
Shadow Flicker Analysis for the Blue Creek Wind Project

Prepared for
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SECTION 1

Introduction

Heartland Wind, LLC (Heartland Wind), a limited liability company whose sole member and manager is Iberdrola Renewables, Inc. (IBR), is proposing to construct, own, and operate a facility with up to 350 megawatts (MW) in nameplate capacity of wind-powered electric generation in Van Wert and Paulding counties, Ohio (the Blue Creek Wind Farm, or the Facility). The Blue Creek Wind Farm is located within Paulding and Van Wert counties, Ohio in the townships of Benton, Blue Creek, and Latty in Paulding County and the townships of Hoaglin, Tully, and Union in Van Wert County. The Facility lies in the north-central portion of Van Wert County, approximately 3.0 miles north of the city of Van Wert, and in south-central portion of Paulding County, approximately 8.0 miles south of the village of Paulding. The Project area stretches generally in a southwesterly to northeasterly direction from State Route 30 just northeast of the village of Convoy.

The Facility would include the following:

- Up to 175 wind turbine generators¹
- Electrical collection system using underground and aboveground 34.5 kilovolt (kV) collection lines and aboveground 115 kV collection lines
- Three intra-project collection substations
- One interconnection substation
- Gravel access roads
- A temporary staging and construction laydown area
- Up to two permanent meteorological facilities consisting of up to two permanent meteorological towers (met towers) and a sonic detection and ranging (SODAR) facility
- A temporary concrete batch plant
- An operation and maintenance (O&M) building

Heartland Wind performed a shadow flicker analysis for 167 Gamesa G90 2.0 MW wind turbines (G-90) on 328-foot (100-meter) -tall towers to evaluate the extent of potential shadow flicker experienced at each residence and primary transportation corridor in the Project area. The G-90 is the most likely turbine to be used because of Heartland Wind's

¹ The proposed Facility will have up to 175 turbines, for a maximum potential output of 350 MW. Figure 1 within this report identifies the specific locations for 167 turbines and other related Facility infrastructure. An additional eight turbines will be located in an area along the eastern portion of the Project area boundary. The Applicant will provide the locations of these eight turbines and appropriate site-specific information by April 1, 2010 in sufficient time for the OPSB staff to consider the information in the staff report.

experience with this machine in other Midwestern sites and large-scale purchase commitment with Gamesa for the next few years.

Shadow flicker is the term used to refer to the alternating changes in light intensity that can occur at times when the rotating blades of wind turbines cast moving shadows on the ground or on structures. Shadow flicker occurs only when the wind turbines are operating during sunny conditions, and is most likely to occur early and late in the day when the sun is at a low angle in the sky. The intensity of shadow flicker is "...defined as the difference or variation in brightness at a given location in the presence or absence of a shadow" (National Research Council, 2007). The frequency of shadow flicker is a function of the number of blades making up the wind turbine rotor and rotor speed. Shadow flicker frequency is measured in terms of alternations per second, or hertz (Hz). The intensity of the shadows cast by the moving blades of wind turbines and thus the perceived intensity of the flickering effect is determined by the distance of the affected area from the turbine, with the most intense, distinct, and focused shadows occurring closest to the turbine (Department of Energy & Climate Change [DECC], 2009). In general, for the size wind turbines constructed today, the shadow flicker effects are most evident within the first 820 feet (250 meters) of the turbine and fade with distance, so that by 3,281 feet (1,000 meters), the shadow contrasts are no longer readily evident (Osten and Pahlke, 1998).

There are two primary concerns about shadow flicker. The first is that shadow flicker could potentially trigger epileptic seizures and the second is that shadow flicker could become a source of annoyance to residents living in close proximity to wind turbines.

The Epilepsy Foundation of America notes that for a small minority (about 3 percent) of the three million people in the United States who are affected by epilepsy, there is a potential for epileptic seizures to be triggered by flashing light. These seizures have the potential to be triggered when the light flashes are in the range of from 5 to 30 Hz. Because the frequency of the shadow flicker created by modern wind turbines is in the range of 0.6 to 1.0 Hz, the shadow flicker effects created by wind turbines do not have the potential to trigger epileptic seizures. (Epilepsy Foundation of America, 2008)

The issue of annoyance is more subjective. There could be cases in which shadow flicker cast on dwellings in very close proximity to wind turbines could be enough of a source of distraction to residents to be considered a nuisance. The National Research Council has observed that shadow flicker is more likely to be a concern in the higher latitude regions of Northern Europe, where the sun is likely to be at a low angle particularly in winter, than in the continental United States, where "...shadow flicker has not been identified as causing even a mild annoyance" (2007).

