Final Report
Palmers Creek Wind Farm, LLC
Shadow Flicker

Palmers Creek Wind Project

February 19,

2018

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Report Update

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

Revision History

Revision No.	Revision Purpose	Date	Revised By
0	Original	10/12/2016	N.Laskovski
1	Final	10/31/2016	N.Laskovski
2	Revised Turbine Locations	1/3/2017	N.Laskovski
3	Revised Turbine Locations	2/16/2018	N.Laskovski

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Executive Summary

EAPC Wind Energy was hired by Palmers Creek Wind Farm, LLC to provide estimates of the potential shadow flicker from a wind farm consisting of GE wind turbines located north of Granite Falls, MN. The project consists of 18 General Electric (GE) wind turbines with rated capacities of 2.3 Megawatts (MW) and 2.5 MW. Hub heights (HH) of 80m and 94m were analyzed and the different configurations are presented below. 49 receptors were provided by the client to be analyzed. On site wind data representative of one year from an 80m met tower were also provided. A WindPRO model was built combining digital elevation data with the information supplied by the client to generate a model suitable for determining potential shadow flicker at the provided receptors.

Based on the shadow flicker calculation, six options have been presented; a site-wide "worst case" scenario for 80m, 80m + 90m, and 80m + 94m turbines and a site-wide "realistic" scenario for 80m, 80m + 90m, and 80m + 94m turbines.

1. INTRODUCTION

Palmers Creek Wind Farm, LLC (Palmers Creek) hired EAPC Wind Energy (EAPC) to conduct a shadow flicker analysis for a wind turbine layout consisting of 18 GE wind turbines. Two locations utilized the GE 2.3-116 with an 80m HH. The remaining 16 locations utilized a GE 2.5-116 with hub heights of either 80m, 90m, or 94m. The wind project, named Palmers Creek Wind Project, is located north of Granite Falls, MN. Coordinates for 49 receptors, located within one mile (1600m) of the nearest turbine, were supplied by the client.

Both theoretical worst case and realistic case analyses were performed. The theoretical worst case model identifies all areas that could possibly experience shadow flicker given the size and shape of the turbines, terrain of the land around them and sun angles throughout the year. This case assumes that it is never cloudy and that there is always sufficient wind to operate the turbine and that the turbine is always perpendicular to the sun. The realistic scenario incorporates weather probabilities based upon long-term average weather conditions to more precisely model when the turbine is likely to be operational and the angle at which the rotor is oriented. Repetitive on site wind data was also included in the realistic model to determine operational time for the turbine as well as rotor direction. Sunshine probability is also included as a realistic model variable because shadow flicker can only occur when the sun is shining with no cloud cover.

2. SITE OVERVIEW

The area of interest is located in South Central Minnesota approximately 100 mi (160 km) west of Minneapolis. The project site is open crop fields with several nearby houses within the project. The turbines have an elevation ranging from 1,010 ft – 1,050 ft (308 – 320m).

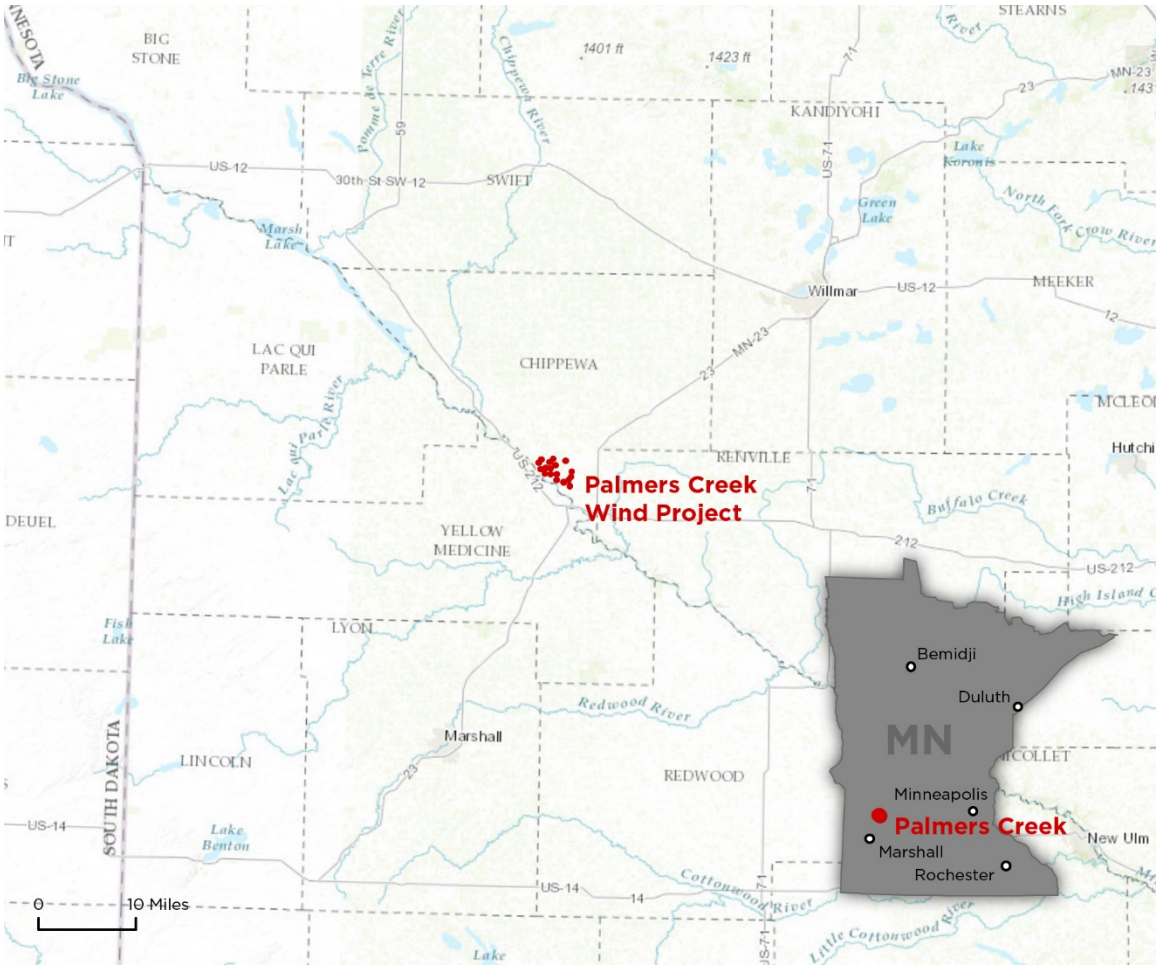


Figure 1. Site Overview Map

3. SHADOW FLICKER

3.1. BACKGROUND

Shadow flicker from wind turbines occur when rotating wind turbine blades move between the sun and the observer. Shadow flicker is generally experienced in areas near wind turbines where the distance between the observer and wind turbine blade is short enough that sunlight has not been significantly diffused by the atmosphere. When the blades rotate, this shadow creates a pulsating effect, known as shadow flicker. If the blade's shadow is passing over the window of a building, it will have the effect of increasing and decreasing the light intensity in the room at a low frequency in the range of 0.5 to 1.2 Hz, hence the term "flicker." This flickering effect can also be experienced outdoors, but the effect is typically less intense and becomes even less intense when farther from the wind turbine causing the flicker. The moving shadow of a wind turbine blade on the ground is similar to the effect one experiences when driving on a road when there are shadows cast across the road by an adjacent row of trees.

The flickering effect is most noticeable within approximately 1,000 m of the turbine, and becomes more and more diffused as distance increases. There are no uniform standards defining what distance from the turbine is regarded as an acceptable limit beyond which the shadow flicker is considered to be insignificant. The same applies to the number of hours of flicker that is deemed to be acceptable. Thirty is the standard allowed maximum hours of shadow per year in other places such as Germany. A distance of 1,600m was used for each iteration of shadow flicker modeling for this report.

Shadow flicker is typically greatest in winter months when the angle of the sun is lower and casts longer shadows. The effect is also more pronounced around sunrise and sunset when the sun is near the horizon and shadows are longer. A number of factors influence the amount of shadow flicker on the shadow receptors (simulated windows). One consideration is the environment around the shadow receptor. Obstacles such as terrain, trees or buildings between the wind turbine and the receptor can significantly reduce or eliminate shadow flicker effects. Deciduous trees may block some degree of shadow flickering depending on the tree density, species present and time of year. They can lead to a reduction of shadow flicker during the summer when the trees are bearing leaves. However, during the winter months, these trees are without their leaves and their impact on shadow flicker is not as significant. Coniferous trees may provide shading year round. For this study, no credit was given to potential shading from any type of tree or other obstacles that would reduce the number of shadow flickering hours at the structures.

Another consideration is the time of day when shadow flicker occurs. For example, a factory or office building would not be significantly affected if all the shadow flicker impact occurred before or after business hours. In contrast, it may be more acceptable for private homes to experience shadow flickering during working hours when family members may be at work or school.

The climate also needs be considered when assessing shadow flicker. In areas with high incidence of overcast weather there would be less shadow flicker. Also, if the wind is not blowing, the turbines would not be operational and therefore not creating shadow flickering.

3.2. STUDY METHODOLOGY

This shadow flicker analysis was performed using WindPRO, a sophisticated wind modeling software program. WindPRO is used to calculate detailed shadow flicker maps across an entire area of interest or at site-specific locations using shadow receptors.

Shadow maps, which indicate where shadows will be cast and for how long, can be calculated at varying resolutions. The Fine resolution setting with WindPRO was used for this study; it represents shadow flicker calculations that determine the

sun angle every 2 minutes, every 3rd day, over the period of an entire year, over a grid resolution of 10 meters, measured at a height of 1.5 meters.

Point-specific shadow flicker calculations are modeled at a higher resolution than the shadow flicker maps to include the highest precision possible within WindPRO. Shadow flicker at each shadow receptor location is calculated every minute of every day throughout the entire year. Shadow receptors can be configured to represent an omni-directional plane of a specific size (greenhouse mode) or a plane facing a single direction (single direction mode). The shadow receptors used in this analysis were configured as greenhouse-mode receptors. All receptors were modeled as 2-meter-wide by 1.5-meter-high, 1 meter from the ground, directly facing the wind turbine. Shadow flicker exposure is recorded by the model if the turbine casts a shadow on any part of this receptor during any minute of any day throughout the year.

As part of the calculation method, WindPRO must determine whether or not the turbine will be visible at the receptor locations due to local topography. It does this by performing a preliminary Zones of Visual Influence (ZVI) calculation using a terrain model with 10-meter x 10-meter grid spacing. If there is no line-of-sight to the turbine within the 10-meter x 10-meter area containing the shadow receptor, the receptor is not included in the shadow flicker calculation.

The inputs for the WindPRO shadow flicker calculation include the following:

- Turbine Coordinates
- Turbine Specifications
- Shadow Receptor Coordinates
- USGS Digital Elevation Model (DEM) (height contour data)
- Sunshine Probability
- Sector-wise Annual Frequency

A description of each input variable and how they affect the shadow flicker calculation are included below.

Turbine Coordinates: The location of a wind turbine in relation to a shadow receptor is one of the most important factors in determining shadow flicker impacts. A line-of-site is required for shadow flicker to occur. The intensity of the shadow flicker is dependent upon the distance from the wind turbine and weather conditions. The coordinates and elevations of the wind turbines used in this study are included in Appendix A.

Turbine Specifications: A wind turbine's total height and rotor diameter are included in the WindPRO shadow flicker model. The taller the wind turbine, the more likely shadow flicker could have an impact on local shadow receptors as the likelihood of clearing obstacles (such as hills or trees) is greater. The larger the rotor diameter is, the wider the area where shadows will be cast. Also included

with the turbine specifications are the cut-in and cut-out wind speeds within which the wind turbine is operational. If the wind speed is below the cut-in threshold or above the cut-out threshold, the turbine rotor will not be spinning and thus shadow flicker will not occur. The specifications of the turbine model used in this study are included in Table 1 below.

Table 1: Palmers Creek Wind Project Turbine Specifications for Shadow Flicker.

Manufacturer	Model	Hub Heights (m)	Rotor Diameter (m)
GE	2.3-116	80	116
GE	2.5-116	80, 90, 94	116

Shadow Receptor Coordinates: As with the wind turbine coordinates, the elevation, distance and orientation of a shadow receptor in relation to wind turbines and the sun are the main factors in determining the impact of shadow flicker. EAPC was provided with coordinates for 49 structures; the coordinates of these shadow receptors are included in Appendix B.

USGS Digital Elevation Model (DEM) (height contour data): For this study, 10m x 10m USGS National Elevation Database (NED 1/3 arc-second) DEMs were used to construct 10 m interval height contour lines for the WindPRO shadow flicker model. The height contour information is important to the shadow flicker calculation since it allows the model to place the wind turbines and the shadow receptors at the correct elevations. The height contour lines also allow the model to include the topography of the site when calculating the zones of visual influence surrounding the wind turbine and shadow receptor locations. A map of the project area which includes the height contour lines is included in Appendix C.

Sunshine Probability: Shadow flicker is only produced when the sun is shining. To calculate a more realistic scenario, EAPC input the sunshine data to reduce worst case shadow flicker hours, achieving a more 'realistic' scenario. Using data from a climate database within WindPRO, EAPC assumed sunshine percentages showing in the following table.

Table 2: Sunshine Probability for Madison, WI

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
4.43	5.24	5.95	7.01	8.58	9.67	9.71	8.48	7.21	5.48	3.66	3.19

Sector-wise Frequency: Shadow flicker is only produced when sunshine is hitting the turbine from a certain direction. To calculate a more realistic scenario, EAPC input the operational hours from 12 sectors. These hours were calculated using on-site met data from an 80m tower. The data was supplied by the client and not validated by EAPC. Using WindPro, a shear exponent of 0.25 was used to shear the 80m data to 90m and 94m.

Table 3: Sector-wise Operational Hours

N	NNE	ENE	E	ESE	SSE	S	SSW	WSW	W	WNW	NNW
528	300	300	396	610	1529	1,184	403	333	542	951	1,392

3.3. RESULTS OF SHADOW FLICKER ANALYSIS

The term *theoretical worst case*, as used in this report, means that turbine operational hours, wind direction, and local sunshine probabilities have not been accounted for. As such, *theoretical worst case* estimates are conservative. The term *realistic*, as used in this report, means that turbine operational time, rotor orientation, and sunshine probabilities are factored into the model. **Blocking or shading effects due to trees or structures have not been accounted for.** Both *theoretical worst case* and *realistic* values are estimates based on model inputs.

A total of 49 receptors (primary structures) were analyzed, and a *fine* resolution shadow flicker map was generated for both *theoretical worst case* and *realistic* modeling scenarios, utlizing two different hub heights within the turbine layouts. The fine resolution shadow flicker maps are included in Appendix B and also shown in the figures below.

