, 2016). Last updated June 2012.

National Health and Medical Research Council (NHMRC). 2010. *Wind Turbines and Health: A Rapid Review of the Evidence.* Australian Government, July 2010.

National Research Council (NRC). 2007. *Environmental Impacts of Wind Energy Projects*. Committee on Environmental Impacts on Wind Energy Projects. The National Academies Press, Washington, D.C., pp. 160-162.

New Hampshire Office of Energy and Planning. 2008. Model Small Wind Energy Systems Ordinance. http://www.nh.gov/oep/resource-library/energy/documents/model-wind-ordinance.doc (Accessed May 2015).

North Carolina Wind Working Group (NCWWG). 2008. *Model wind ordinance for wind energy facilities in North Carolina*. http://wind.appstate.edu/sites/wind.appstate.edu/files/NCModelWindOrdinance_July2008.pdf (Accessed February, 2016).

Ohio Power Siting Board (OPSB). 2011a. *Opinion, Order, and Certificate in the Matter of Hog Creek Windfarm, LLC.* Case No. 10-654-EL-BGN, Section V, (44), p. 32.

OPSB. 2011b. *Opinion, Order, and Certificate in the Matter of Hardin Wind Energy, LLC.* Case No. 11-3446-EL-BGA. Opinion Section D, p. 5.

OPSB. 2012. *Opinion, Order, and Certificate in the Matter of Champaign Wind, LLC.* Case No. 12-160-EL-BGN. Section VI, (F), P. 48.

OPSB. 2013. *Opinion, Order, and Certificate in the Matter of Northwest Ohio Wind, LLC.* Case No. 13-0197-EL-BGN. Section V, (39).

OPSB. 2014. *Opinion, Order, and Certificate in the Matter of Hardin Wind, LLC.* Case No. 13-1177-EL-BGN. Opinion Section D, p. 2.

States Committee for Pollution Control – Nordrhein-Westfalen, 2002. Notes on the Identification and Evaluation of the Optical Emissions of Wind Turbines. Available at: http://www.umwelt.sachsen.de/umwelt/download/laerm_licht_mobilfunk/WEA-Schattenwurf-Hinweise_LAI.pdf (Accessed February, 2016).

U.S. Department of Energy (USDOE) National Renewable Energy Laboratory. 2008. *An Overview of Existing Wind Energy Ordinances*. Available at: http://www.windpoweringamerica.gov/pdfs/policy/2008/ordinances_overview.pdf (Accessed February, 2016).

U.S. Department of Energy (USDOE). 2012. *Wind Energy Ordinances*. Wind Program. Available at: http://www.windpoweringamerica.gov/policy/ordinances.asp (Accessed February, 2016).

U.S. Department of the Interior. 2005. *Final Programmatic Environmental Impact Statement on Wind Energy Development on BLM-Administered Lands in the Western United States.* Bureau of Land Management.

Wisconsin Public Service Commission. 2012. *Wisconsin Administrative Code, PSC 128.15*.