Shadow Flicker Analysis

Prevailing Winds, LLC

Prevailing Winds Wind Farm
Project No. 91343

Revision 2
06/28/2016

Shadow Flicker Analysis

prepared for

Prevailing Winds, LLC
Prevailing Winds Wind Farm
Bon Homme and Charles Mix Counties, South Dakota

Project No. 91343

Revision 2
06/28/2016

prepared by

Burns & McDonnell Engineering Company, Inc.
Kansas City, Missouri

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LIST OF ABBREVIATIONS

Abbreviation	Term/Phrase/Name
Burns & McDonnell	Burns & McDonnell Engineering Company, Inc.
Client	Prevailing Winds, LLC
DEM	Digital elevation model
GE	General Electric
kg/m^3	Kilograms per cubic meter
m/s	Meters per second
Owner	Prevailing Winds, LLC
Project	Prevailing Winds Wind Farm
Project Site	Prevailing Winds Wind Farm in Bon Homme and Charles Mix Counties
Study	Shadow Flicker Analysis

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REVISION HISTORY

Rev	Issue Date	Release Notes
0	16-June-2016	Original release.
1	20-June-2016	Incorporated client comments.
2	28-June-2016	Adjusted turbine layout and incorporated client comments.

1.0 INTRODUCTION

1.1 Study Overview

Burns & McDonnell Engineering Company, Inc. ("Burns & McDonnell") was retained by Prevailing Winds, LLC (the "Owner") to conduct a shadow flicker analysis (the "Study") for the proposed Prevailing Winds Wind Farm (the "Project"). The objective of the Study was to estimate the annual frequency of shadow flicker on occupied residences caused by Project wind turbines. No attempt was made in this Study to examine or opine on health effects related to shadow flicker.

1.2 Project Overview

The proposed Prevailing Winds Wind Farm will be located in Bon Homme and Charles Mix Counties in South Dakota, approximately 10 miles east of the town of Wagner and approximately 75 miles southwest of the city of Sioux Falls (the "Project Site"). The Project may include up to 100 turbines with an aggregate nameplate capacity of up to 200.1 megawatts. For purposes of this Study, Owner provided a hypothetical layout consisting of 87 General Electric ("GE") 2.3-116 wind turbine generators.

A map showing the general location and configuration of the Project Site is included as Appendix A.

1.3 Shadow Flicker Overview

Shadow flicker occurs when wind turbine blades pass in front of the sun to create recurring shadows on an object. Such shadows occur only under very specific conditions, including sun position, wind direction, time of day, and other similar factors.

The intensity of shadow flicker varies significantly with distance, and as separation between a turbine and receptor increases, shadow flicker intensity correspondingly diminishes. Shadow flicker intensity for distances greater than 10 rotor diameters (i.e., 1,160 meters for the Project) is generally low and considered imperceptible. At such distances, shadow flicker is typically only caused at sunrise or sunset, when cast shadows are sufficiently long.

Shadow flicker impacts are not currently regulated in applicable state or federal law, nor are there requirements in the current Charles Mix County (SD) ordinances. However, Bon Homme County (SD) ordinances limit shadow flicker on a specific residence to a maximum of 30 minutes per day or 30 hours per year at perceivable shadow flicker intensity. Thus, although the Project turbines fall within both Charles Mix and Bon Homme Counties, the existing Bon Homme County requirements were used as a baseline for this Study.

2.0 MODELING PARAMETERS AND INPUTS

2.1 Modeling Overview

Shadow flicker was modeled at the Project Site using WindPRO, an industry-leading software package for the design and planning of wind energy projects. This package models the sun's path with respect to every turbine location during every minute over a complete year. Any shadow flicker caused by each turbine is then aggregated for each receptor for the entire year.

The following sections are summaries of the inputs utilized in the WindPRO model for this Study.

2.2 Turbine Coordinates

Shadow flicker intensity is partially dependent upon the distance from a receptor to the turbine causing the shadow. The location of each turbine at the Project Site was provided by Owner and modeled accordingly.

