# Shadow Flicker Report

## Baron Winds Project

**Towns of Cohocton, Dansville, Fremont, and Wayland - Steuben County, New York**

Prepared for:


Baron Winds LLC, a subsidiary of
EverPower Wind Holdings, Inc.
1251 Waterfront Place, 3rd Floor
Pittsburgh, PA 15222
412.253.9400


Prepared by:


Environmental Design & Research,
Landscape Architecture, Engineering & Environmental Services, D.P.C.
217 Montgomery Street, Suite 1000
Syracuse, New York 13202
315.471.0688


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## 1.0 PROJECT OVERVIEW

Baron Winds 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 Cohocton, Dansville, Fremont, and Wayland, which are located in Steuben County, New York (hereafter referred to as the Project) (see Figure 1). The proposed Project will consist of up to 76 turbines for a total anticipated nameplate generating capacity of 300 megawatt (MW). The actual number of turbines constructed will depend on the capacity of the turbine model selected. However, no more than 76 turbines will be built and therefore this number of turbines has been assumed for purposes of this evaluation. This report provides 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 a 10-rotor diameter area (1,400 meters) around the proposed turbines (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. An analysis of aerial imagery was performed to identify all potential sensitive receptors from which a Geographic Information Systems (GIS) shapefile was created of sensitive receptors. Following the aerial imagery analysis, the entire Study Area was ground proofed in person in 2016. All of the roads were driven and any differences in the desktop sensitive receptors were marked with a GPS point and/or edits made to the receptor type on a paper map.

Several wind turbine generators are being considered for this Project; however, the model with the largest rotor diameter is the Senvion MM140 (3.6 megawatt [MW]) wind turbine. Each wind turbine consists of three major mechanical components: the tower, nacelle, and rotor. Assuming use of the Senvion MM140 turbines or equivalent, the anticipated tower height or "hub height" (height from foundation to the center of the rotor), for each turbine is approximately 80 meters (262 feet). The Senvion MM140 has a rotor diameter of 140 meters (459 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 Steuben County, New York, approximately 27 miles north of the Pennsylvania border, 50 miles south of Rochester, and approximately 43 miles southeast of the City of Elmira. The Project is located within the Appalachian Plateau physiographic province of New York State. Elevations in the area range from between 1,400 feet above mean sea level (amsl) in eastern Steuben County to 2,100 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 1,400 meters based on the Senvion 3.6 MW MM140 turbine model or equivalent proposed for the Project) 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, approximately five percent of individuals with epilepsy have sensitivity to light (Epilepsy Society, 2012). 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 Senvion 3.6 MW MM140 model) 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; NHMRC, 2010; Parsons Brinckerhoff, 2011).

Currently, with the exception of flashing fire alarms, the United States does not have any recommendations, guidelines, standards, regulations, or rules regarding photosensitivity (Harding et al., 2005). Large wind turbines (2 MW or more), such as those proposed for this Project, typically rotate at a frequency lower than the frequency that would pose risk to developing photoepileptic seizures (McCunney et al., 2014). As of 2014, there has been no published report of a rotating wind turbine triggering a photoepileptic seizure (McCunney et al., 2014).

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 itself a disease or physical illness; 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 realistic 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 76 Senvion 3.6 MW MM140 turbines, each with a rotor diameter of 140 meters and a hub height of 80 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 Senvion 3.6 MW MM140 turbine used in this analysis, 10 rotor diameters equals 1,400 meters (4,200 feet). A maximum distance of potential effect of 1,400 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 76 proposed wind turbine sites (provided by the Applicant).
- Latitude and longitude coordinates for 435 potential receptors located in the 10-rotor diameter (1,400 meters) Study Area (provided by the Applicant).
- U.S. Geological Survey (USGS) 1:24,000 topographic mapping and USGS 10-meter resolution digital elevation model (DEM) data.
- The rotor diameter (140 meters) and hub height (80 meters) for the Senvion 3.6 MW MM140 model.

- 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 National Oceanic and Atmospheric Administration (NOAA) weather station in Binghamton, New York, was used. Data was obtained from NOAA's "Comparative Climatic Data for the United States through 2015" (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 1,400-meter radius of all proposed turbine locations (see Figure 3).

The model calculations include the cumulative sum of shadow flicker 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 76 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. The tree canopy, or even the tree trunks and branches during "leaf-off" conditions, would also reduce the amount of light reaching these receptors. The shadow flicker effect will be significantly reduced compared to receptors outside of forested areas.