4. CONCLUSIONS

The conservative results of this study indicate that of the 49 receptors modeled, 10 modeled zero shadow flicker across all scenarios, 16 modeled 30 or more hours per year *theoretical worst case with 80m HH*, 18 modeled 30 hours or per year *theoretical worst case* with 80m + 90m HH, 18 modeled 30 hours or per year *theoretical worst case* with 80m + 94m HH, 4 receptors modeled over 30 hours per year under *realistic conditions* for 80mHH, 4 receptors modeled over 30 hours per year under *realistic conditions* for 80mHH + 90m HH, and 4 receptors modeled over 30 hours per year under *realistic conditions* for 80m + 94m HH. The *realistic* shadow flicker impacts on receptors were calculated with consideration for turbine operational time and orientation (using on-site wind data provided by the client) and sunshine probabilities. This analysis is based on a number of other assumptions including:

- A human would always be present at the receptor to observe the effect.
- A human would be situated in an area where the flickering occurs.
- The receptors are omni-directional rather than modeling specific aspects of building facades or window openings.
    - Receptor windows are 2m in width x 1.5m in height x 1m above ground level; 90 deg vertical.

The overall effect of using these assumptions indicates that the actual number of hours of realistic shadow flicker that would be observed will likely be less than those predicted by this study.

Appendix A: Wind Turbine Coordinates

Turbine	Coordinates (WGS 84)		Turbine	Hub Height (m)
	Latitude	Longitude		
1	44.869294°	-95.606875°	GE 2.5-116	80, 90, 94
2	44.874661°	-95.603139°	GE 2.5-116	80, 90, 94
3	44.869392°	-95.583828°	GE 2.5-116	80, 90, 94
4	44.875264°	-95.576389°	GE 2.5-116	80, 90, 94
5	44.864522°	-95.605892°	GE 2.5-116	80, 90, 94
6	44.861344°	-95.592361°	GE 2.5-116	80, 90, 94
7	44.861153°	-95.581006°	GE 2.5-116	80, 90, 94
8	44.864814°	-95.573914°	GE 2.5-116	80, 90, 94
9	44.856100°	-95.591775°	GE 2.5-116	80, 90, 94
10	44.854156°	-95.580089°	GE 2.5-116	80, 90, 94
11	44.852581°	-95.569217°	GE 2.5-116	80, 90, 94
12	44.845481°	-95.569200°	GE 2.5-116	80, 90, 94
13	44.841564°	-95.553758°	GE 2.5-116	80, 90, 94
14	44.836622°	-95.541662°	GE 2.3-116	80
15	44.844631°	-95.543356°	GE 2.3-116	80
16	44.849525°	-95.537703°	GE 2.5-116	80, 90, 94
17	44.856906°	-95.537478°	GE 2.5-116	80, 90, 94
18	44.874103°	-95.553051°	GE 2.5-116	80, 90, 94

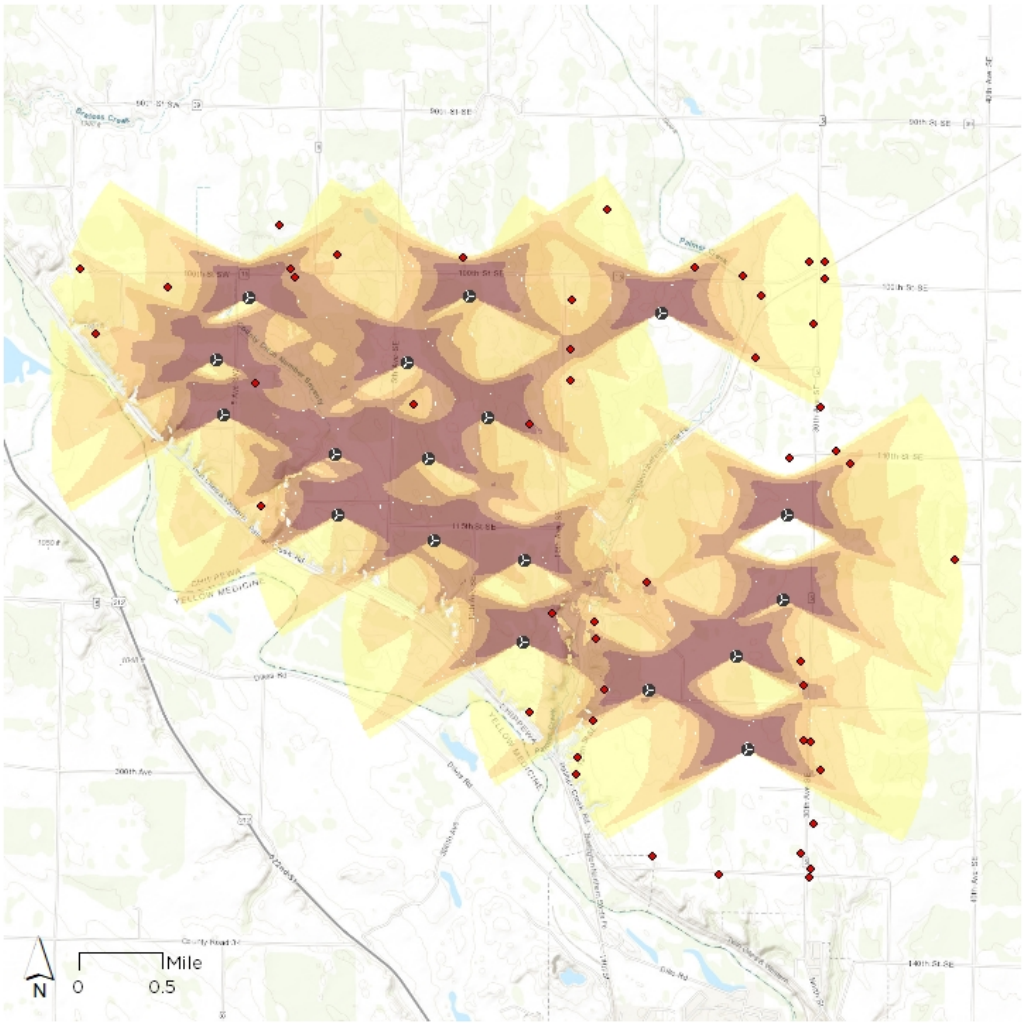
Appendix B: Receptor Coordinates and Flicker Results

Receptor	Coordinates (UTM WGS 84)		Elevation (m)	Description	Flicker (h:m/ year) **80m** HH **- Worst Case**	Flicker (h:m/ year) **80m** HH **+ 90m** HH - **Worst Case**	Flicker (h:m/ year) **80m** HH **+ 94m** HH - **Worst Case**	Flicker (h:m/ year) **80m** HH - ***Realisti c*** **Case**	Flicker (h:m/ year) **80m** HH **+ 90m** HH - ***Realistic*** **Case**	Flicker (h:m/ year) **80m** HH **+ 94m** HH - ***Realistic*** **Case**
1	44.825638°	-95.533842°	319.3	Resident 01	0:00	0:00	0:00	0:00	0:00	0:00
2	44.826359°	-95.533704°	318.5	Resident 02	0:00	0:00	0:00	0:00	0:00	0:00
3	44.827696°	-95.534989°	317.9	Resident 03	0:00	0:00	0:00	0:00	0:00	0:00
4	44.830307°	-95.533451°	317.9	Resident 04	0:00	0:00	0:00	0:00	0:00	0:00
5	44.834853°	-95.532683°	319.8	Resident 05	25:36	25:36	25:36	10:30	10:33	10:34
6	44.837284°	-95.534019°	321.1	Resident 06	30:26	31:04	31:21	10:15	10:15	10:22
7	44.837363°	-95.534825°	322.5	Resident 07	38:15	38:57	39:15	12:11	12:32	12:40
8	44.842124°	-95.534954°	318.1	Resident 08	52:31	53:05	53:19	23:23	23:41	23:47
9	44.844227°	-95.535337°	319.2	Resident 09	31:09	31:47	31:59	11:11	11:25	11:29
10	44.853297°	-95.516886°	321.2	Resident 10	3:09	4:08	4:35	1:04	1:24	1:33
11	44.861760°	-95.537188°	319.8	Resident 11	0:00	0:00	0:00	0:00	0:00	0:00
12	44.862421°	-95.531666°	318	Resident 12	0:00	0:00	0:00	0:00	0:00	0:00
13	44.861382°	-95.529807°	318.6	Resident 13	39:40	43:02	43:57	7:28	8:10	8:21
14	44.866156°	-95.533598°	319.5	Resident 14	0:00	0:00	0:00	0:00	0:00	0:00
15	44.870285°	-95.541625°	316.8	Resident 15	28:17	30:36	31:12	12:57	14:05	14:23
16	44.873292°	-95.534581°	318.3	Resident 16	2:56	3:36	3:49	1:03	1:18	1:22
17	44.877298°	-95.533334°	317.7	Resident 17	2:03	2:36	2:44	0:34	0:43	0:46
18	44.878708°	-95.533434°	318.7	Resident 18	1:56	2:28	2:42	0:30	0:39	0:43
19	44.878631°	-95.535326°	320.9	Resident 19	2:41	3:23	3:37	0:42	0:53	0:57
20	44.875754°	-95.540947°	313.6	Resident 20	10:26	11:31	11:48	3:04	3:25	3:31
21	44.877427°	-95.543273°	312.7	Resident 21	17:25	18:39	19:09	4:17	4:38	4:46
22	44.877963°	-95.549112°	313.6	Resident 22	28:29	38:09	41:51	5:07	7:00	7:43
23	44.882819°	-95.559915°	319.5	Resident 23	3:45	4:38	5:03	0:47	0:58	1:04
24	44.878542°	-95.577203°	316.3	Resident 24	0:00	10:50	19:31	0:00	2:38	4:54
25	44.877208°	-95.597991°	318.1	Resident 25	90:38	90:22	88:29	20:24	21:02	20:53
26	44.876494°	-95.597527°	317.5	Resident 26	66:29	70:06	70:21	17:48	19:03	19:15
27	44.880968°	-95.599588°	317.5	Resident 27	0:00	0:00	0:00	0:00	0:00	0:00
28	44.875402°	-95.612918°	315.9	Resident 28	16:56	18:30	19:03	6:03	6:39	6:52
29	44.876903°	-95.623577°	317.5	Resident 29	5:42	7:02	7:29	1:53	2:21	2:30
30	44.871308°	-95.621627°	315.3	Resident 30	13:45	16:18	17:15	4:35	5:28	5:48
31	44.867319°	-95.602094°	318.2	Resident 31	158:36	159:31	157:04	40:38	39:28	37:59
32	44.865745°	-95.582822°	319.9	Resident 32	40:57	44:18	45:17	11:31	12:32	12:51

33	44.874963°	-95.563933°	316.9	Resident 33	25:11	28:08	29:10	8:48	9:51	10:13
34	44.870771°	-95.563925°	315.1	Resident 34	76:11	85:55	89:05	23:56	26:58	27:56
35	44.868106°	-95.563889°	317.4	Resident 35	20:26	23:22	24:23	5:13	6:02	6:19
36	44.864178°	-95.568776°	316.4	Resident 36	118:59	133:01	140:48	46:46	53:08	56:38
37	44.856727°	-95.601147°	308.7	Resident 37	24:41	27:12	27:39	8:41	9:37	9:47
38	44.850846°	-95.554238°	314.7	Resident 38	45:25	51:35	53:25	14:35	16:41	17:19
39	44.847905°	-95.565658°	311.4	Resident 39	146:54	151:36	152:43	30:20	31:57	32:26
40	44.847249°	-95.560488°	307.3	Resident 40	30:26	36:29	39:31	9:11	11:12	12:13
41	44.845851°	-95.560249°	311.1	Resident 41	69:56	75:14	76:51	22:28	24:20	24:55
42	44.841427°	-95.559105°	318.2	Resident 42	97:31	100:03	100:26	35:57	37:14	37:30
43	44.839398°	-95.568088°	310.7	Resident 43	8:00	9:04	9:31	2:33	2:54	3:03
44	44.838731°	-95.560323°	315.8	Resident 44	24:56	23:28	20:59	7:52	7:28	6:42
45	44.835534°	-95.562243°	309.2	Resident 45	2:14	2:14	2:14	0:45	0:45	0:45
46	44.834158°	-95.562369°	309.5	Resident 46	2:05	2:05	2:05	0:41	0:41	0:41
47	44.825700°	-95.544746°	319.2	Resident 47	0:00	0:00	0:00	0:00	0:00	0:00
48	44.827202°	-95.552901°	313.1	Substation-OfficeShop	0:00	0:00	0:00	0:00	0:00	0:00
49	44.878552°	-95.592478°	319.2	Swensen-Farm-Museum	16:38	18:58	19:50	4:21	5:02	5:17

Red numbers indicate hours/ year at or greater than 30.

Appendix C: Palmers Creek Wind Shadow Flicker Map



Palmers Creek Wind Project - Granite Falls, MN

Worst Case Shadow Flicker Modeling

Worst Case Shadow Flicker

- 0 - 10 hours
- 10 - 30
- 30 - 50
- 50 - 100
- 100 - 1262

- WTG Site
- Receptor Site

Appendix D: WindPRO Shadow Flicker Reports

Project:
Palmers Creek Wind Farm

Description:
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Nicholas Laskovski / n.laskovski@eapcwindenergy.com
Calculated:
2/14/2018 1:20 PM/3.0.654

SHADOW - Main Result

Calculation: 180214 Worst Case - Greehouse Mode - 80m HH

Assumptions for shadow calculations

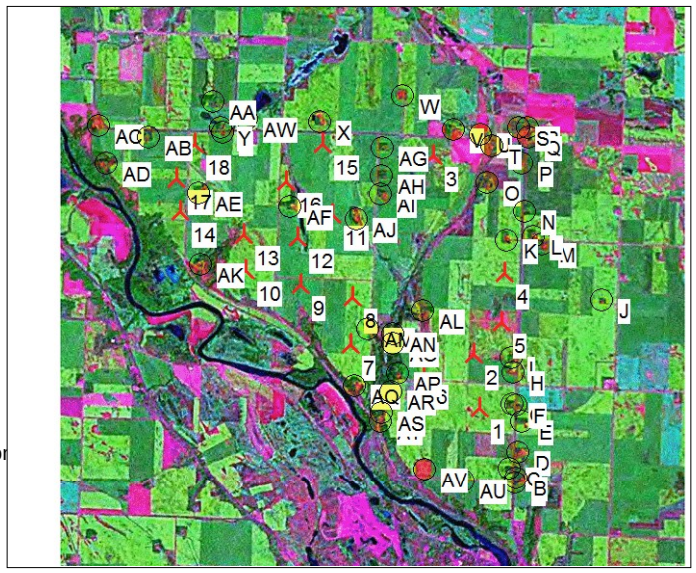
Maximum distance for influence
Calculate only when more than 20 % of sun is covered by the blade
Please look in WTG table

Minimum sun height over horizon for influence	3 °
Day step for calculation	1 days
Time step for calculation	1 minutes

The calculated times are "worst case" given by the following assumptions:
- The sun is shining all the day, from sunrise to sunset
- The rotor plane is always perpendicular to the line from the WTG to the sun
- The WTG is always operating