2.3 Turbine Dimensions

The size of a wind turbine, including both hub height and rotor diameter, contributes to the length and width of the shadows that may be cast by that turbine. The GE 2.3-116 wind turbine generators were each modeled with a rotor diameter of 116 meters and a hub height of 80 meters.

2.4 Receptors

A quantity of 135 occupied residences were modeled at the Project Site. The coordinates for these receptors were provided by Owner; the physical location of each was subsequently verified by Burns & McDonnell using aerial imagery. The coordinates of each receptor are presented in Appendix B, and the location of each receptor is presented graphically in Appendix A.

Each receptor was modeled in "green house" mode within the WindPRO model. This conservative approach provides a worst-case estimate of the amount of time when shadow flicker could occur by modeling each receptor as having windows on all sides and effectively causing the home to be susceptible to flicker effects in all directions.

2.5 Terrain

The WindPRO model utilizes topography data to place turbines and receptors at the proper elevations. This information is also used by the model to consider any natural land features between a turbine and a receptor that may block shadows from being seen at a receptor.

Publically-available terrain data was downloaded from the National Elevation Dataset, a product of the United States Geological Survey. The 10-meter resolution digital elevation model ("DEM") was exported at 10-foot intervals for use in the WindPRO model. Elevations were assigned by Burns & McDonnell to each turbine and each receptor using this data.

2.6 Obstacles

Obstacles located between a receptor and a turbine, such as trees or buildings, may significantly reduce or eliminate the duration and/or intensity of shadow flicker. However, because Burns & McDonnell did not visit the Project Site as part of this Study and could not make in-person observations regarding the size or influence of obstacles, no attempt was made to model the presence of potential obstacles. This approach also provides the most conservative estimate of the amount of time when shadow flicker could occur.

2.7 Turbine Operation

Shadow flicker is contingent upon the movement of the turbine blades. Shadow flicker can only occur when the turbine is in operation (i.e., when the turbine blades are rotating). Moreover, shadow flicker is generally most notable when a turbine is facing a receptor, as this results in the widest-possible shadow being cast. To more accurately reflect the periods of operation of each Project wind turbine, on-site wind data provided by Owner was used to indicate the periods when the turbines are inactive due to wind speeds below the turbine cut-in speed or above the turbine cut-out speed, at which time the turbine rotor is not in motion and no shadow flicker will occur.

Project Site-specific wind data was also utilized to model the actual orientation of the turbines relative to each receptor. The Owner-provided wind data includes data collected by an on-site meteorological mast between August 2009 and April 2016. The provided on-site wind speed and direction data is shown in Appendix C.

A power curve for the GE 2.3-116 was provided by Owner showing a cut-in speed of 3.0 meters per second ("m/s") and a cut-out speed of 25.0 m/s. This power curve was added to the WindPRO model to more accurately reflect the turbine's operational characteristics. The Owner-provided power curve is shown in Appendix E.

Collectively, the power curve and the met mast data were used to determine the occurrence of shadow flicker caused by each turbine relative to the operating conditions of the turbine and the wind details observed at the Project Site.

2.8 Flicker Relevance

At distances beyond 10 rotor diameters (i.e., 1,160 meters for the Project), shadow flicker effects are generally considered low, as shadows diffuse and become imperceptible. Thus, a distance of 1,160 meters was modeled as the maximum distance at which shadow flicker was considered relevant; turbines greater than this distance from a given receptor were not evaluated. The proximity of this buffer relative to each receptor is presented graphically in Appendix A.

2.9 Sun Angle

The sun's path with respect to each turbine location is calculated by the WindPRO model to determine the cast shadow paths during every minute over a complete year. However, at very low sun angles, the light must pass through more atmosphere and becomes too diffused to form a coherent shadow. Thus, a value of three (3) degrees was utilized for the height at which the sun would not cause noticeable flicker.

2.10 Environment

Shadow flicker is only caused when the sun is shining. Sunshine probability data (see Appendix D) was obtained by Burns & McDonnell from www.city-data.com. This data represents the percentage of hours each month that the sun is expected to be shining during daylight hours, with consideration given for cloud cover, rainy days, fog, or other similar occurrences that may diminish the potential occurrence or severity of shadow flicker.