There are currently no federal or state standards regulating frequency or duration of shadow flicker for wind turbines. International studies and guidelines from Europe and Australia, including the *Best Practice Guidelines for the Irish Wind Energy Industry* (Irish Wind Energy Association [IWEA], 2008), have suggested 30 hours of shadow flicker per year as the threshold of significant impact, or the point at which shadow flicker can be considered a nuisance. Heartland Wind used a threshold of 30 hours per year for this analysis to identify affected residences. The threshold of 30 hours per year represents approximately 0.3 percent of the total hours (8,760) in a year, so three times this number represents shadow flicker of less than one percent of the year.

SECTION 2

Methods Used to Predict Shadow Flicker Effects

CH2M HILL conducted the shadow flicker analysis using the shadow flicker module of WindFarm 4.1.1.2, a comprehensive software package developed to aid in designing wind farm projects and in evaluating their environmental effects. To calculate shadow flicker levels at a residence, WindFarm takes into account the location of the residence, the orientations of each of the residence's sides, the location of each wind turbine, turbine hub height, turbine rotor width, latitude and longitude, and data on the sun's path through the sky on each day of the year.

The model domain included all proposed turbines and nearby residences. USGS digital elevation model files with 33-foot (10-meter) resolution were used by the program to account for elevation differences and topographic features in the distance in the line of sight when viewed from a window. As the sun approaches the horizon, it is less intense; therefore, the shadow influence is reduced. An angle of 3 degrees above the horizon was specified in the model, below which shadow influence was not calculated.

For the Project, the WindFarm model evaluated the shadow flicker effects of 167 G-90 wind turbines, which have a hub height of 328 feet (100 meters) and a rotor diameter of 295 feet (90 meters). Heartland Wind evaluated all residences within 2,950 feet (900 meters) of a turbine site for potential shadow flicker impacts. The 2,950 feet (900 meters) figure represents ten times the rotor diameter of a turbine (295 feet [90 meters]). The IWEA guidelines suggest this distance (IWEA, 2008), and several government sources suggest that shadow flicker effects become relatively insignificant beyond 10 rotor diameters (U.S. Department of Interior, 2005; DECC, 2008).

The shadow flicker analysis involved a three-step process. The first step was to make an initial model run to identify all residential structures located within 2,950 feet (900 meters) of the nearest wind turbine that would have the potential to be exposed to 30 or more hours of shadow flicker per year. Once those residences were identified, the second step included a structure-specific field survey was undertaken to determine the actual orientation of windows on each of these houses. In addition, the survey identified any potential obstructions in the line of sight between the residence and the turbine blades such as trees and other structures, and the presence of existing window treatments such as awnings that would reduce the visibility of the blade shadows at the residence.

The third step was a second modeling analysis performed to determine the shadow flicker effects at discrete points using specific house coordinates and structure specific data. At residences where detailed data on fenestration was not available, the WindFarm model was run assuming windows face all directions. Because of this, it is likely that at these residences, the model results over predict shadow flicker if these residences do not have windows facing a turbine that could cause shadow effects. The results of this modeling are presented in Table 1, which identifies 39 residences located within 2,950 feet (900 meters) of

the proposed turbines that would potentially be exposed to 30 or more hours of shadow flicker a year.

The shadow flicker data generated by WindFarm provides a worst-case assessment that overestimates the daily minutes and total annual hours of shadow flicker. Factors that the model does not account for in generating the shadow flicker data include the following:

1. There is likely to be times when the rotors will not be turning because of insufficient wind.
2. The direction of the wind may sometimes be such that the turbine blades are turned in a direction that decreases the creation of blade shadow effects.
3. The presence of haze in the air that can have the effect of reducing the intensity of light and reducing the distances at which shadows can be cast.
4. Shadows created by the portions of the rotor closest to the hub are more intense and can be perceived at a longer distance than the shadows created by the tips of the blades. The model treats the shadows created by all parts of the blade as if they were the shadows created by the portions closest to the hub. As a result, the model may overstate the distances at which shadows can be seen and may overstate their effects.
5. The potential for structures and vegetation lying between the residence and the turbines to block shadows created by the rotating turbine blades, thus preventing shadow flicker from occurring at the residence.

In addition, the WindFarm shadow flicker program does not account for the occurrence of clouds and fog, the effect of these sunless conditions on limiting the number of days on which shadow flicker can occur, and the annual number of hours that shadow flicker is likely to be experienced. To consider weather conditions, the output of the WindFarm shadow flicker program was adjusted using percent sky cover from historical climate data from Fort Wayne, Indiana.

SECTION 3

Analysis Results

The information presented in Table 1 includes

- The distance of each residence from the closest flicker-generating turbine;
- The number of hours of shadow flicker the model predicts the residence would be exposed to over the course of a year;
- An identification of the turbines that would contribute to shadow flicker at that residence; and
- Any features noted during the site visit with the potential to prevent the shadow flickering from being visible at the residence.