Moreover, 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, the full screening effect of existing trees and other vegetation 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. However, standards developed by some states and countries provide guidance in this regard. 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 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). The New York State Department of Public Service has suggested "operations shall be limited to a maximum of 30 hours annually at any non-participating residential receptor" (NYSDPS, 2017). 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 435 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 435 receptors is presented below:

- 101 (23%) of the receptors are not expected to experience any shadow flicker,
- 3 (1%) of the receptors may be affected 0-1 hour/year,
- 113 (26%) of the receptors may be affected 1-10 hours/year,
- 120 (28%) of the receptors may be affected 10-20 hours/year,
- 43 (10%) of the receptors may be affected 20-30 hours/year,
- 55 (13%) of the receptors may be affected for more than 30 hours/year.

As these results indicate, 87% of the receptors are predicted to receive less than 30 hours of shadow flicker per year, with 50% 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 1 hour and 47 minutes (at receptor 2616, see Attachment B).

Attachment B provides the results of the predicted shadow flicker at each structure. 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 and for receptors over 30 hours 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 Annually

As indicated above, results of the shadow flicker analysis for the Facility indicate that up to 55 receptors could exceed the 30-hour per year threshold. However, nine of these receptors (16%) are located on properties owned by Project participants. An additional three receptors (5%) are identified as cabins. Because these structures are generally occupied only periodically throughout the year, the occupants will not be present during all shadow flicker events. Finally, three receptors (5%) are identified as "unknown structures" that most likely consist of agricultural and maintenance buildings and so are not occupied. As these structures are only periodically occupied, these six structures (three cabins, three unknown) are considered non-participating receptors rather than non-participating residential receptors. With respect to the remaining structures—which are classified as non-participating residential receptors—it is possible that some of the structures are seasonal structures that are not occupied year-round, limiting potential exposure to shadow flicker by occupants. However, we have assumed for the purposes of this analysis that they are non-participating residential receptors. Therefore, only 40 non-participating residential receptors could potentially exceed the 30-hour per year threshold.

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 Annually**

| Receptor ID | Receptor Type[1] | Project Status | Predicted Annual Shadow Flicker (hh:mm) | Predicted Max Daily Shadow Flicker (hh:mm) | Predicted Shadow Flicker (days/year) |
|---|---|---|---|---|---|
| 589 | Residential | Non-Participating | 30:25:00 | 1:12 | 159 |
| 811 | Residential | Non-Participating | 30:51:00 | 0:59 | 165 |
| 561 | Residential | Non-Participating | 31:09:00 | 0:52 | 203 |
| 4506 | Residential | Non-Participating | 32:04:00 | 0:55 | 125 |
| 912 | Residential | Non-Participating | 32:54:00 | 1:11 | 165 |
| 584 | Residential | Non-Participating | 33:56:00 | 0:48 | 196 |
| 768 | Residential | Non-Participating | 34:00:00 | 0:53 | 114 |
| 3670 | Residential | Non-Participating | 34:01:00 | 1:23 | 134 |
| 427 | Residential | Non-Participating | 34:26:00 | 0:47 | 160 |
| 585 | Residential | Non-Participating | 34:29:00 | 0:41 | 204 |
| 2620 | Residential | Non-Participating | 34:36:00 | 1:04 | 196 |
| 592 | Unknown[2] | Non-Participating | 34:58:00 | 1:06 | 163 |
| 687 | Residential | Non-Participating | 35:17:00 | 0:49 | 132 |
| 966 | Residential | Non-Participating | 36:11:00 | 0:55 | 203 |
| 604 | Residential | Non-Participating | 36:14:00 | 0:57 | 165 |
| 4084 | Residential | Non-Participating | 36:34:00 | 1:21 | 177 |