A ZVI (Zones of Visual Influence) calculation is performed before flicker calculation so non visible WTG do not contribute to calculated flicker values. A WTG will be visible if it is visible from any part of the receiver window. The ZVI calculation is based on the following assumptions:
Height contours used: Project Wizard Elevation Data Grid (US NED 1/3 arc-secon
Obstacles used in calculation
Eye height: 1.5 m
Grid resolution: 10.0 m

All coordinates are in
Geo [deg]-WGS84



Scale 1:125,000
New WTG
Shadow receptor

WTGs

	Longitude	Latitude	Z	Row data/Description	WTG type Valid	Manufact.	Type-generator	Power, rated	Rotor diameter	Hub height	Shadow data Calculation distance	RPM
			[m]					[kW]	[m]	[m]	[m]	[RPM]
1	-95.541662° E	44.836622° N	313.0	WTG 14 - GE 2.3-11...	Yes	GE WIND ENERGY	GE 2.3-116-2,300	2,300	116.0	80.0	1,732	15.7
2	-95.543356° E	44.844631° N	314.6	WTG 15 - GE 2.3-11...	Yes	GE WIND ENERGY	GE 2.3-116-2,300	2,300	116.0	80.0	1,732	15.7
3	-95.553051° E	44.874103° N	317.6	WTG 18	Yes	GE WIND ENERGY	GE 2.5-116-2,500	2,500	116.0	80.0	1,732	15.7
4	-95.537478° E	44.856906° N	317.7	WTG 17	Yes	GE WIND ENERGY	GE 2.5-116-2,500	2,500	116.0	80.0	1,732	15.7
5	-95.537703° E	44.849525° N	315.7	WTG 16	Yes	GE WIND ENERGY	GE 2.5-116-2,500	2,500	116.0	80.0	1,732	15.7
6	-95.553758° E	44.841564° N	316.5	WTG 13	Yes	GE WIND ENERGY	GE 2.5-116-2,500	2,500	116.0	80.0	1,732	15.7
7	-95.569200° E	44.845481° N	311.8	WTG 12	Yes	GE WIND ENERGY	GE 2.5-116-2,500	2,500	116.0	80.0	1,732	15.7
8	-95.569217° E	44.852581° N	315.1	WTG 11	Yes	GE WIND ENERGY	GE 2.5-116-2,500	2,500	116.0	80.0	1,732	15.7
9	-95.580089° E	44.854156° N	311.2	WTG 10	Yes	GE WIND ENERGY	GE 2.5-116-2,500	2,500	116.0	80.0	1,732	15.7
10	-95.591775° E	44.856100° N	315.7	WTG 09	Yes	GE WIND ENERGY	GE 2.5-116-2,500	2,500	116.0	80.0	1,732	15.7
11	-95.573914° E	44.864814° N	315.8	WTG 08	Yes	GE WIND ENERGY	GE 2.5-116-2,500	2,500	116.0	80.0	1,732	15.7
12	-95.581006° E	44.861153° N	316.1	WTG 07	Yes	GE WIND ENERGY	GE 2.5-116-2,500	2,500	116.0	80.0	1,732	15.7
13	-95.592361° E	44.861344° N	319.4	WTG 06	Yes	GE WIND ENERGY	GE 2.5-116-2,500	2,500	116.0	80.0	1,732	15.7
14	-95.605892° E	44.864522° N	315.1	WTG 05	Yes	GE WIND ENERGY	GE 2.5-116-2,500	2,500	116.0	80.0	1,732	15.7
15	-95.576389° E	44.875264° N	315.5	WTG 04	Yes	GE WIND ENERGY	GE 2.5-116-2,500	2,500	116.0	80.0	1,732	15.7
16	-95.583828° E	44.869392° N	318.6	WTG 03	Yes	GE WIND ENERGY	GE 2.5-116-2,500	2,500	116.0	80.0	1,732	15.7
17	-95.606875° E	44.869294° N	315.7	WTG 01	Yes	GE WIND ENERGY	GE 2.5-116-2,500	2,500	116.0	80.0	1,732	15.7
18	-95.603139° E	44.874661° N	312.2	WTG 02	Yes	GE WIND ENERGY	GE 2.5-116-2,500	2,500	116.0	80.0	1,732	15.7

Shadow receptor-Input

No.	Name	Longitude	Latitude	Z	Width	Height	Height a.g.l.	Degrees from south cw	Slope of window	Direction mode
				[m]	[m]	[m]	[m]	[°]	[°]	
A	Resident 01	-95.533842° E	44.825638° N	319.3	2.0	1.5	1.0	0.0	90.0	"Green house mode"
B	Resident 02	-95.533704° E	44.826359° N	318.5	2.0	1.5	1.0	0.0	90.0	"Green house mode"
C	Resident 03	-95.534989° E	44.827696° N	317.9	2.0	1.5	1.0	0.0	90.0	"Green house mode"
D	Resident 04	-95.533451° E	44.830307° N	317.9	2.0	1.5	1.0	0.0	90.0	"Green house mode"
E	Resident 05	-95.532683° E	44.834853° N	319.8	2.0	1.5	1.0	0.0	90.0	"Green house mode"
F	Resident 06	-95.534019° E	44.837284° N	321.1	2.0	1.5	1.0	0.0	90.0	"Green house mode"
G	Resident 07	-95.534825° E	44.837363° N	322.5	2.0	1.5	1.0	0.0	90.0	"Green house mode"

To be continued on next page...

SHADOW - Main Result

Calculation: 180214 Worst Case - Greehouse Mode - 80m HH

...continued from previous page

No.	Name	Longitude	Latitude	Z [m]	Width [m]	Height [m]	Height a.g.l. [m]	Degrees from south cw [°]	Slope of window [°]	Direction mode
H	Resident 08	-95.534954° E	44.842124° N	318.1	2.0	1.5	1.0	0.0	90.0	"Green house mode"
I	Resident 09	-95.535337° E	44.844227° N	319.2	2.0	1.5	1.0	0.0	90.0	"Green house mode"
J	Resident 10	-95.516886° E	44.853297° N	321.2	2.0	1.5	1.0	0.0	90.0	"Green house mode"
K	Resident 11	-95.537188° E	44.861760° N	319.8	2.0	1.5	1.0	0.0	90.0	"Green house mode"
L	Resident 12	-95.531666° E	44.862421° N	318.0	2.0	1.5	1.0	0.0	90.0	"Green house mode"
M	Resident 13	-95.529807° E	44.861382° N	318.6	2.0	1.5	1.0	0.0	90.0	"Green house mode"
N	Resident 14	-95.533598° E	44.866156° N	319.5	2.0	1.5	1.0	0.0	90.0	"Green house mode"
O	Resident 15	-95.541625° E	44.870285° N	316.8	2.0	1.5	1.0	0.0	90.0	"Green house mode"
P	Resident 16	-95.534581° E	44.873292° N	318.3	2.0	1.5	1.0	0.0	90.0	"Green house mode"
Q	Resident 17	-95.533334° E	44.877298° N	317.7	2.0	1.5	1.0	0.0	90.0	"Green house mode"
R	Resident 18	-95.533434° E	44.878708° N	318.7	2.0	1.5	1.0	0.0	90.0	"Green house mode"
S	Resident 19	-95.535326° E	44.878631° N	320.9	2.0	1.5	1.0	0.0	90.0	"Green house mode"
T	Resident 20	-95.540947° E	44.875754° N	313.6	2.0	1.5	1.0	0.0	90.0	"Green house mode"
U	Resident 21	-95.543273° E	44.877427° N	312.7	2.0	1.5	1.0	0.0	90.0	"Green house mode"
V	Resident 22	-95.549112° E	44.877963° N	313.6	2.0	1.5	1.0	0.0	90.0	"Green house mode"
W	Resident 23	-95.559915° E	44.882819° N	319.5	2.0	1.5	1.0	0.0	90.0	"Green house mode"
X	Resident 24	-95.577203° E	44.878542° N	316.3	2.0	1.5	1.0	0.0	90.0	"Green house mode"
Y	Resident 25	-95.597991° E	44.877208° N	318.1	2.0	1.5	1.0	0.0	90.0	"Green house mode"
Z	Resident 26	-95.597527° E	44.876494° N	317.5	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AA	Resident 27	-95.599588° E	44.880968° N	317.5	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AB	Resident 28	-95.612918° E	44.875402° N	315.9	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AC	Resident 29	-95.623577° E	44.876903° N	317.5	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AD	Resident 30	-95.621627° E	44.871308° N	315.3	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AE	Resident 31	-95.602094° E	44.867319° N	318.2	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AF	Resident 32	-95.582822° E	44.865745° N	319.9	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AG	Resident 33	-95.563933° E	44.874963° N	316.9	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AH	Resident 34	-95.563925° E	44.870771° N	315.1	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AI	Resident 35	-95.563889° E	44.868106° N	317.4	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AJ	Resident 36	-95.568776° E	44.864178° N	316.4	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AK	Resident 37	-95.601147° E	44.856727° N	308.7	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AL	Resident 38	-95.554238° E	44.850846° N	314.7	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AM	Resident 39	-95.565658° E	44.847905° N	311.4	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AN	Resident 40	-95.560488° E	44.847249° N	307.3	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AO	Resident 41	-95.560249° E	44.845851° N	311.1	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AP	Resident 42	-95.559105° E	44.841427° N	318.2	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AQ	Resident 43	-95.568088° E	44.839398° N	310.7	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AR	Resident 44	-95.560323° E	44.838731° N	315.8	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AS	Resident 45	-95.562243° E	44.835534° N	309.2	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AT	Resident 46	-95.562369° E	44.834158° N	309.5	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AU	Resident 47	-95.544746° E	44.825700° N	319.2	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AV	Substation-OfficeShop	-95.552901° E	44.827202° N	313.1	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AW	Swensen-Farm-Museum	-95.592478° E	44.878552° N	319.2	2.0	1.5	1.0	0.0	90.0	"Green house mode"

Calculation Results

Shadow receptor

No.	Name	Shadow, worst case: Shadow hours per year [h/year]	Shadow days per year [days/year]	Max shadow hours per day [h/day]
A	Resident 01	0:00	0	0:00
B	Resident 02	0:00	0	0:00
C	Resident 03	0:00	0	0:00
D	Resident 04	0:00	0	0:00
E	Resident 05	25:36	62	0:37
F	Resident 06	30:26	77	0:44
G	Resident 07	38:15	85	0:49
H	Resident 08	52:31	119	0:40

To be continued on next page...

SHADOW - Main Result

Calculation: 180214 Worst Case - Greehouse Mode - 80m HH

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No.	Name	Shadow, worst case Shadow hours per year [h/year]	Shadow days per year [days/year]	Max shadow hours per day [h/day]
I	Resident 09	31:09	77	0:43
J	Resident 10	3:09	32	0:09
K	Resident 11	0:00	0	0:00
L	Resident 12	0:00	0	0:00
M	Resident 13	39:40	77	0:38
N	Resident 14	0:00	0	0:00
O	Resident 15	28:17	84	0:28
P	Resident 16	2:56	20	0:13
Q	Resident 17	2:03	17	0:11
R	Resident 18	1:56	17	0:10
S	Resident 19	2:41	20	0:13
T	Resident 20	10:26	35	0:27
U	Resident 21	17:25	48	0:32
V	Resident 22	28:29	50	0:43
W	Resident 23	3:45	30	0:13
X	Resident 24	0:00	0	0:00
Y	Resident 25	90:38	137	0:57
Z	Resident 26	66:29	159	0:56
AA	Resident 27	0:00	0	0:00
AB	Resident 28	16:56	44	0:34
AC	Resident 29	5:42	46	0:13
AD	Resident 30	13:45	80	0:20
AE	Resident 31	158:36	180	1:36
AF	Resident 32	40:57	110	0:38
AG	Resident 33	25:11	83	0:31
AH	Resident 34	76:11	169	0:46
AI	Resident 35	20:26	82	0:31
AJ	Resident 36	118:59	172	1:06
AK	Resident 37	24:41	80	0:37
AL	Resident 38	45:25	198	0:25
AM	Resident 39	146:54	152	1:37
AN	Resident 40	30:26	83	0:52
AO	Resident 41	69:56	127	0:43
AP	Resident 42	97:31	171	1:04
AQ	Resident 43	8:00	32	0:22
AR	Resident 44	24:56	93	0:30
AS	Resident 45	2:14	18	0:11
AT	Resident 46	2:05	18	0:11
AU	Resident 47	0:00	0	0:00
AV	Substation-OfficeShop	0:00	0	0:00
AW	Swensen-Farm-Museum	16:38	66	0:28

Total amount of flickering on the shadow receptors caused by each WTG

No.	Name	Worst case [h/year]	Expected [h/year]
1	WTG 14 - GE 2.3-116 80m HH	73:47	
2	WTG 15 - GE 2.3-116 80m HH	119:22	
3	WTG 18	133:49	
4	WTG 17	51:02	
5	WTG 16	5:45	
6	WTG 13	164:06	
7	WTG 12	191:30	
8	WTG 11	6:13	
9	WTG 10	9:25	
10	WTG 09	20:30	
11	WTG 08	156:10	
12	WTG 07	21:04	

To be continued on next page...