The long-term effect of each obstruction identified could not be predicted because none of them is necessarily permanent. Figure 1 identifies the locations of the 39 residences predicted to be exposed to 30 hours or more per year of shadow flicker.

TABLE 1
Predicted Shadow Flicker

Residence ID	Predicted Shadow Flicker (hours/year) ^a	Turbines Contributing to Shadow Flicker	Distance to Closest Contributing Turbine (m)	Noteworthy Obstructions
41	41:59	47, 42	430	Row of evergreen trees to north and west
44	40:19	40, 41, 42, 47	465	Large deciduous trees surrounding house
45	43:27	41, 42, 46, 47	461	Structures west of house, mixed trees north and east
96	44:03	59, 60	381	Barns west of house
98	36:08	59, 60	404	Evergreen fence surrounding house
107	33:39	26, 37, 38	424	Garage and barn east of house
114	39:55	139, 140, 141	453	Structures north of house and deciduous trees west of house
116	42:26	139, 140, 141	461	Garage southeast of house, deciduous trees south of house
117	35:33	117, 118, 119	520	Row of evergreens southwest of house
124	40:44	120, 121, 122	379	Garage north of house and barns south of house
126	42:54	117, 118, 119	424	Large deciduous trees on property

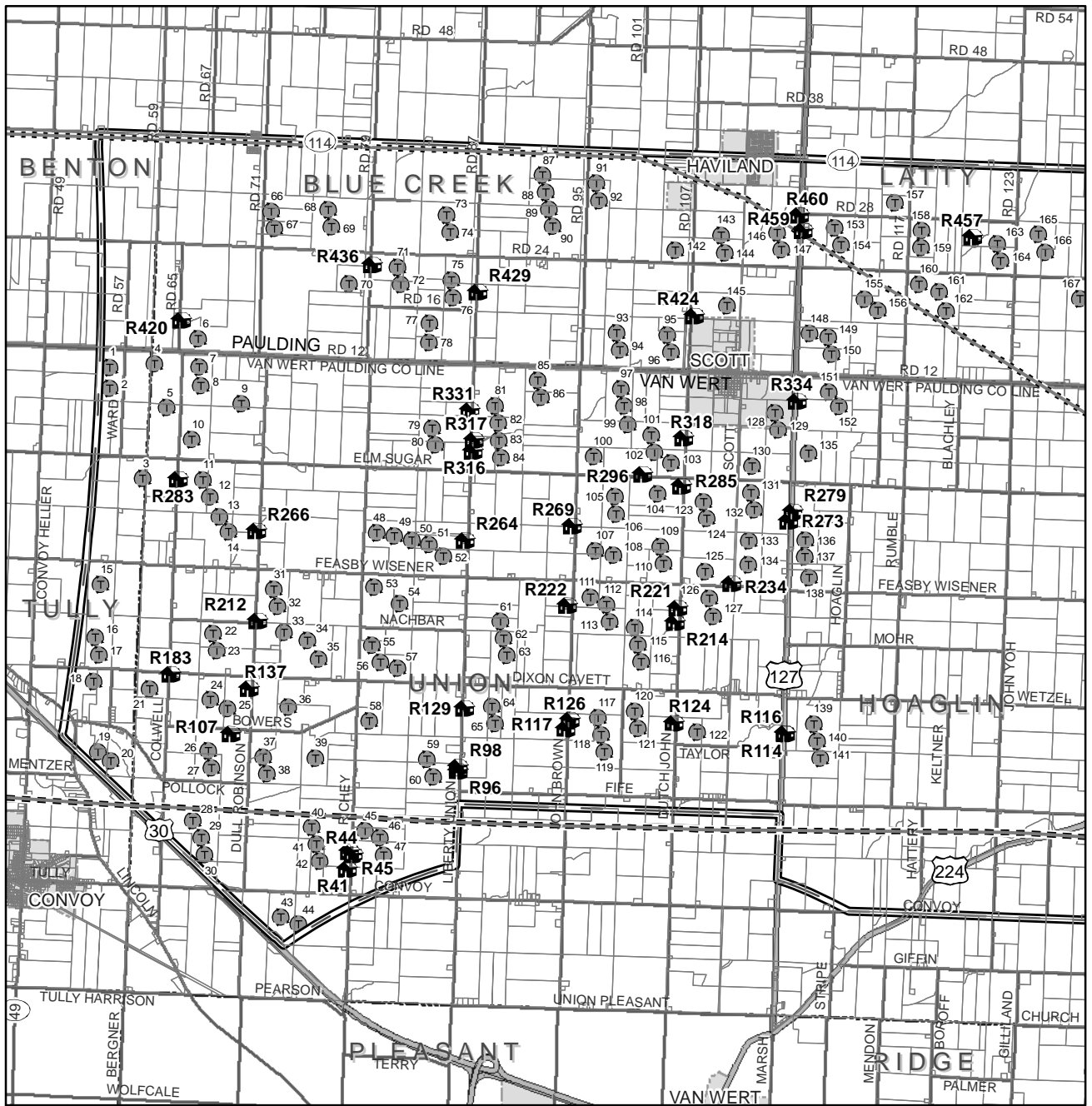
TABLE 1
Predicted Shadow Flicker

Residence ID	Predicted Shadow Flicker (hours/year)^a	Turbines Contributing to Shadow Flicker	Distance to Closest Contributing Turbine (m)	Noteworthy Obstructions
129	34:25	64, 65	415	Structures south of house
137	32:27	24, 25, 36	446	Barns north of house
183	33:11	21, 24	383	Evergreens east and west of house
212	32:35	22, 23, 33, 34	442	Property surrounded by evergreen fence
214	32:05	114, 115, 127	589	Garage south of house
221	38:43	114, 126, 127	502	Barns and garage north of house, mixed trees on property
222	34:42	111, 112, 113	378	Deciduous trees east of house
234	47:28	125, 126	396	
264	41:01	50, 51, 52	403	Garage southwest of house, deciduous tree north of house
266	32:38	13, 14	421	Garage south of house and row of evergreens east of house
269	34:55	106, 107, 108	523	Structures west of house, mixed trees north and east of house
273	51:31	132, 133, 136	387	Buildings west of house
279	32:38	131, 132, 133	580	Garage northeast of house
283	52:32	3, 11, 12, 13	552	Barns and garages north of house and mixed trees south of house
285	41:34	104, 123, 124	413	House surrounded by many evergreen and deciduous trees
296	56:21	100, 103, 104, 105	377	Large barn north of house and deciduous trees south of house
316	43:38	79, 80, 83, 84	426	Structures east of house, row of evergreens north of house
317	56:26	79, 80, 83, 84	374	Structures east of house, deciduous trees south and west of house
318	35:24	99, 101, 102	482	Mixed trees on property
331	67:18	79, 81, 82, 83	391	Garage west of house, evergreens north of house, mixed trees on property