| Receptor ID | Receptor Type[1] | Project Status | Predicted Annual Shadow Flicker (hh:mm) | Predicted Max Daily Shadow Flicker (hh:mm) | Predicted Shadow Flicker (days/year) |
|---|---|---|---|---|---|
| 2629 | Residential | Non-Participating | 36:53:00 | 1:26 | 183 |
| 2807 | Unknown[2] | Non-Participating | 37:12:00 | 0:57 | 168 |
| 2627 | Residential | Non-Participating | 37:40:00 | 1:21 | 191 |
| 650 | Residential | Non-Participating | 38:12:00 | 1:15 | 170 |
| 570 | Unknown[2] | Non-Participating | 38:41:00 | 1:11 | 93 |
| 806 | Residential | Non-Participating | 39:47:00 | 0:40 | 243 |
| 4449 | Cabin | Non-Participating | 39:49:00 | 1:01 | 195 |
| 544 | Residential | Non-Participating | 39:53:00 | 1:09 | 159 |
| 807 | Residential | Non-Participating | 40:34:00 | 0:41 | 242 |
| 4058 | Residential | Non-Participating | 40:37:00 | 1:08 | 208 |
| 991 | Residential | Non-Participating | 40:41:00 | 1:44 | 133 |
| 648 | Residential | Non-Participating | 42:15:00 | 1:19 | 148 |
| 4085 | Residential | Non-Participating | 44:07:00 | 1:11 | 177 |
| 968 | Residential | Non-Participating | 44:44:00 | 1:03 | 225 |
| 547 | Residential | Non-Participating | 45:05:00 | 0:53 | 223 |
| 564 | Residential | Non-Participating | 46:00:00 | 0:59 | 253 |
| 967 | Residential | Non-Participating | 46:49:00 | 1:03 | 234 |
| 576 | Residential | Non-Participating | 47:12:00 | 1:09 | 246 |
| 574 | Residential | Non-Participating | 49:32:00 | 0:53 | 190 |
| 770 | Residential | Non-Participating | 52:35:00 | 1:03 | 148 |
| 769 | Residential | Non-Participating | 56:17:00 | 1:08 | 150 |
| 542 | Residential | Non-Participating | 57:30:00 | 1:10 | 244 |
| 851 | Residential | Non-Participating | 62:09:00 | 1:26 | 236 |
| 977 | Residential | Non-Participating | 64:00:00 | 1:14 | 215 |
| 2801 | Cabin | Non-Participating | 64:13:00 | 1:45 | 265 |
| 4468 | Residential | Non-Participating | 65:30:00 | 1:02 | 288 |
| 425 | Residential | Non-Participating | 67:38:00 | 1:28 | 264 |
| 4470 | Cabin | Non-Participating | 68:00:00 | 1:34 | 213 |
| 4448 | Residential | Non-Participating | 69:18:00 | 1:23 | 225 |
| 837 | Residential | Non-Participating | 98:56:00 | 1:40 | 195 |
| 979 | Residential | Participating | 37:54:00 | 1:42 | 178 |
| 2616 | Residential | Participating | 38:27:00 | 1:47 | 184 |
| 578 | Residential | Participating | 39:18:00 | 0:50 | 238 |
| 2651 | Residential | Participating | 44:41:00 | 0:53 | 235 |
| 907 | Residential | Participating | 46:02:00 | 1:07 | 251 |

| Receptor ID | Receptor Type[1] | Project Status | Predicted Annual Shadow Flicker (hh:mm) | Predicted Max Daily Shadow Flicker (hh:mm) | Predicted Shadow Flicker (days/year) |
|---|---|---|---|---|---|
| 426 | Residential | Participating | 46:18:00 | 1:34 | 153 |
| 836 | Residential | Participating | 54:43:00 | 1:12 | 155 |
| 583 | Residential | Participating | 58:53:00 | 1:01 | 296 |
| 4471 | Residential | Participating | 59:20:00 | 0:47 | 321 |

[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 theoretically 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 and that each receptor location is occupied year-round. In addition, as stated previously, 16% of these receptors are on parcels owned by Project participants, 5% are periodically/seasonally occupied cabins, and an additional 5% are unknown structures that are usually associated with agriculture or maintenance buildings.

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).

Details regarding shadow flicker effects predicted at the remaining non-participant receptors are presented in Table 2 below. Results of predicted shadow flicker at each receptor (participating and non-participating) is provided in Attachment B.