SHADOW - Main Result

Calculation: 180214 Worst Case - Greehouse Mode - 80m HH

...continued from previous page

No.	Name	Worst case [h/year]	Expected [h/year]
13	WTG 06	41:48	
14	WTG 05	100:19	
15	WTG 04	42:42	
16	WTG 03	36:43	
17	WTG 01	48:10	
18	WTG 02	142:09	

Project:
Palmers Creek Wind Farm

Description:
Mike Rutledge
Environmental Services Dept. Head
FAGEN ENGINEERING, LLC
P.O. Box 159
Granite Falls, MN 56241
320-564-3324 Main
320-564-2625 Direct
320-564-4861 Fax

Licensed user:
EAPC Wind Energy
3100 DeMers Avenue
US-GRAND FORKS, ND 58201
+1 701 775 3000
Nicholas Laskovski / n.laskovski@eapcwindenergy.com
Calculated:
2/15/2018 8:53 PM/3.0.654

SHADOW - Main Result

Calculation: 180214 Worst Case - Greehouse Mode - 80m HH + 90m HH

Assumptions for shadow calculations

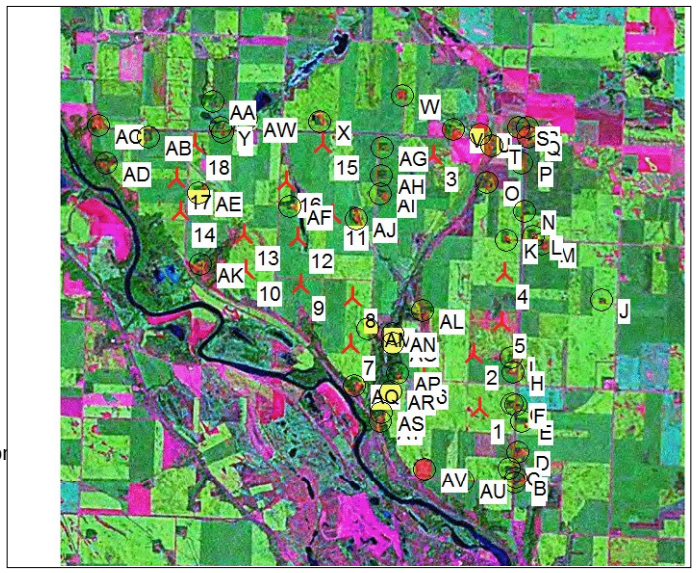
Maximum distance for influence
Calculate only when more than 20 % of sun is covered by the blade
Please look in WTG table

Minimum sun height over horizon for influence	3 °
Day step for calculation	1 days
Time step for calculation	1 minutes

The calculated times are "worst case" given by the following assumptions:
- The sun is shining all the day, from sunrise to sunset
- The rotor plane is always perpendicular to the line from the WTG to the sun
- The WTG is always operating

A ZVI (Zones of Visual Influence) calculation is performed before flicker calculation so non visible WTG do not contribute to calculated flicker values. A WTG will be visible if it is visible from any part of the receiver window. The ZVI calculation is based on the following assumptions:
Height contours used: Project Wizard Elevation Data Grid (US NED 1/3 arc-secon
Obstacles used in calculation
Eye height: 1.5 m
Grid resolution: 10.0 m

All coordinates are in
Geo [deg]-WGS84



WTGs

	Longitude	Latitude	Z	Row data/Description	WTG type Valid	Manufact.	Type-generator	Power, rated	Rotor diameter	Hub height	Shadow data Calculation distance	RPM
			[m]					[kW]	[m]	[m]	[m]	[RPM]
1	-95.541662° E	44.836622° N	313.0	WTG 14 - GE 2.3-11...	Yes	GE WIND ENERGY	GE 2.3-116-2,300	2,300	116.0	80.0	1,732	15.7
2	-95.543356° E	44.844631° N	314.6	WTG 15 - GE 2.3-11...	Yes	GE WIND ENERGY	GE 2.3-116-2,300	2,300	116.0	80.0	1,732	15.7
3	-95.553051° E	44.874103° N	317.6	WTG 18	Yes	GE WIND ENERGY	GE 2.5-116-2,500	2,500	116.0	90.0	1,732	15.7
4	-95.537478° E	44.856906° N	317.7	WTG 17	Yes	GE WIND ENERGY	GE 2.5-116-2,500	2,500	116.0	90.0	1,732	15.7
5	-95.537703° E	44.849525° N	315.7	WTG 16	Yes	GE WIND ENERGY	GE 2.5-116-2,500	2,500	116.0	90.0	1,732	15.7
6	-95.553758° E	44.841564° N	316.5	WTG 13	Yes	GE WIND ENERGY	GE 2.5-116-2,500	2,500	116.0	90.0	1,732	15.7
7	-95.569200° E	44.845481° N	311.8	WTG 12	Yes	GE WIND ENERGY	GE 2.5-116-2,500	2,500	116.0	90.0	1,732	15.7
8	-95.569217° E	44.852581° N	315.1	WTG 11	Yes	GE WIND ENERGY	GE 2.5-116-2,500	2,500	116.0	90.0	1,732	15.7
9	-95.580089° E	44.854156° N	311.2	WTG 10	Yes	GE WIND ENERGY	GE 2.5-116-2,500	2,500	116.0	90.0	1,732	15.7
10	-95.591775° E	44.856100° N	315.7	WTG 09	Yes	GE WIND ENERGY	GE 2.5-116-2,500	2,500	116.0	90.0	1,732	15.7
11	-95.573914° E	44.864814° N	315.8	WTG 08	Yes	GE WIND ENERGY	GE 2.5-116-2,500	2,500	116.0	90.0	1,732	15.7
12	-95.581006° E	44.861153° N	316.1	WTG 07	Yes	GE WIND ENERGY	GE 2.5-116-2,500	2,500	116.0	90.0	1,732	15.7
13	-95.592361° E	44.861344° N	319.4	WTG 06	Yes	GE WIND ENERGY	GE 2.5-116-2,500	2,500	116.0	90.0	1,732	15.7
14	-95.605892° E	44.864522° N	315.1	WTG 05	Yes	GE WIND ENERGY	GE 2.5-116-2,500	2,500	116.0	90.0	1,732	15.7
15	-95.576389° E	44.875264° N	315.5	WTG 04	Yes	GE WIND ENERGY	GE 2.5-116-2,500	2,500	116.0	90.0	1,732	15.7
16	-95.583828° E	44.869392° N	318.6	WTG 03	Yes	GE WIND ENERGY	GE 2.5-116-2,500	2,500	116.0	90.0	1,732	15.7
17	-95.606875° E	44.869294° N	315.7	WTG 01	Yes	GE WIND ENERGY	GE 2.5-116-2,500	2,500	116.0	90.0	1,732	15.7
18	-95.603139° E	44.874661° N	312.2	WTG 02	Yes	GE WIND ENERGY	GE 2.5-116-2,500	2,500	116.0	90.0	1,732	15.7

Shadow receptor-Input

No.	Name	Longitude	Latitude	Z	Width	Height	Height a.g.l.	Degrees from south cw	Slope of window	Direction mode
				[m]	[m]	[m]	[m]	[°]	[°]	
A	Resident 01	-95.533842° E	44.825638° N	319.3	2.0	1.5	1.0	0.0	90.0	"Green house mode"
B	Resident 02	-95.533704° E	44.826359° N	318.5	2.0	1.5	1.0	0.0	90.0	"Green house mode"
C	Resident 03	-95.534989° E	44.827696° N	317.9	2.0	1.5	1.0	0.0	90.0	"Green house mode"
D	Resident 04	-95.533451° E	44.830307° N	317.9	2.0	1.5	1.0	0.0	90.0	"Green house mode"
E	Resident 05	-95.532683° E	44.834853° N	319.8	2.0	1.5	1.0	0.0	90.0	"Green house mode"
F	Resident 06	-95.534019° E	44.837284° N	321.1	2.0	1.5	1.0	0.0	90.0	"Green house mode"
G	Resident 07	-95.534825° E	44.837363° N	322.5	2.0	1.5	1.0	0.0	90.0	"Green house mode"

To be continued on next page...

SHADOW - Main Result

Calculation: 180214 Worst Case - Greehouse Mode - 80m HH + 90m HH

...continued from previous page

No.	Name	Longitude	Latitude	Z [m]	Width [m]	Height [m]	Height a.g.l. [m]	Degrees from south cw [°]	Slope of window [°]	Direction mode
H	Resident 08	-95.534954° E	44.842124° N	318.1	2.0	1.5	1.0	0.0	90.0	"Green house mode"
I	Resident 09	-95.535337° E	44.844227° N	319.2	2.0	1.5	1.0	0.0	90.0	"Green house mode"
J	Resident 10	-95.516886° E	44.853297° N	321.2	2.0	1.5	1.0	0.0	90.0	"Green house mode"
K	Resident 11	-95.537188° E	44.861760° N	319.8	2.0	1.5	1.0	0.0	90.0	"Green house mode"
L	Resident 12	-95.531666° E	44.862421° N	318.0	2.0	1.5	1.0	0.0	90.0	"Green house mode"
M	Resident 13	-95.529807° E	44.861382° N	318.6	2.0	1.5	1.0	0.0	90.0	"Green house mode"
N	Resident 14	-95.533598° E	44.866156° N	319.5	2.0	1.5	1.0	0.0	90.0	"Green house mode"
O	Resident 15	-95.541625° E	44.870285° N	316.8	2.0	1.5	1.0	0.0	90.0	"Green house mode"
P	Resident 16	-95.534581° E	44.873292° N	318.3	2.0	1.5	1.0	0.0	90.0	"Green house mode"
Q	Resident 17	-95.533334° E	44.877298° N	317.7	2.0	1.5	1.0	0.0	90.0	"Green house mode"
R	Resident 18	-95.533434° E	44.878708° N	318.7	2.0	1.5	1.0	0.0	90.0	"Green house mode"
S	Resident 19	-95.535326° E	44.878631° N	320.9	2.0	1.5	1.0	0.0	90.0	"Green house mode"
T	Resident 20	-95.540947° E	44.875754° N	313.6	2.0	1.5	1.0	0.0	90.0	"Green house mode"
U	Resident 21	-95.543273° E	44.877427° N	312.7	2.0	1.5	1.0	0.0	90.0	"Green house mode"
V	Resident 22	-95.549112° E	44.877963° N	313.6	2.0	1.5	1.0	0.0	90.0	"Green house mode"
W	Resident 23	-95.559915° E	44.882819° N	319.5	2.0	1.5	1.0	0.0	90.0	"Green house mode"
X	Resident 24	-95.577203° E	44.878542° N	316.3	2.0	1.5	1.0	0.0	90.0	"Green house mode"
Y	Resident 25	-95.597991° E	44.877208° N	318.1	2.0	1.5	1.0	0.0	90.0	"Green house mode"
Z	Resident 26	-95.597527° E	44.876494° N	317.5	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AA	Resident 27	-95.599588° E	44.880968° N	317.5	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AB	Resident 28	-95.612918° E	44.875402° N	315.9	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AC	Resident 29	-95.623577° E	44.876903° N	317.5	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AD	Resident 30	-95.621627° E	44.871308° N	315.3	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AE	Resident 31	-95.602094° E	44.867319° N	318.2	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AF	Resident 32	-95.582822° E	44.865745° N	319.9	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AG	Resident 33	-95.563933° E	44.874963° N	316.9	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AH	Resident 34	-95.563925° E	44.870771° N	315.1	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AI	Resident 35	-95.563889° E	44.868106° N	317.4	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AJ	Resident 36	-95.568776° E	44.864178° N	316.4	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AK	Resident 37	-95.601147° E	44.856727° N	308.7	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AL	Resident 38	-95.554238° E	44.850846° N	314.7	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AM	Resident 39	-95.565658° E	44.847905° N	311.4	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AN	Resident 40	-95.560488° E	44.847249° N	307.3	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AO	Resident 41	-95.560249° E	44.845851° N	311.1	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AP	Resident 42	-95.559105° E	44.841427° N	318.2	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AQ	Resident 43	-95.568088° E	44.839398° N	310.7	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AR	Resident 44	-95.560323° E	44.838731° N	315.8	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AS	Resident 45	-95.562243° E	44.835534° N	309.2	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AT	Resident 46	-95.562369° E	44.834158° N	309.5	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AU	Resident 47	-95.544746° E	44.825700° N	319.2	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AV	Substation-OfficeShop	-95.552901° E	44.827202° N	313.1	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AW	Swensen-Farm-Museum	-95.592478° E	44.878552° N	319.2	2.0	1.5	1.0	0.0	90.0	"Green house mode"

Calculation Results

Shadow receptor

No.	Name	Shadow, worst case: Shadow hours per year [h/year]	Shadow days per year [days/year]	Max shadow hours per day [h/day]
A	Resident 01	0:00	0	0:00
B	Resident 02	0:00	0	0:00
C	Resident 03	0:00	0	0:00
D	Resident 04	0:00	0	0:00
E	Resident 05	25:36	62	0:37
F	Resident 06	31:04	78	0:44
G	Resident 07	38:57	86	0:49
H	Resident 08	53:05	119	0:40

To be continued on next page...

SHADOW - Main Result

Calculation: 180214 Worst Case - Greehouse Mode - 80m HH + 90m HH

...continued from previous page

Shadow, worst case

No.	Name	Shadow hours per year [h/year]	Shadow days per year [days/year]	Max shadow hours per day [h/day]
I	Resident 09	31:47	79	0:43
J	Resident 10	4:08	36	0:11
K	Resident 11	0:00	0	0:00
L	Resident 12	0:00	0	0:00
M	Resident 13	43:02	82	0:37
N	Resident 14	0:00	0	0:00
O	Resident 15	30:36	82	0:29
P	Resident 16	3:36	22	0:15
Q	Resident 17	2:36	19	0:12
R	Resident 18	2:28	18	0:12
S	Resident 19	3:23	22	0:15
T	Resident 20	11:31	36	0:28
U	Resident 21	18:39	47	0:33
V	Resident 22	38:09	58	0:49
W	Resident 23	4:38	32	0:15
X	Resident 24	10:50	26	0:32
Y	Resident 25	90:22	144	0:57
Z	Resident 26	70:06	163	0:56
AA	Resident 27	0:00	0	0:00
AB	Resident 28	18:30	44	0:35
AC	Resident 29	7:02	50	0:14
AD	Resident 30	16:18	84	0:22
AE	Resident 31	159:31	177	1:35
AF	Resident 32	44:18	110	0:38
AG	Resident 33	28:08	85	0:32
AH	Resident 34	85:55	171	0:50
AI	Resident 35	23:22	87	0:32
AJ	Resident 36	133:01	184	1:06
AK	Resident 37	27:12	85	0:36
AL	Resident 38	51:35	214	0:25
AM	Resident 39	151:36	158	1:35
AN	Resident 40	36:29	106	0:53
AO	Resident 41	75:14	135	0:43
AP	Resident 42	100:03	171	1:06
AQ	Resident 43	9:04	34	0:23
AR	Resident 44	23:28	93	0:29
AS	Resident 45	2:14	18	0:11
AT	Resident 46	2:05	18	0:11
AU	Resident 47	0:00	0	0:00
AV	Substation-OfficeShop	0:00	0	0:00
AW	Swensen-Farm-Museum	18:58	71	0:29

Total amount of flickering on the shadow receptors caused by each WTG

No.	Name	Worst case [h/year]	Expected [h/year]
1	WTG 14 - GE 2.3-116 80m HH	73:47	
2	WTG 15 - GE 2.3-116 80m HH	119:22	
3	WTG 18	155:50	
4	WTG 17	58:31	
5	WTG 16	6:48	
6	WTG 13	174:28	
7	WTG 12	198:49	
8	WTG 11	7:13	
9	WTG 10	11:27	
10	WTG 09	21:41	
11	WTG 08	170:56	
12	WTG 07	25:05	

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SHADOW - Main Result

Calculation: 180214 Worst Case - Greehouse Mode - 80m HH + 90m HH

...continued from previous page

No.	Name	Worst case [h/year]	Expected [h/year]
13	WTG 06	45:55	
14	WTG 05	107:14	
15	WTG 04	58:38	
16	WTG 03	45:13	
17	WTG 01	41:39	
18	WTG 02	145:47	

Project:
Palmers Creek Wind Farm

Description:
Mike Rutledge
Environmental Services Dept. Head
FAGEN ENGINEERING, LLC
P.O. Box 159
Granite Falls, MN 56241
320-564-3324 Main
320-564-2625 Direct
320-564-4861 Fax

Licensed user:
EAPC Wind Energy
3100 DeMers Avenue
US-GRAND FORKS, ND 58201
+1 701 775 3000
Nicholas Laskovski / n.laskovski@eapcwindenergy.com
Calculated:
2/15/2018 4:52 PM/3.0.654