334	52:31	128, 151, 152	375	Multiple structures west and south of house
420	30:09	6	380	Large deciduous tree east of house
424	38:48	95, 145	497	

TABLE 1
Predicted Shadow Flicker

Residence ID	Predicted Shadow Flicker (hours/year)^a	Turbines Contributing to Shadow Flicker	Distance to Closest Contributing Turbine (m)	Noteworthy Obstructions
429	50:05	75, 76, 77	380	Structures east of house, many trees on property
436	51:24	70, 71, 72	384	Row of evergreens north of house, mixed trees throughout property
457	44:04	158, 159, 163, 164	388	Barn east of house
459	61:45	146, 147, 153, 154	390	Structures northeast of house, deciduous trees south and west of house
460	37:22	146, 153, 154	421	Deciduous tree southwest of house

a Model results adjusted by mean monthly sky cover from Fort Wayne, Indiana.



VICINITY MAP



LEGEND

- Homes Over 30 Hours per Year of Shadow Flicker
- Proposed Turbine and Turbine ID Number
- Existing 138 kV Transmission Line
- Existing 345 kV Transmission Line
- Taxlot Boundary
- Project Area Boundary
- City Boundary
- Township Boundary
- County Boundary

Notes:

1. Base data sources:

ESRI Data and Maps (2008)
 {airports, counties outside Ohio, states}
 Ohio Department of Transportation (2004)
 {counties, townships, roads, active railroads, cities}
 Ohio Geographically Referenced Information Program (2005)
 {local roads}

2. Taxlots:

Taxlot information is preliminary.
 Spatial accuracy and attributes validation is ongoing.

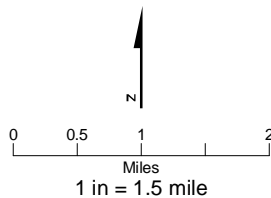


FIGURE 1
Homes With Shadow Flicker
Over 30 Days Per Year
 Blue Creek Wind Farm Area
 Created: December 11, 2009



SECTION 4

Mitigation Measures

There are currently no federal or state standards regulating frequency or duration of shadow flicker for wind turbines. International studies and 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 can be considered a nuisance. Heartland Wind used a threshold of 30 hours per year for this analysis to identify affected residences.

The results presented here are representative of the maximum Facility shadow flicker impacts and an overall reduction in Facility shadow flicker impacts is expected to be realized through the micro-siting process. Heartland Wind plans to use a number of mitigation measures to reduce projected shadow flicker impacts to 30 hours or less per year for affected residences. Mitigation measures may include:

- Turbine micro-siting to minimize projected impacts
- Good Neighbor Agreements to offer compensation to affected residents
- Window blinds, window awnings, and vegetative plantings to be offered to affected residents, including those with and without Good Neighbor Agreements.

SECTION 5

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