In addition, 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 17 of the 46 non-participating receptors (13 of the 40 non-participating residential 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 | 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 |
|---|---|---|---|---|
| 589 | 30:25 | T76, T79, T87 | 2:15PM - 3:30PM | Visible |
| 811 | 30:51 | T55, T72, T83, T89 | 6:30AM - 7:15AM | Visible |
| | | | 2:45PM - 4:00PM | |
| | | | 5:30PM - 5:45PM | |
| | | | 6:00PM - 7:45PM | |
| 561 | 31:09 | T35, T40, T76, T79 | 7:30AM - 8:30AM | Visible |
| | | | 8:45AM - 9:45 AM | |
| | | | 6:00PM - 8:00PM | |
| 4506 | 32:04 | T65, T69 | 6:45PM - 8:00PM | Not Visible |
| 912 | 32:54 | T24, T29, T33 | 7:00AM - 9:30AM | Visible |
| 584 | 33:56 | T64, T79, T87 | 6:00AM - 7:15AM | Visible |
| | | | 3:30PM - 4:30PM | |
| | | | 4:45PM - 6:15PM | |
| 768 | 34:00 | T44, T47, T52, T60 | 6:00AM - 6:45AM | Visible |
| | | | 7:00PM - 8:30PM | |
| 3670 | 34:01 | T7, T18 | 2:00PM - 4:15PM | Not Visible |
| 427 | 34:26 | T44, T46, T47 | 7:00AM - 8:30AM | Not Visible |
| | | | 7:30PM - 8:30PM | |
| 585 | 34:29 | T64, T79, T87 | 6:00AM - 7:00AM | Visible |
| | | | 3:30PM - 4:30PM | |
| | | | 4:45PM - 6:30PM | |
| 2620 | 34:36 | T63, T73, T77, T85, T92, T93 | 7:00AM - 9:00AM | Visible |
| | | | 9:30AM - 10:00AM | |
| | | | 4:00PM - 5:00PM | |
| 592[2] | 34:58 | T68, T76, T87 | 2:45PM - 5:00PM | Visible |
| | | | 5:45PM - 7:00PM | |
| 687 | 35:17 | T76, T87 | 6:30AM - 7:30AM | Visible |
| 966 | 36:11 | T4, T6, T11, T22, T37 | 7:15AM - 9:15AM | Not Visible |
| | | | 1:30PM - 2:15PM | |
| | | | 4:45PM - 7:00PM | |
| 604 | 36:14 | T68, T769, T76 | 3:15PM - 4:15PM | Visible |
| | | | 7:00 PM - 8:15PM | |
| 4084 | 36:34 | | 7:30AM - 10:30AM | Not Visible |

| Receptor ID | 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 |
|---|---|---|---|---|
| | | T1, T9, T22, T26, T34 | 4:30PM - 7:45PM | |
| 2629 | 36:53 | T63, T77, T82, T85 | 7:00AM - 8:45AM | Visible |
| | | | 2:30PM - 4:00PM | |
| 2807[2] | 37:12 | T50, T51, T84 | 6:00PM - 8:00PM | Visible |
| 2627 | 37:40 | T63, T77, T82, T85 | 6:45AM - 8:45AM | Visible |
| | | | 2:15PM - 4:00PM | |
| 650 | 38:12 | T53, T55, T81, T86 | 7:15AM - 9:00AM | Visible |
| | | | 4:30PM - 7:30PM | |
| 570[2] | 38:41 | T40 | 6:00AM - 7:30AM | Not Visible |
| 806 | 39:47 | T53, T55, T89, T91 | 6:30AM -8:00AM | Visible |
| | | | 2:30PM - 3:30PM | |
| | | | 4:30PM - 5:30PM | |
| 4449[2] | 39:49 | T73, T77, T82, T85 | 3:30PM - 6:45PM | Not Visible |
| | | | 7:00PM - 8:00PM | |
| 544 | 39:53 | T35, T62, T66, T91 | 6:30AM - 8:00AM | Visible |
| | | | 4:00PM - 5:45PM | |
| 807 | 40:34 | T53, T55, T89, T91 | 6:30AM - 7:45AM | Not Visible |
| | | | 3:00PM - 4:00PM | |
| | | | 4:30PM - 6:15PM | |
| 4058 | 40:37 | T4, T6, T11, T17, T22 | 8:00AM - 10:15AM | Visible |
| | | | 2:30PM - 3:15PM | |
| | | | 6:00PM - 7:30PM | |
| 991 | 40:41 | T44, T47, T52, T59, T60 | 7:30AM - 9:45AM | Not Visible |
| | | | 4:45PM - 7:45PM | |
| 648 | 42:15 | T53, T55, T81, T86 | 7:15AM - 8:45AM | Visible |
| | | | 3:30PM - 5:30PM | |
| | | | 6:00PM - 7:00PM | |
| 4085 | 44:07 | T1, T9, T22, T26, T34 | 8:00AM - 9:30AM | Not Visible |
| | | | 10:00AM - 10:30AM | |
| | | | 4:30PM - 6:00PM | |
| | | | 6:15PM - 7:30PM | |
| 968 | 44:44 | T4, T6, T11, T22, T37 | 7:00AM - 9:00AM | Not Visible |
| | | | 1:00PM - 2:00PM | |
| | | | 5:00PM - 5:15PM | |