SHADOW - Main Result

Calculation: 180214 Worst Case - Greehouse Mode - 80m HH + 94m HH

Assumptions for shadow calculations

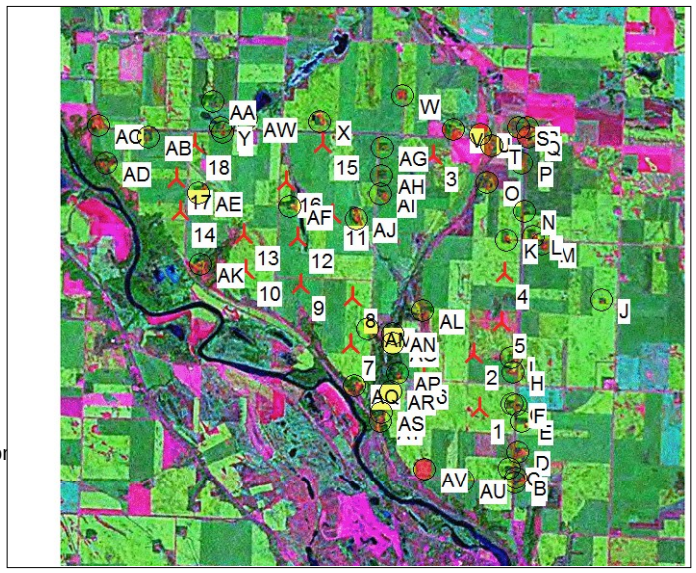
Maximum distance for influence
Calculate only when more than 20 % of sun is covered by the blade
Please look in WTG table

Minimum sun height over horizon for influence	3 °
Day step for calculation	1 days
Time step for calculation	1 minutes

The calculated times are "worst case" given by the following assumptions:
- The sun is shining all the day, from sunrise to sunset
- The rotor plane is always perpendicular to the line from the WTG to the sun
- The WTG is always operating

A ZVI (Zones of Visual Influence) calculation is performed before flicker calculation so non visible WTG do not contribute to calculated flicker values. A WTG will be visible if it is visible from any part of the receiver window. The ZVI calculation is based on the following assumptions:
Height contours used: Project Wizard Elevation Data Grid (US NED 1/3 arc-secon
Obstacles used in calculation
Eye height: 1.5 m
Grid resolution: 10.0 m

All coordinates are in
Geo [deg]-WGS84



WTGs

	Longitude	Latitude	Z	Row data/Description	WTG type Valid	Manufact.	Type-generator	Power, rated	Rotor diameter	Hub height	Shadow data Calculation distance	RPM
			[m]					[kW]	[m]	[m]	[m]	[RPM]
1	-95.541662° E	44.836622° N	313.0	WTG 14 - GE 2.3-11...	Yes	GE WIND ENERGY	GE 2.3-116-2,300	2,300	116.0	80.0	1,732	15.7
2	-95.543356° E	44.844631° N	314.6	WTG 15 - GE 2.3-11...	Yes	GE WIND ENERGY	GE 2.3-116-2,300	2,300	116.0	80.0	1,732	15.7
3	-95.553051° E	44.874103° N	317.6	WTG 18	Yes	GE WIND ENERGY	GE 2.5-116-2,500	2,500	116.0	94.0	1,732	15.7
4	-95.537478° E	44.856906° N	317.7	WTG 17	Yes	GE WIND ENERGY	GE 2.5-116-2,500	2,500	116.0	94.0	1,732	15.7
5	-95.537703° E	44.849525° N	315.7	WTG 16	Yes	GE WIND ENERGY	GE 2.5-116-2,500	2,500	116.0	94.0	1,732	15.7
6	-95.553758° E	44.841564° N	316.5	WTG 13	Yes	GE WIND ENERGY	GE 2.5-116-2,500	2,500	116.0	94.0	1,732	15.7
7	-95.569200° E	44.845481° N	311.8	WTG 12	Yes	GE WIND ENERGY	GE 2.5-116-2,500	2,500	116.0	94.0	1,732	15.7
8	-95.569217° E	44.852581° N	315.1	WTG 11	Yes	GE WIND ENERGY	GE 2.5-116-2,500	2,500	116.0	94.0	1,732	15.7
9	-95.580089° E	44.854156° N	311.2	WTG 10	Yes	GE WIND ENERGY	GE 2.5-116-2,500	2,500	116.0	94.0	1,732	15.7
10	-95.591775° E	44.856100° N	315.7	WTG 09	Yes	GE WIND ENERGY	GE 2.5-116-2,500	2,500	116.0	94.0	1,732	15.7
11	-95.573914° E	44.864814° N	315.8	WTG 08	Yes	GE WIND ENERGY	GE 2.5-116-2,500	2,500	116.0	94.0	1,732	15.7
12	-95.581006° E	44.861153° N	316.1	WTG 07	Yes	GE WIND ENERGY	GE 2.5-116-2,500	2,500	116.0	94.0	1,732	15.7
13	-95.592361° E	44.861344° N	319.4	WTG 06	Yes	GE WIND ENERGY	GE 2.5-116-2,500	2,500	116.0	94.0	1,732	15.7
14	-95.605892° E	44.864522° N	315.1	WTG 05	Yes	GE WIND ENERGY	GE 2.5-116-2,500	2,500	116.0	94.0	1,732	15.7
15	-95.576389° E	44.875264° N	315.5	WTG 04	Yes	GE WIND ENERGY	GE 2.5-116-2,500	2,500	116.0	94.0	1,732	15.7
16	-95.583828° E	44.869392° N	318.6	WTG 03	Yes	GE WIND ENERGY	GE 2.5-116-2,500	2,500	116.0	94.0	1,732	15.7
17	-95.606875° E	44.869294° N	315.7	WTG 01	Yes	GE WIND ENERGY	GE 2.5-116-2,500	2,500	116.0	94.0	1,732	15.7
18	-95.603139° E	44.874661° N	312.2	WTG 02	Yes	GE WIND ENERGY	GE 2.5-116-2,500	2,500	116.0	94.0	1,732	15.7

Shadow receptor-Input

No.	Name	Longitude	Latitude	Z	Width	Height	Height a.g.l.	Degrees from south cw	Slope of window	Direction mode
				[m]	[m]	[m]	[m]	[°]	[°]	
A	Resident 01	-95.533842° E	44.825638° N	319.3	2.0	1.5	1.0	0.0	90.0	"Green house mode"
B	Resident 02	-95.533704° E	44.826359° N	318.5	2.0	1.5	1.0	0.0	90.0	"Green house mode"
C	Resident 03	-95.534989° E	44.827696° N	317.9	2.0	1.5	1.0	0.0	90.0	"Green house mode"
D	Resident 04	-95.533451° E	44.830307° N	317.9	2.0	1.5	1.0	0.0	90.0	"Green house mode"
E	Resident 05	-95.532683° E	44.834853° N	319.8	2.0	1.5	1.0	0.0	90.0	"Green house mode"
F	Resident 06	-95.534019° E	44.837284° N	321.1	2.0	1.5	1.0	0.0	90.0	"Green house mode"
G	Resident 07	-95.534825° E	44.837363° N	322.5	2.0	1.5	1.0	0.0	90.0	"Green house mode"

To be continued on next page...

SHADOW - Main Result

Calculation: 180214 Worst Case - Greehouse Mode - 80m HH + 94m HH

...continued from previous page

No.	Name	Longitude	Latitude	Z [m]	Width [m]	Height [m]	Height a.g.l. [m]	Degrees from south cw [°]	Slope of window [°]	Direction mode
H	Resident 08	-95.534954° E	44.842124° N	318.1	2.0	1.5	1.0	0.0	90.0	"Green house mode"
I	Resident 09	-95.535337° E	44.844227° N	319.2	2.0	1.5	1.0	0.0	90.0	"Green house mode"
J	Resident 10	-95.516886° E	44.853297° N	321.2	2.0	1.5	1.0	0.0	90.0	"Green house mode"
K	Resident 11	-95.537188° E	44.861760° N	319.8	2.0	1.5	1.0	0.0	90.0	"Green house mode"
L	Resident 12	-95.531666° E	44.862421° N	318.0	2.0	1.5	1.0	0.0	90.0	"Green house mode"
M	Resident 13	-95.529807° E	44.861382° N	318.6	2.0	1.5	1.0	0.0	90.0	"Green house mode"
N	Resident 14	-95.533598° E	44.866156° N	319.5	2.0	1.5	1.0	0.0	90.0	"Green house mode"
O	Resident 15	-95.541625° E	44.870285° N	316.8	2.0	1.5	1.0	0.0	90.0	"Green house mode"
P	Resident 16	-95.534581° E	44.873292° N	318.3	2.0	1.5	1.0	0.0	90.0	"Green house mode"
Q	Resident 17	-95.533334° E	44.877298° N	317.7	2.0	1.5	1.0	0.0	90.0	"Green house mode"
R	Resident 18	-95.533434° E	44.878708° N	318.7	2.0	1.5	1.0	0.0	90.0	"Green house mode"
S	Resident 19	-95.535326° E	44.878631° N	320.9	2.0	1.5	1.0	0.0	90.0	"Green house mode"
T	Resident 20	-95.540947° E	44.875754° N	313.6	2.0	1.5	1.0	0.0	90.0	"Green house mode"
U	Resident 21	-95.543273° E	44.877427° N	312.7	2.0	1.5	1.0	0.0	90.0	"Green house mode"
V	Resident 22	-95.549112° E	44.877963° N	313.6	2.0	1.5	1.0	0.0	90.0	"Green house mode"
W	Resident 23	-95.559915° E	44.882819° N	319.5	2.0	1.5	1.0	0.0	90.0	"Green house mode"
X	Resident 24	-95.577203° E	44.878542° N	316.3	2.0	1.5	1.0	0.0	90.0	"Green house mode"
Y	Resident 25	-95.597991° E	44.877208° N	318.1	2.0	1.5	1.0	0.0	90.0	"Green house mode"
Z	Resident 26	-95.597527° E	44.876494° N	317.5	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AA	Resident 27	-95.599588° E	44.880968° N	317.5	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AB	Resident 28	-95.612918° E	44.875402° N	315.9	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AC	Resident 29	-95.623577° E	44.876903° N	317.5	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AD	Resident 30	-95.621627° E	44.871308° N	315.3	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AE	Resident 31	-95.602094° E	44.867319° N	318.2	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AF	Resident 32	-95.582822° E	44.865745° N	319.9	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AG	Resident 33	-95.563933° E	44.874963° N	316.9	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AH	Resident 34	-95.563925° E	44.870771° N	315.1	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AI	Resident 35	-95.563889° E	44.868106° N	317.4	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AJ	Resident 36	-95.568776° E	44.864178° N	316.4	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AK	Resident 37	-95.601147° E	44.856727° N	308.7	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AL	Resident 38	-95.554238° E	44.850846° N	314.7	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AM	Resident 39	-95.565658° E	44.847905° N	311.4	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AN	Resident 40	-95.560488° E	44.847249° N	307.3	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AO	Resident 41	-95.560249° E	44.845851° N	311.1	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AP	Resident 42	-95.559105° E	44.841427° N	318.2	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AQ	Resident 43	-95.568088° E	44.839398° N	310.7	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AR	Resident 44	-95.560323° E	44.838731° N	315.8	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AS	Resident 45	-95.562243° E	44.835534° N	309.2	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AT	Resident 46	-95.562369° E	44.834158° N	309.5	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AU	Resident 47	-95.544746° E	44.825700° N	319.2	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AV	Substation-OfficeShop	-95.552901° E	44.827202° N	313.1	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AW	Swensen-Farm-Museum	-95.592478° E	44.878552° N	319.2	2.0	1.5	1.0	0.0	90.0	"Green house mode"

Calculation Results

Shadow receptor

No.	Name	Shadow, worst case: Shadow hours per year [h/year]	Shadow days per year [days/year]	Max shadow hours per day [h/day]
A	Resident 01	0:00	0	0:00
B	Resident 02	0:00	0	0:00
C	Resident 03	0:00	0	0:00
D	Resident 04	0:00	0	0:00
E	Resident 05	25:36	62	0:37
F	Resident 06	31:21	79	0:44
G	Resident 07	39:15	87	0:49
H	Resident 08	53:19	120	0:40

To be continued on next page...

SHADOW - Main Result

Calculation: 180214 Worst Case - Greehouse Mode - 80m HH + 94m HH

...continued from previous page

No.	Name	Shadow, worst case Shadow hours per year [h/year]	Shadow days per year [days/year]	Max shadow hours per day [h/day]
I	Resident 09	31:59	79	0:43
J	Resident 10	4:35	37	0:11
K	Resident 11	0:00	0	0:00
L	Resident 12	0:00	0	0:00
M	Resident 13	43:57	82	0:37
N	Resident 14	0:00	0	0:00
O	Resident 15	31:12	81	0:29
P	Resident 16	3:49	22	0:15
Q	Resident 17	2:44	19	0:13
R	Resident 18	2:42	19	0:13
S	Resident 19	3:37	23	0:15
T	Resident 20	11:48	35	0:28
U	Resident 21	19:09	48	0:33
V	Resident 22	41:51	62	0:50
W	Resident 23	5:03	34	0:15
X	Resident 24	19:31	34	0:43
Y	Resident 25	88:29	145	0:56
Z	Resident 26	70:21	162	0:56
AA	Resident 27	0:00	0	0:00
AB	Resident 28	19:03	45	0:35
AC	Resident 29	7:29	50	0:15
AD	Resident 30	17:15	88	0:22
AE	Resident 31	157:04	174	1:33
AF	Resident 32	45:17	108	0:38
AG	Resident 33	29:10	84	0:33
AH	Resident 34	89:05	171	0:52
AI	Resident 35	24:23	88	0:32
AJ	Resident 36	140:48	182	1:07
AK	Resident 37	27:39	86	0:36
AL	Resident 38	53:25	215	0:25
AM	Resident 39	152:43	161	1:34
AN	Resident 40	39:31	113	0:54
AO	Resident 41	76:51	139	0:43
AP	Resident 42	100:26	170	1:08
AQ	Resident 43	9:31	36	0:24
AR	Resident 44	20:59	93	0:27
AS	Resident 45	2:14	18	0:11
AT	Resident 46	2:05	18	0:11
AU	Resident 47	0:00	0	0:00
AV	Substation-OfficeShop	0:00	0	0:00
AW	Swensen-Farm-Museum	19:50	70	0:29

Total amount of flickering on the shadow receptors caused by each WTG

No.	Name	Worst case [h/year]	Expected [h/year]
1	WTG 14 - GE 2.3-116 80m HH	73:47	
2	WTG 15 - GE 2.3-116 80m HH	119:22	
3	WTG 18	163:16	
4	WTG 17	60:38	
5	WTG 16	7:16	
6	WTG 13	176:49	
7	WTG 12	200:14	
8	WTG 11	7:31	
9	WTG 10	12:16	
10	WTG 09	21:38	
11	WTG 08	178:49	
12	WTG 07	26:45	

To be continued on next page...

SHADOW - Main Result

Calculation: 180214 Worst Case - Greehouse Mode - 80m HH + 94m HH

...continued from previous page

No.	Name	Worst case [h/year]	Expected [h/year]
13	WTG 06	47:17	
14	WTG 05	109:17	
15	WTG 04	69:14	
16	WTG 03	48:31	
17	WTG 01	36:51	
18	WTG 02	144:46	

Project:
Palmers Creek Wind Farm

Description:
Mike Rutledge
Environmental Services Dept. Head
FAGEN ENGINEERING, LLC
P.O. Box 159
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Nicholas Laskovski / n.laskovski@eapcwindenergy.com
Calculated:
2/15/2018 11:37 PM/3.0.654

SHADOW - Main Result

Calculation: 180214 Realistic Case - 80m HH Turbines

Assumptions for shadow calculations

Maximum distance for influence
Calculate only when more than 20 % of sun is covered by the blade
Please look in WTG table

Minimum sun height over horizon for influence	3 °
Day step for calculation	1 days
Time step for calculation	1 minutes

Sunshine probability S (Average daily sunshine hours) [MADISON]

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
4.43	5.24	5.95	7.01	8.58	9.67	9.71	8.48	7.21	5.48	3.66	3.19

Operational hours are calculated from WTGs in calculation and wind distribution:
Palmers 80m Met

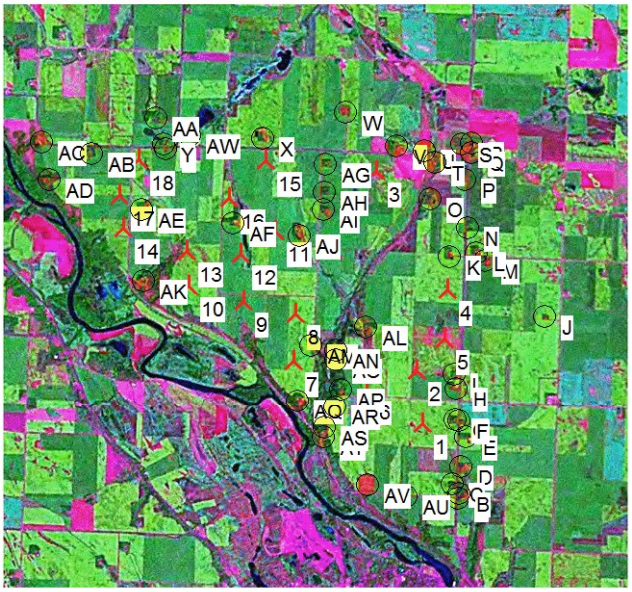
Operational time

N	NNE	ENE	E	ESE	SSE	S	SSW	WSW	W	WNW	NNW	Sum
528	300	300	396	610	1,529	1,184	403	333	542	951	1,392	8,468

Idle start wind speed: Cut in wind speed from power curve

A ZVI (Zones of Visual Influence) calculation is performed before flicker calculation so non visible WTG do not contribute to calculated flicker values. A WTG will be visible if it is visible from any part of the receiver window. The ZVI calculation is based on the following assumptions:
Height contours used: Project Wizard Elevation Data Grid (US NED 1/3 arc-secon
Obstacles used in calculation
Eye height: 1.5 m
Grid resolution: 10.0 m

All coordinates are in
Geo [deg]-WGS84



Scale 1:125,000

New WTG Shadow receptor

WTGs

	Longitude	Latitude	Z	Row data/Description	WTG type Valid	Manufact.	Type-generator	Power, rated	Rotor diameter	Hub height	Shadow data Calculation distance	RPM
			[m]					[kW]	[m]	[m]	[m]	[RPM]
1	-95.541662° E	44.836622° N	313.0	WTG 14 - GE 2.3-11...	Yes	GE WIND ENERGY	GE 2.3-116-2,300	2,300	116.0	80.0	1,732	15.7
2	-95.543356° E	44.844631° N	314.6	WTG 15 - GE 2.3-11...	Yes	GE WIND ENERGY	GE 2.3-116-2,300	2,300	116.0	80.0	1,732	15.7
3	-95.553051° E	44.874103° N	317.6	WTG 18	Yes	GE WIND ENERGY	GE 2.5-116-2,500	2,500	116.0	80.0	1,732	15.7
4	-95.537478° E	44.856906° N	317.7	WTG 17	Yes	GE WIND ENERGY	GE 2.5-116-2,500	2,500	116.0	80.0	1,732	15.7
5	-95.537703° E	44.849525° N	315.7	WTG 16	Yes	GE WIND ENERGY	GE 2.5-116-2,500	2,500	116.0	80.0	1,732	15.7
6	-95.553758° E	44.841564° N	316.5	WTG 13	Yes	GE WIND ENERGY	GE 2.5-116-2,500	2,500	116.0	80.0	1,732	15.7
7	-95.569200° E	44.845481° N	311.8	WTG 12	Yes	GE WIND ENERGY	GE 2.5-116-2,500	2,500	116.0	80.0	1,732	15.7
8	-95.569217° E	44.852581° N	315.1	WTG 11	Yes	GE WIND ENERGY	GE 2.5-116-2,500	2,500	116.0	80.0	1,732	15.7
9	-95.580089° E	44.854156° N	311.2	WTG 10	Yes	GE WIND ENERGY	GE 2.5-116-2,500	2,500	116.0	80.0	1,732	15.7
10	-95.591775° E	44.856100° N	315.7	WTG 09	Yes	GE WIND ENERGY	GE 2.5-116-2,500	2,500	116.0	80.0	1,732	15.7
11	-95.573914° E	44.864814° N	315.8	WTG 08	Yes	GE WIND ENERGY	GE 2.5-116-2,500	2,500	116.0	80.0	1,732	15.7
12	-95.581006° E	44.861153° N	316.1	WTG 07	Yes	GE WIND ENERGY	GE 2.5-116-2,500	2,500	116.0	80.0	1,732	15.7
13	-95.592361° E	44.861344° N	319.4	WTG 06	Yes	GE WIND ENERGY	GE 2.5-116-2,500	2,500	116.0	80.0	1,732	15.7
14	-95.605892° E	44.864522° N	315.1	WTG 05	Yes	GE WIND ENERGY	GE 2.5-116-2,500	2,500	116.0	80.0	1,732	15.7
15	-95.576389° E	44.875264° N	315.5	WTG 04	Yes	GE WIND ENERGY	GE 2.5-116-2,500	2,500	116.0	80.0	1,732	15.7
16	-95.583828° E	44.869392° N	318.6	WTG 03	Yes	GE WIND ENERGY	GE 2.5-116-2,500	2,500	116.0	80.0	1,732	15.7
17	-95.606875° E	44.869294° N	315.7	WTG 01	Yes	GE WIND ENERGY	GE 2.5-116-2,500	2,500	116.0	80.0	1,732	15.7
18	-95.603139° E	44.874661° N	312.2	WTG 02	Yes	GE WIND ENERGY	GE 2.5-116-2,500	2,500	116.0	80.0	1,732	15.7

SHADOW - Main Result

Calculation: 180214 Realistic Case - 80m HH Turbines

Shadow receptor-Input

No.	Name	Longitude	Latitude	Z [m]	Width [m]	Height [m]	Height a.g.l. [m]	Degrees from south cw [°]	Slope of window [°]	Direction mode
A	Resident 01	-95.533842° E	44.825638° N	319.3	2.0	1.5	1.0	0.0	90.0	"Green house mode"
B	Resident 02	-95.533704° E	44.826359° N	318.5	2.0	1.5	1.0	0.0	90.0	"Green house mode"
C	Resident 03	-95.534989° E	44.827696° N	317.9	2.0	1.5	1.0	0.0	90.0	"Green house mode"
D	Resident 04	-95.533451° E	44.830307° N	317.9	2.0	1.5	1.0	0.0	90.0	"Green house mode"
E	Resident 05	-95.532683° E	44.834853° N	319.8	2.0	1.5	1.0	0.0	90.0	"Green house mode"
F	Resident 06	-95.534019° E	44.837284° N	321.1	2.0	1.5	1.0	0.0	90.0	"Green house mode"
G	Resident 07	-95.534825° E	44.837363° N	322.5	2.0	1.5	1.0	0.0	90.0	"Green house mode"
H	Resident 08	-95.534954° E	44.842124° N	318.1	2.0	1.5	1.0	0.0	90.0	"Green house mode"
I	Resident 09	-95.535337° E	44.844227° N	319.2	2.0	1.5	1.0	0.0	90.0	"Green house mode"
J	Resident 10	-95.516886° E	44.853297° N	321.2	2.0	1.5	1.0	0.0	90.0	"Green house mode"
K	Resident 11	-95.537188° E	44.861760° N	319.8	2.0	1.5	1.0	0.0	90.0	"Green house mode"
L	Resident 12	-95.531666° E	44.862421° N	318.0	2.0	1.5	1.0	0.0	90.0	"Green house mode"
M	Resident 13	-95.529807° E	44.861382° N	318.6	2.0	1.5	1.0	0.0	90.0	"Green house mode"
N	Resident 14	-95.533598° E	44.866156° N	319.5	2.0	1.5	1.0	0.0	90.0	"Green house mode"
O	Resident 15	-95.541625° E	44.870285° N	316.8	2.0	1.5	1.0	0.0	90.0	"Green house mode"
P	Resident 16	-95.534581° E	44.873292° N	318.3	2.0	1.5	1.0	0.0	90.0	"Green house mode"
Q	Resident 17	-95.533334° E	44.877298° N	317.7	2.0	1.5	1.0	0.0	90.0	"Green house mode"
R	Resident 18	-95.533434° E	44.878708° N	318.7	2.0	1.5	1.0	0.0	90.0	"Green house mode"
S	Resident 19	-95.535326° E	44.878631° N	320.9	2.0	1.5	1.0	0.0	90.0	"Green house mode"
T	Resident 20	-95.540947° E	44.875754° N	313.6	2.0	1.5	1.0	0.0	90.0	"Green house mode"
U	Resident 21	-95.543273° E	44.877427° N	312.7	2.0	1.5	1.0	0.0	90.0	"Green house mode"
V	Resident 22	-95.549112° E	44.877963° N	313.6	2.0	1.5	1.0	0.0	90.0	"Green house mode"
W	Resident 23	-95.559915° E	44.882819° N	319.5	2.0	1.5	1.0	0.0	90.0	"Green house mode"
X	Resident 24	-95.577203° E	44.878542° N	316.3	2.0	1.5	1.0	0.0	90.0	"Green house mode"
Y	Resident 25	-95.597991° E	44.877208° N	318.1	2.0	1.5	1.0	0.0	90.0	"Green house mode"
Z	Resident 26	-95.597527° E	44.876494° N	317.5	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AA	Resident 27	-95.599588° E	44.880968° N	317.5	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AB	Resident 28	-95.612918° E	44.875402° N	315.9	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AC	Resident 29	-95.623577° E	44.876903° N	317.5	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AD	Resident 30	-95.621627° E	44.871308° N	315.3	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AE	Resident 31	-95.602094° E	44.867319° N	318.2	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AF	Resident 32	-95.582822° E	44.865745° N	319.9	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AG	Resident 33	-95.563933° E	44.874963° N	316.9	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AH	Resident 34	-95.563925° E	44.870771° N	315.1	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AI	Resident 35	-95.563889° E	44.868106° N	317.4	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AJ	Resident 36	-95.568776° E	44.864178° N	316.4	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AK	Resident 37	-95.601147° E	44.856727° N	308.7	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AL	Resident 38	-95.554238° E	44.850846° N	314.7	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AM	Resident 39	-95.565658° E	44.847905° N	311.4	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AN	Resident 40	-95.560488° E	44.847249° N	307.3	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AO	Resident 41	-95.560249° E	44.845851° N	311.1	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AP	Resident 42	-95.559105° E	44.841427° N	318.2	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AQ	Resident 43	-95.568088° E	44.839398° N	310.7	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AR	Resident 44	-95.560323° E	44.838731° N	315.8	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AS	Resident 45	-95.562243° E	44.835534° N	309.2	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AT	Resident 46	-95.562369° E	44.834158° N	309.5	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AU	Resident 47	-95.544746° E	44.825700° N	319.2	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AV	Substation-OfficeShop	-95.552901° E	44.827202° N	313.1	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AW	Swensen-Farm-Museum	-95.592478° E	44.878552° N	319.2	2.0	1.5	1.0	0.0	90.0	"Green house mode"

Calculation Results

Shadow receptor

No.	Name	Shadow, expected values Shadow hours per year [h/year]
A	Resident 01	0:00

To be continued on next page...

SHADOW - Main Result

Calculation: 180214 Realistic Case - 80m HH Turbines

...continued from previous page

No.	Name	Shadow, expected values Shadow hours per year [h/year]
B	Resident 02	0:00
C	Resident 03	0:00
D	Resident 04	0:00
E	Resident 05	10:30
F	Resident 06	9:56
G	Resident 07	12:11
H	Resident 08	23:23
I	Resident 09	11:11
J	Resident 10	1:04
K	Resident 11	0:00
L	Resident 12	0:00
M	Resident 13	7:28
N	Resident 14	0:00
O	Resident 15	12:57
P	Resident 16	1:03
Q	Resident 17	0:34
R	Resident 18	0:30
S	Resident 19	0:42
T	Resident 20	3:04
U	Resident 21	4:17
V	Resident 22	5:07
W	Resident 23	0:47
X	Resident 24	0:00
Y	Resident 25	20:24
Z	Resident 26	17:48
AA	Resident 27	0:00
AB	Resident 28	6:03
AC	Resident 29	1:53
AD	Resident 30	4:35
AE	Resident 31	40:38
AF	Resident 32	11:31
AG	Resident 33	8:48
AH	Resident 34	23:56
AI	Resident 35	5:13
AJ	Resident 36	46:46
AK	Resident 37	8:41
AL	Resident 38	14:35
AM	Resident 39	30:20
AN	Resident 40	9:11
AO	Resident 41	22:28
AP	Resident 42	35:57
AQ	Resident 43	2:33
AR	Resident 44	7:52
AS	Resident 45	0:45
AT	Resident 46	0:41
AU	Resident 47	0:00
AV	Substation-OfficeShop	0:00
AW	Swensen-Farm-Museum	4:21

Total amount of flickering on the shadow receptors caused by each WTG

No.	Name	Worst case [h/year]	Expected [h/year]
1	WTG 14 - GE 2.3-116 80m HH	73:47	26:01
2	WTG 15 - GE 2.3-116 80m HH	119:22	45:50
3	WTG 18	133:49	43:00
4	WTG 17	51:02	11:12
5	WTG 16	5:45	1:56

To be continued on next page...