| Receptor ID | 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 |
|---|---|---|---|---|
| | | | 5:30PM - 7:30PM | |
| 547 | 45:05 | T64, T75, T79 | 6:30AM - 9:00AM | Visible |
| | | | 3:45PM - 4:30PM | |
| 564 | 46:00 | T35, T40, T76, T79 | 7:15AM - 9:30AM | Visible |
| | | | 6:00PM - 8:00PM | |
| 967 | 46:49 | T4, T6, T11, T22, T37 | 7:00AM - 9:00AM | Not Visible |
| | | | 1:00PM - 2:00PM | |
| | | | 5:00PM - 5:15PM | |
| | | | 5:30PM - 7:30PM | |
| 576 | 47:12 | T35, T40, T76, T79 | 7:00AM - 9:30AM | Visible |
| | | | 6:00PM - 7:00PM | |
| | | | 7:30PM - 8:15PM | |
| 574 | 49:32 | T76, T79, T87 | 6:30AM - 8:45AM | Visible |
| 770 | 52:35 | T44, T47, T52, T60 | 6:00AM - 7:30AM | Visible |
| | | | 6:30PM - 8:15PM | |
| 769 | 56:17 | T44, T47, T52, T60 | 6:00AM - 7:30AM | Visible |
| | | | 6:30PM - 8:30PM | |
| 542 | 57:30 | T35, T40, T62, T66, T91 | 6:00AM - 7:45AM | Visible |
| | | | 3:45PM - 6:00PM | |
| 851 | 62:09 | T2, T3, T5, T7 | 7:00AM - 9:30AM | Visible |
| | | | 7:00PM - 8:30PM | |
| 977 | 64:00 | T1, T9, T26, T34 | 7:00AM - 9:15AM | Not Visible |
| | | | 6:30PM - 7:30PM | |
| 2801[2] | 64:13 | T32, T42, T51, T80, T84 | 6:00AM - 6:30AM | Not Visible |
| | | | 7:00AM - 8:30AM | |
| | | | 3:15PM - 6:00PM | |
| | | | 7:30PM - 8:30PM | |
| 4468 | 65:30 | T4, T6, T11, T22, T26 | 6:30AM - 7:15AM | Not Visible |
| | | | 8:00AM - 9:15AM | |
| | | | 3:00PM - 5:00PM | |
| | | | 7:00PM - 7:45PM | |
| 425 | 67:38 | T44, T46, T59, T74, T88 | 7:30AM - 9:30AM | Visible |
| | | | 3:15PM - 6:30PM | |
| 4470[2] | 68:00 | T8, T9, T19, T43 | 6:15AM - 8:30AM | Not Visible |
| | | | 6:30PM - 8:00PM | |

| Receptor ID | 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 |
|---|---|---|---|---|
| 4448 | 69:18 | T8, T9, T19, T43 | 6:00AM - 8:30AM | Visible |
| | | | 6:30PM - 8:00PM | |
| 837 | 98:56 | T61, T62, T89 | 6:30AM - 8:30AM | Not 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.
[2] Structures are either unoccupied or periodically occupied cabins or unknown structures typically associated with agriculture or maintenance buildings. These structures are considered non-participating receptors, rather than non-participating residential receptors.

### 5.2 Potential Impacts on Recreational Areas

A qualitative review of the potential impact from shadow flicker on recreational areas was also conducted. Recreational resources (parks, trails, campgrounds) were mapped in relation to the shadow flicker model results/isolines (see Figure 4). Two regional snowmobile trails (Bath Snowflakes Snowmobile Trail and Quad County Snowmobile Trail), a bike trail, and a scenic overlook 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 typically do not occupy these areas for extended periods and so will not be subject to shadow flicker for more than a brief period. 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 the Project turbines, thus 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

Because the Baron Winds Project is located adjacent to the Cohocton Wind Project and the Dutch Hill Wind Project, there exists the potential for cumulative shadow flicker impacts at certain receptors (i.e., those occurring within a 10-rotor diameter distance of Baron Winds turbines and a 10-rotor diameter distance of turbines in one of both of the other project(s)). To evaluate the potential for cumulative shadow flicker impacts from the Cohocton Wind and the Dutch Hill Wind projects, a second shadow flicker analysis was run for selected turbines. Both the Cohocton Wind and Dutch Hill Wind projects use Clipper C96 turbines with a rotor diameter of 96 meters. To determine receptors that would be potentially affected by turbines from both projects, a buffer defining the maximum distance of potential effect was applied to the existing Cohocton Wind turbines (960 meters), Dutch Hill turbines (960 meters), and to the proposed Baron Winds turbines (1,400 meters). No receptors were located within the areas where the Dutch Hill and Baron Winds buffers overlapped, so no cumulative impacts are anticipated as a result of these turbines. The 10 receptors located within the area where the Cohocton Wind and Baron Winds buffers overlap have the potential for cumulative shadow flicker impacts.