SHADOW - Main Result

Calculation: 180214 Realistic Case - 80m HH Turbines

...continued from previous page

No.	Name	Worst case [h/year]	Expected [h/year]
6	WTG 13	164:06	51:55
7	WTG 12	191:30	47:53
8	WTG 11	6:13	2:22
9	WTG 10	9:25	4:08
10	WTG 09	20:30	7:21
11	WTG 08	156:10	54:34
12	WTG 07	21:04	5:03
13	WTG 06	41:48	8:40
14	WTG 05	100:19	20:23
15	WTG 04	42:42	15:37
16	WTG 03	36:43	12:34
17	WTG 01	48:10	21:14
18	WTG 02	142:09	35:30

Project:
Palmers Creek Wind Farm

Description:
Mike Rutledge
Environmental Services Dept. Head
FAGEN ENGINEERING, LLC
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Nicholas Laskovski / n.laskovski@eapcwindenergy.com
Calculated:
2/16/2018 6:08 AM/3.0.654

SHADOW - Main Result

Calculation: 180214 Realistic Case - 80m + 90m HH Turbines

Assumptions for shadow calculations

Maximum distance for influence
Calculate only when more than 20 % of sun is covered by the blade
Please look in WTG table

Minimum sun height over horizon for influence	3 °
Day step for calculation	1 days
Time step for calculation	1 minutes

Sunshine probability S (Average daily sunshine hours) [MADISON]

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
4.43	5.24	5.95	7.01	8.58	9.67	9.71	8.48	7.21	5.48	3.66	3.19

Operational hours are calculated from WTGs in calculation and wind distribution:
Palmers 80m Met

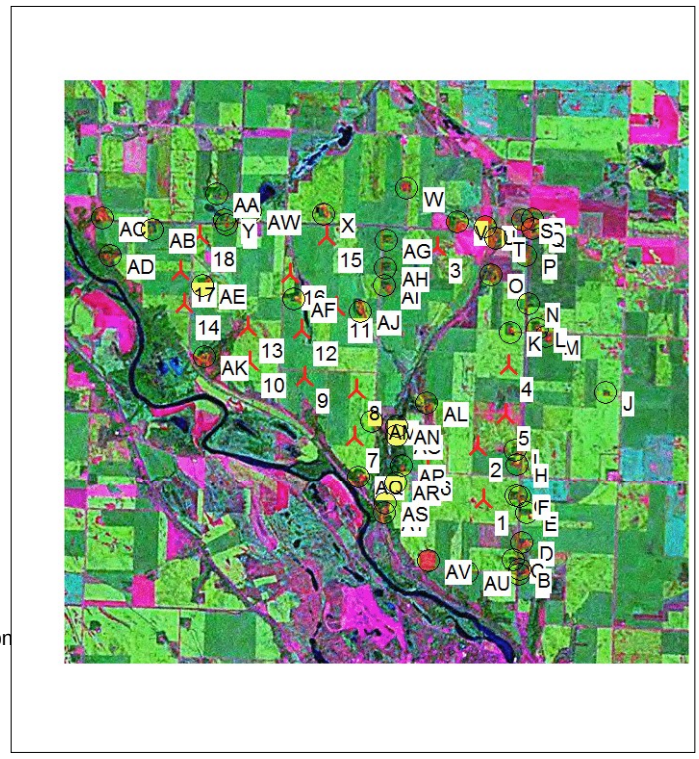
Operational time

N	NNE	ENE	E	ESE	SSE	S	SSW	WSW	W	WNW	NNW	Sum
530	302	302	397	612	1,535	1,189	405	335	544	955	1,398	8,504

Idle start wind speed: Cut in wind speed from power curve

A ZVI (Zones of Visual Influence) calculation is performed before flicker calculation so non visible WTG do not contribute to calculated flicker values. A WTG will be visible if it is visible from any part of the receiver window. The ZVI calculation is based on the following assumptions:
Height contours used: Project Wizard Elevation Data Grid (US NED 1/3 arc-secon
Obstacles used in calculation
Eye height: 1.5 m
Grid resolution: 10.0 m

All coordinates are in
Geo [deg]-WGS84



Scale 1:125,000

New WTG Shadow receptor

WTGs

	Longitude	Latitude	Z	Row data/Description	WTG type Valid	Manufact.	Type-generator	Power, rated	Rotor diameter	Hub height	Shadow data Calculation distance	RPM
			[m]					[kW]	[m]	[m]	[m]	[RPM]
1	-95.541662° E	44.836622° N	313.0	WTG 14 - GE 2.3-11...	Yes	GE WIND ENERGY	GE 2.3-116-2,300	2,300	116.0	80.0	1,732	15.7
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4	-95.537478° E	44.856906° N	317.7	WTG 17	Yes	GE WIND ENERGY	GE 2.5-116-2,500	2,500	116.0	90.0	1,732	15.7
5	-95.537703° E	44.849525° N	315.7	WTG 16	Yes	GE WIND ENERGY	GE 2.5-116-2,500	2,500	116.0	90.0	1,732	15.7
6	-95.553758° E	44.841564° N	316.5	WTG 13	Yes	GE WIND ENERGY	GE 2.5-116-2,500	2,500	116.0	90.0	1,732	15.7
7	-95.569200° E	44.845481° N	311.8	WTG 12	Yes	GE WIND ENERGY	GE 2.5-116-2,500	2,500	116.0	90.0	1,732	15.7
8	-95.569217° E	44.852581° N	315.1	WTG 11	Yes	GE WIND ENERGY	GE 2.5-116-2,500	2,500	116.0	90.0	1,732	15.7
9	-95.580089° E	44.854156° N	311.2	WTG 10	Yes	GE WIND ENERGY	GE 2.5-116-2,500	2,500	116.0	90.0	1,732	15.7
10	-95.591775° E	44.856100° N	315.7	WTG 09	Yes	GE WIND ENERGY	GE 2.5-116-2,500	2,500	116.0	90.0	1,732	15.7
11	-95.573914° E	44.864814° N	315.8	WTG 08	Yes	GE WIND ENERGY	GE 2.5-116-2,500	2,500	116.0	90.0	1,732	15.7
12	-95.581006° E	44.861153° N	316.1	WTG 07	Yes	GE WIND ENERGY	GE 2.5-116-2,500	2,500	116.0	90.0	1,732	15.7
13	-95.592361° E	44.861344° N	319.4	WTG 06	Yes	GE WIND ENERGY	GE 2.5-116-2,500	2,500	116.0	90.0	1,732	15.7
14	-95.605892° E	44.864522° N	315.1	WTG 05	Yes	GE WIND ENERGY	GE 2.5-116-2,500	2,500	116.0	90.0	1,732	15.7
15	-95.576389° E	44.875264° N	315.5	WTG 04	Yes	GE WIND ENERGY	GE 2.5-116-2,500	2,500	116.0	90.0	1,732	15.7
16	-95.583828° E	44.869392° N	318.6	WTG 03	Yes	GE WIND ENERGY	GE 2.5-116-2,500	2,500	116.0	90.0	1,732	15.7
17	-95.606875° E	44.869294° N	315.7	WTG 01	Yes	GE WIND ENERGY	GE 2.5-116-2,500	2,500	116.0	90.0	1,732	15.7
18	-95.603139° E	44.874661° N	312.2	WTG 02	Yes	GE WIND ENERGY	GE 2.5-116-2,500	2,500	116.0	90.0	1,732	15.7

SHADOW - Main Result

Calculation: 180214 Realistic Case - 80m + 90m HH Turbines

Shadow receptor-Input

No.	Name	Longitude	Latitude	Z [m]	Width [m]	Height [m]	Height a.g.l. [m]	Degrees from south cw [°]	Slope of window [°]	Direction mode
A	Resident 01	-95.533842° E	44.825638° N	319.3	2.0	1.5	1.0	0.0	90.0	"Green house mode"
B	Resident 02	-95.533704° E	44.826359° N	318.5	2.0	1.5	1.0	0.0	90.0	"Green house mode"
C	Resident 03	-95.534989° E	44.827696° N	317.9	2.0	1.5	1.0	0.0	90.0	"Green house mode"
D	Resident 04	-95.533451° E	44.830307° N	317.9	2.0	1.5	1.0	0.0	90.0	"Green house mode"
E	Resident 05	-95.532683° E	44.834853° N	319.8	2.0	1.5	1.0	0.0	90.0	"Green house mode"
F	Resident 06	-95.534019° E	44.837284° N	321.1	2.0	1.5	1.0	0.0	90.0	"Green house mode"
G	Resident 07	-95.534825° E	44.837363° N	322.5	2.0	1.5	1.0	0.0	90.0	"Green house mode"
H	Resident 08	-95.534954° E	44.842124° N	318.1	2.0	1.5	1.0	0.0	90.0	"Green house mode"
I	Resident 09	-95.535337° E	44.844227° N	319.2	2.0	1.5	1.0	0.0	90.0	"Green house mode"
J	Resident 10	-95.516886° E	44.853297° N	321.2	2.0	1.5	1.0	0.0	90.0	"Green house mode"
K	Resident 11	-95.537188° E	44.861760° N	319.8	2.0	1.5	1.0	0.0	90.0	"Green house mode"
L	Resident 12	-95.531666° E	44.862421° N	318.0	2.0	1.5	1.0	0.0	90.0	"Green house mode"
M	Resident 13	-95.529807° E	44.861382° N	318.6	2.0	1.5	1.0	0.0	90.0	"Green house mode"
N	Resident 14	-95.533598° E	44.866156° N	319.5	2.0	1.5	1.0	0.0	90.0	"Green house mode"
O	Resident 15	-95.541625° E	44.870285° N	316.8	2.0	1.5	1.0	0.0	90.0	"Green house mode"
P	Resident 16	-95.534581° E	44.873292° N	318.3	2.0	1.5	1.0	0.0	90.0	"Green house mode"
Q	Resident 17	-95.533334° E	44.877298° N	317.7	2.0	1.5	1.0	0.0	90.0	"Green house mode"
R	Resident 18	-95.533434° E	44.878708° N	318.7	2.0	1.5	1.0	0.0	90.0	"Green house mode"
S	Resident 19	-95.535326° E	44.878631° N	320.9	2.0	1.5	1.0	0.0	90.0	"Green house mode"
T	Resident 20	-95.540947° E	44.875754° N	313.6	2.0	1.5	1.0	0.0	90.0	"Green house mode"
U	Resident 21	-95.543273° E	44.877427° N	312.7	2.0	1.5	1.0	0.0	90.0	"Green house mode"
V	Resident 22	-95.549112° E	44.877963° N	313.6	2.0	1.5	1.0	0.0	90.0	"Green house mode"
W	Resident 23	-95.559915° E	44.882819° N	319.5	2.0	1.5	1.0	0.0	90.0	"Green house mode"
X	Resident 24	-95.577203° E	44.878542° N	316.3	2.0	1.5	1.0	0.0	90.0	"Green house mode"
Y	Resident 25	-95.597991° E	44.877208° N	318.1	2.0	1.5	1.0	0.0	90.0	"Green house mode"
Z	Resident 26	-95.597527° E	44.876494° N	317.5	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AA	Resident 27	-95.599588° E	44.880968° N	317.5	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AB	Resident 28	-95.612918° E	44.875402° N	315.9	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AC	Resident 29	-95.623577° E	44.876903° N	317.5	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AD	Resident 30	-95.621627° E	44.871308° N	315.3	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AE	Resident 31	-95.602094° E	44.867319° N	318.2	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AF	Resident 32	-95.582822° E	44.865745° N	319.9	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AG	Resident 33	-95.563933° E	44.874963° N	316.9	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AH	Resident 34	-95.563925° E	44.870771° N	315.1	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AI	Resident 35	-95.563889° E	44.868106° N	317.4	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AJ	Resident 36	-95.568776° E	44.864178° N	316.4	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AK	Resident 37	-95.601147° E	44.856727° N	308.7	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AL	Resident 38	-95.554238° E	44.850846° N	314.7	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AM	Resident 39	-95.565658° E	44.847905° N	311.4	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AN	Resident 40	-95.560488° E	44.847249° N	307.3	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AO	Resident 41	-95.560249° E	44.845851° N	311.1	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AP	Resident 42	-95.559105° E	44.841427° N	318.2	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AQ	Resident 43	-95.568088° E	44.839398° N	310.7	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AR	Resident 44	-95.560323° E	44.838731° N	315.8	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AS	Resident 45	-95.562243° E	44.835534° N	309.2	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AT	Resident 46	-95.562369° E	44.834158° N	309.5	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AU	Resident 47	-95.544746° E	44.825700° N	319.2	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AV	Substation-OfficeShop	-95.552901° E	44.827202° N	313.1	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AW	Swensen-Farm-Museum	-95.592478° E	44.878552° N	319.2	2.0	1.5	1.0	0.0	90.0	"Green house mode"

Calculation Results

Shadow receptor

No.	Name	Shadow, expected values: Shadow hours per year [h/year]
A	Resident 01	0:00

To be continued on next page...

SHADOW - Main Result

Calculation: 180214 Realistic Case - 80m + 90m HH Turbines

...continued from previous page

Shadow, expected values

No.	Name	Shadow hours per year [h/year]
B	Resident 02	0:00
C	Resident 03	0:00
D	Resident 04	0:00
E	Resident 05	10:33
F	Resident 06	10:15
G	Resident 07	12:32
H	Resident 08	23:41
I	Resident 09	11:25
J	Resident 10	1:24
K	Resident 11	0:00
L	Resident 12	0:00
M	Resident 13	8:10
N	Resident 14	0:00
O	Resident 15	14:05
P	Resident 16	1:18
Q	Resident 17	0:43
R	Resident 18	0:39
S	Resident 19	0:53
T	Resident 20	3:25
U	Resident 21	4:38
V	Resident 22	7:00
W	Resident 23	0:58
X	Resident 24	2:38
Y	Resident 25	21:02
Z	Resident 26	19:03
AA	Resident 27	0:00
AB	Resident 28	6:39
AC	Resident 29	2:21
AD	Resident 30	5:28
AE	Resident 31	39:28
AF	Resident 32	12:32
AG	Resident 33	9:51
AH	Resident 34	26:58
AI	Resident 35	6:02
AJ	Resident 36	53:08
AK	Resident 37	9:37
AL	Resident 38	16:41
AM	Resident 39	31:57
AN	Resident 40	11:12
AO	Resident 41	24:20
AP	Resident 42	37:14
AQ	Resident 43	2:54
AR	Resident 44	7:28
AS	Resident 45	0:45
AT	Resident 46	0:41
AU	Resident 47	0:00
AV	Substation-OfficeShop	0:00
AW	Swensen-Farm-Museum	5:02

Total amount of flickering on the shadow receptors caused by each WTG

No.	Name	Worst case [h/year]	Expected [h/year]
1	WTG 14 - GE 2.3-116 80m HH	73:47	26:07
2	WTG 15 - GE 2.3-116 80m HH	119:22	46:03
3	WTG 18	155:50	49:34
4	WTG 17	58:31	13:15
5	WTG 16	6:48	2:17

To be continued on next page...