The analysis was run using the same software described in Section 3.1, along with latitude and longitude coordinates for 10 receptors that were located in the area of potential cumulative impact. The remaining input variables, assumptions, and model methodology used are the same as described in Section 3.1. The results of this analysis are presented in Table 3, below, with the "predicted" columns representing shadow flicker from the Baron Winds Project only, and the "cumulative predicted" columns representing the combined shadow flicker impacts from both Baron Winds and Cohocton Wind facilities. Only receptors that were predicted to have shadow flicker from the Baron Winds Project are included in Table 3.

**Table 3. Daily Effect to Structures with Potential Cumulative Shadow Flicker**

| Receptor ID | Receptor Type | Receptor Status | Predicted Annual Shadow Flicker (hh:mm/ year) | Cumulative Predicted Annual Shadow Flicker (hh:mm/ year) | Predicted Max Daily Shadow Flicker (hh:mm/ day) | Cumulative Predicted Max Daily Shadow Flicker (hh:mm/ day) | Predicted Shadow Flicker (days/ year) | Cumulative Predicted Shadow Flicker (days/ year) | Viewshed Analysis Results |
|---|---|---|---|---|---|---|---|---|---|
| 767 | Residential | Non-Participating | 3:08 | 9:00 | 0:24 | 0:28 | 27 | 101 | Not Visible |
| 771 | Cabin | Non-Participating | 11:35 | 12:24 | 0:27 | 0:27 | 77 | 99 | Visible |

As indicated in Table 3, the cumulative shadow flicker analysis results indicate that no receptors will exceed 30 hours of shadow flicker per year. Thus, no additional receptors are anticipated to exceed the 30-hour threshold when the effect of both projects is taken into consideration.

## 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. Nine of these receptors are located on properties owned by Project participants, while the remaining 46 receptors are non-participating. However, six of the non-participating receptors are unoccupied or occupied only periodically (cabins/seasonal structures/unknown structures). As a result, there is little, if any, likelihood that individuals will actually experience 30 hours per year of shadow flicker at these locations.

More generally, the assumptions underlying the shadow flicker analysis are extremely conservative. Although shadow flicker at these receptors is calculated to exceed the 30-hour per year threshold, the analysis does not take into account important real-world factors, including the actual location and orientation of windows and the screening effects associated with existing, site-specific conditions and obstacles such as trees and/or buildings. Further, the analysis assumes turbine rotors are in continuous motion. Given these assumptions, the predicted shadow-flicker frequency represents a conservative scenario, and 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, nine of the receptors are located on properties owned by Project participants, while the remaining 46 receptors are non-participating. Of these 46 non-participating receptors, 40 are non-participating residential receptors. Additional evaluation through viewshed analysis was conducted for all receptors predicted to receive more than 30 hours of shadow flicker per year. This analysis revealed that of 46 non-participating receptors, 17 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 non-participating receptors predicted to receive more than 30 hours per year. Of these 29 non-participating receptors, two are unknown structures, which are typically structures in rural settings usually associated with agriculture or maintenance buildings and are therefore non-residential. These structures are not residential and, as such, individuals at these structures will not actually experience 30 hours per year of shadow flicker. Therefore, only 27 non-participating residential receptors will have views of the facility and potentially experience over 30 hours of shadow flicker per year.

Depending on the final turbine layout and model selected, there may be no non-participating residential 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. Following final turbine model selection, the Applicant will prepare an updated receptor-specific shadow flicker analysis for all non-participating residential receptors. This analysis will take into account any screening by existing yard trees, buildings, or proximity to stands of trees and the number and/or orientation of windows in residential receptors. Additionally, this analysis will use Project-specific meteorological data to account for wind being below or above generation speeds.

Following the final shadow-clicker analysis, if shadow flicker is modeled to exceed 30 hours per year at a non-participating residential receptor, the following mitigation options are available: 1) work with the landowner to sign a neighbor agreement and become a Project participant, 2) plant trees or install window blinds to block the shadow flicker, and/or 3) install detection systems on the turbines resulting in greater than 30 hours per year of shadow flicker at non-participating receptors. These mitigation options can be easily implemented even after the Facility has been constructed.

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