SHADOW - Main Result

Calculation: 180214 Realistic Case - 80m + 90m HH Turbines

...continued from previous page

No.	Name	Worst case [h/year]	Expected [h/year]
6	WTG 13	174:28	55:27
7	WTG 12	198:49	50:32
8	WTG 11	7:13	2:46
9	WTG 10	11:27	5:02
10	WTG 09	21:41	7:49
11	WTG 08	170:56	60:31
12	WTG 07	25:05	6:01
13	WTG 06	45:55	9:38
14	WTG 05	107:14	22:09
15	WTG 04	58:38	19:55
16	WTG 03	45:13	15:53
17	WTG 01	41:39	18:06
18	WTG 02	145:47	37:06

Project:
Palmers Creek Wind Farm

Description:
Mike Rutledge
Environmental Services Dept. Head
FAGEN ENGINEERING, LLC
P.O. Box 159
Granite Falls, MN 56241
320-564-3324 Main
320-564-2625 Direct
320-564-4861 Fax

Licensed user:
EAPC Wind Energy
3100 DeMers Avenue
US-GRAND FORKS, ND 58201
+1 701 775 3000
Nicholas Laskovski / n.laskovski@eapcwindenergy.com
Calculated:
2/16/2018 10:07 AM/3.0.654

SHADOW - Main Result

Calculation: 180214 Realistic Case - 80m + 94m HH Turbines

Assumptions for shadow calculations

Maximum distance for influence
Calculate only when more than 20 % of sun is covered by the blade
Please look in WTG table

Minimum sun height over horizon for influence	3 °
Day step for calculation	1 days
Time step for calculation	1 minutes

Sunshine probability S (Average daily sunshine hours) [MADISON]

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
4.43	5.24	5.95	7.01	8.58	9.67	9.71	8.48	7.21	5.48	3.66	3.19

Operational hours are calculated from WTGs in calculation and wind distribution:
Palmers 80m Met

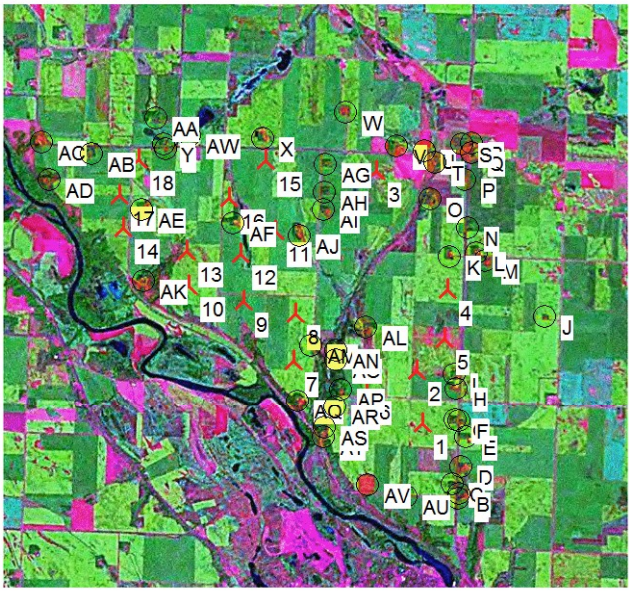
Operational time

N	NNE	ENE	E	ESE	SSE	S	SSW	WSW	W	WNW	NNW	Sum
531	302	302	398	613	1,537	1,191	405	335	545	957	1,400	8,516

Idle start wind speed: Cut in wind speed from power curve

A ZVI (Zones of Visual Influence) calculation is performed before flicker calculation so non visible WTG do not contribute to calculated flicker values. A WTG will be visible if it is visible from any part of the receiver window. The ZVI calculation is based on the following assumptions:
Height contours used: Project Wizard Elevation Data Grid (US NED 1/3 arc-secon
Obstacles used in calculation
Eye height: 1.5 m
Grid resolution: 10.0 m

All coordinates are in
Geo [deg]-WGS84



Scale 1:125,000

New WTG Shadow receptor

WTGs

	Longitude	Latitude	Z	Row data/Description	WTG type Valid	Manufact.	Type-generator	Power, rated	Rotor diameter	Hub height	Shadow data Calculation distance	RPM
			[m]					[kW]	[m]	[m]	[m]	[RPM]
1	-95.541662° E	44.836622° N	313.0	WTG 14 - GE 2.3-11...	Yes	GE WIND ENERGY	GE 2.3-116-2,300	2,300	116.0	80.0	1,732	15.7
2	-95.543356° E	44.844631° N	314.6	WTG 15 - GE 2.3-11...	Yes	GE WIND ENERGY	GE 2.3-116-2,300	2,300	116.0	80.0	1,732	15.7
3	-95.553051° E	44.874103° N	317.6	WTG 18	Yes	GE WIND ENERGY	GE 2.5-116-2,500	2,500	116.0	94.0	1,732	15.7
4	-95.537478° E	44.856906° N	317.7	WTG 17	Yes	GE WIND ENERGY	GE 2.5-116-2,500	2,500	116.0	94.0	1,732	15.7
5	-95.537703° E	44.849525° N	315.7	WTG 16	Yes	GE WIND ENERGY	GE 2.5-116-2,500	2,500	116.0	94.0	1,732	15.7
6	-95.553758° E	44.841564° N	316.5	WTG 13	Yes	GE WIND ENERGY	GE 2.5-116-2,500	2,500	116.0	94.0	1,732	15.7
7	-95.569200° E	44.845481° N	311.8	WTG 12	Yes	GE WIND ENERGY	GE 2.5-116-2,500	2,500	116.0	94.0	1,732	15.7
8	-95.569217° E	44.852581° N	315.1	WTG 11	Yes	GE WIND ENERGY	GE 2.5-116-2,500	2,500	116.0	94.0	1,732	15.7
9	-95.580089° E	44.854156° N	311.2	WTG 10	Yes	GE WIND ENERGY	GE 2.5-116-2,500	2,500	116.0	94.0	1,732	15.7
10	-95.591775° E	44.856100° N	315.7	WTG 09	Yes	GE WIND ENERGY	GE 2.5-116-2,500	2,500	116.0	94.0	1,732	15.7
11	-95.573914° E	44.864814° N	315.8	WTG 08	Yes	GE WIND ENERGY	GE 2.5-116-2,500	2,500	116.0	94.0	1,732	15.7
12	-95.581006° E	44.861153° N	316.1	WTG 07	Yes	GE WIND ENERGY	GE 2.5-116-2,500	2,500	116.0	94.0	1,732	15.7
13	-95.592361° E	44.861344° N	319.4	WTG 06	Yes	GE WIND ENERGY	GE 2.5-116-2,500	2,500	116.0	94.0	1,732	15.7
14	-95.605892° E	44.864522° N	315.1	WTG 05	Yes	GE WIND ENERGY	GE 2.5-116-2,500	2,500	116.0	94.0	1,732	15.7
15	-95.576389° E	44.875264° N	315.5	WTG 04	Yes	GE WIND ENERGY	GE 2.5-116-2,500	2,500	116.0	94.0	1,732	15.7
16	-95.583828° E	44.869392° N	318.6	WTG 03	Yes	GE WIND ENERGY	GE 2.5-116-2,500	2,500	116.0	94.0	1,732	15.7
17	-95.606875° E	44.869294° N	315.7	WTG 01	Yes	GE WIND ENERGY	GE 2.5-116-2,500	2,500	116.0	94.0	1,732	15.7
18	-95.603139° E	44.874661° N	312.2	WTG 02	Yes	GE WIND ENERGY	GE 2.5-116-2,500	2,500	116.0	94.0	1,732	15.7

SHADOW - Main Result

Calculation: 180214 Realistic Case - 80m + 94m HH Turbines

Shadow receptor-Input

No.	Name	Longitude	Latitude	Z [m]	Width [m]	Height [m]	Height a.g.l. [m]	Degrees from south cw [°]	Slope of window [°]	Direction mode
A	Resident 01	-95.533842° E	44.825638° N	319.3	2.0	1.5	1.0	0.0	90.0	"Green house mode"
B	Resident 02	-95.533704° E	44.826359° N	318.5	2.0	1.5	1.0	0.0	90.0	"Green house mode"
C	Resident 03	-95.534989° E	44.827696° N	317.9	2.0	1.5	1.0	0.0	90.0	"Green house mode"
D	Resident 04	-95.533451° E	44.830307° N	317.9	2.0	1.5	1.0	0.0	90.0	"Green house mode"
E	Resident 05	-95.532683° E	44.834853° N	319.8	2.0	1.5	1.0	0.0	90.0	"Green house mode"
F	Resident 06	-95.534019° E	44.837284° N	321.1	2.0	1.5	1.0	0.0	90.0	"Green house mode"
G	Resident 07	-95.534825° E	44.837363° N	322.5	2.0	1.5	1.0	0.0	90.0	"Green house mode"
H	Resident 08	-95.534954° E	44.842124° N	318.1	2.0	1.5	1.0	0.0	90.0	"Green house mode"
I	Resident 09	-95.535337° E	44.844227° N	319.2	2.0	1.5	1.0	0.0	90.0	"Green house mode"
J	Resident 10	-95.516886° E	44.853297° N	321.2	2.0	1.5	1.0	0.0	90.0	"Green house mode"
K	Resident 11	-95.537188° E	44.861760° N	319.8	2.0	1.5	1.0	0.0	90.0	"Green house mode"
L	Resident 12	-95.531666° E	44.862421° N	318.0	2.0	1.5	1.0	0.0	90.0	"Green house mode"
M	Resident 13	-95.529807° E	44.861382° N	318.6	2.0	1.5	1.0	0.0	90.0	"Green house mode"
N	Resident 14	-95.533598° E	44.866156° N	319.5	2.0	1.5	1.0	0.0	90.0	"Green house mode"
O	Resident 15	-95.541625° E	44.870285° N	316.8	2.0	1.5	1.0	0.0	90.0	"Green house mode"
P	Resident 16	-95.534581° E	44.873292° N	318.3	2.0	1.5	1.0	0.0	90.0	"Green house mode"
Q	Resident 17	-95.533334° E	44.877298° N	317.7	2.0	1.5	1.0	0.0	90.0	"Green house mode"
R	Resident 18	-95.533434° E	44.878708° N	318.7	2.0	1.5	1.0	0.0	90.0	"Green house mode"
S	Resident 19	-95.535326° E	44.878631° N	320.9	2.0	1.5	1.0	0.0	90.0	"Green house mode"
T	Resident 20	-95.540947° E	44.875754° N	313.6	2.0	1.5	1.0	0.0	90.0	"Green house mode"
U	Resident 21	-95.543273° E	44.877427° N	312.7	2.0	1.5	1.0	0.0	90.0	"Green house mode"
V	Resident 22	-95.549112° E	44.877963° N	313.6	2.0	1.5	1.0	0.0	90.0	"Green house mode"
W	Resident 23	-95.559915° E	44.882819° N	319.5	2.0	1.5	1.0	0.0	90.0	"Green house mode"
X	Resident 24	-95.577203° E	44.878542° N	316.3	2.0	1.5	1.0	0.0	90.0	"Green house mode"
Y	Resident 25	-95.597991° E	44.877208° N	318.1	2.0	1.5	1.0	0.0	90.0	"Green house mode"
Z	Resident 26	-95.597527° E	44.876494° N	317.5	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AA	Resident 27	-95.599588° E	44.880968° N	317.5	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AB	Resident 28	-95.612918° E	44.875402° N	315.9	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AC	Resident 29	-95.623577° E	44.876903° N	317.5	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AD	Resident 30	-95.621627° E	44.871308° N	315.3	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AE	Resident 31	-95.602094° E	44.867319° N	318.2	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AF	Resident 32	-95.582822° E	44.865745° N	319.9	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AG	Resident 33	-95.563933° E	44.874963° N	316.9	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AH	Resident 34	-95.563925° E	44.870771° N	315.1	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AI	Resident 35	-95.563889° E	44.868106° N	317.4	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AJ	Resident 36	-95.568776° E	44.864178° N	316.4	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AK	Resident 37	-95.601147° E	44.856727° N	308.7	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AL	Resident 38	-95.554238° E	44.850846° N	314.7	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AM	Resident 39	-95.565658° E	44.847905° N	311.4	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AN	Resident 40	-95.560488° E	44.847249° N	307.3	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AO	Resident 41	-95.560249° E	44.845851° N	311.1	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AP	Resident 42	-95.559105° E	44.841427° N	318.2	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AQ	Resident 43	-95.568088° E	44.839398° N	310.7	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AR	Resident 44	-95.560323° E	44.838731° N	315.8	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AS	Resident 45	-95.562243° E	44.835534° N	309.2	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AT	Resident 46	-95.562369° E	44.834158° N	309.5	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AU	Resident 47	-95.544746° E	44.825700° N	319.2	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AV	Substation-OfficeShop	-95.552901° E	44.827202° N	313.1	2.0	1.5	1.0	0.0	90.0	"Green house mode"
AW	Swensen-Farm-Museum	-95.592478° E	44.878552° N	319.2	2.0	1.5	1.0	0.0	90.0	"Green house mode"

Calculation Results

Shadow receptor

No.	Name	Shadow, expected values Shadow hours per year [h/year]
A	Resident 01	0:00

To be continued on next page...

SHADOW - Main Result

Calculation: 180214 Realistic Case - 80m + 94m HH Turbines

...continued from previous page

No.	Name	Shadow, expected values Shadow hours per year [h/year]
B	Resident 02	0:00
C	Resident 03	0:00
D	Resident 04	0:00
E	Resident 05	10:34
F	Resident 06	10:22
G	Resident 07	12:40
H	Resident 08	23:47
I	Resident 09	11:29
J	Resident 10	1:33
K	Resident 11	0:00
L	Resident 12	0:00
M	Resident 13	8:21
N	Resident 14	0:00
O	Resident 15	14:23
P	Resident 16	1:22
Q	Resident 17	0:46
R	Resident 18	0:43
S	Resident 19	0:57
T	Resident 20	3:31
U	Resident 21	4:46
V	Resident 22	7:43
W	Resident 23	1:04
X	Resident 24	4:54
Y	Resident 25	20:53
Z	Resident 26	19:15
AA	Resident 27	0:00
AB	Resident 28	6:52
AC	Resident 29	2:30
AD	Resident 30	5:48
AE	Resident 31	37:59
AF	Resident 32	12:51
AG	Resident 33	10:13
AH	Resident 34	27:56
AI	Resident 35	6:19
AJ	Resident 36	56:38
AK	Resident 37	9:47
AL	Resident 38	17:19
AM	Resident 39	32:26
AN	Resident 40	12:13
AO	Resident 41	24:55
AP	Resident 42	37:30
AQ	Resident 43	3:03
AR	Resident 44	6:42
AS	Resident 45	0:45
AT	Resident 46	0:41
AU	Resident 47	0:00
AV	Substation-OfficeShop	0:00
AW	Swensen-Farm-Museum	5:17

Total amount of flickering on the shadow receptors caused by each WTG

No.	Name	Worst case [h/year]	Expected [h/year]
1	WTG 14 - GE 2.3-116 80m HH	73:47	26:09
2	WTG 15 - GE 2.3-116 80m HH	119:22	46:08
3	WTG 18	163:16	51:42
4	WTG 17	60:38	13:52
5	WTG 16	7:16	2:27

To be continued on next page...

SHADOW - Main Result

Calculation: 180214 Realistic Case - 80m + 94m HH Turbines

...continued from previous page

No.	Name	Worst case [h/year]	Expected [h/year]
6	WTG 13	176:49	56:18
7	WTG 12	200:14	51:11
8	WTG 11	7:31	2:53
9	WTG 10	12:16	5:24
10	WTG 09	21:38	7:49
11	WTG 08	178:49	63:51
12	WTG 07	26:45	6:25
13	WTG 06	47:17	9:58
14	WTG 05	109:17	22:45
15	WTG 04	69:14	22:49
16	WTG 03	48:31	17:09
17	WTG 01	36:51	15:48
18	WTG 02	144:46	37:06