3.0 RESULTS

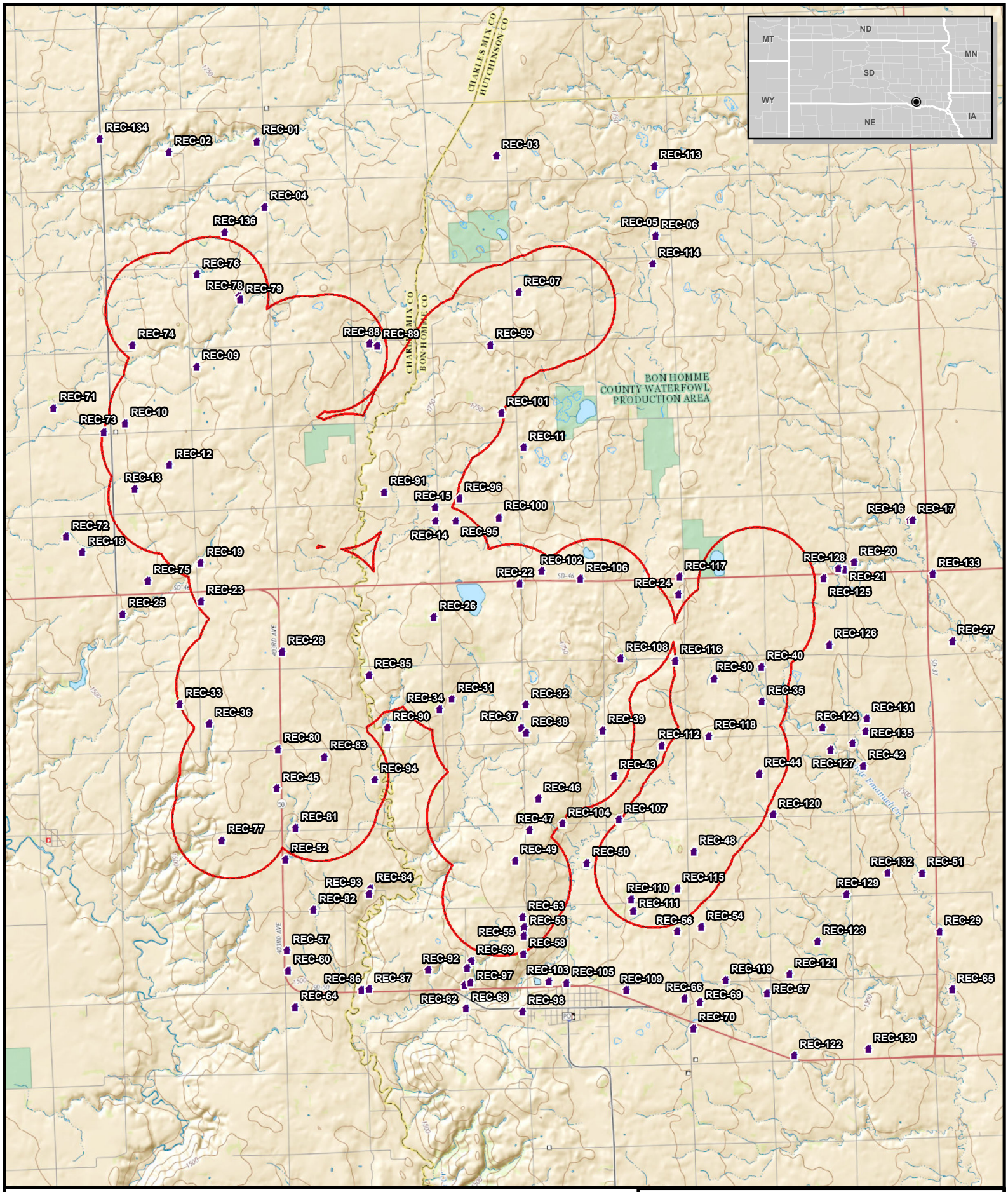
Using the inputs and parameters defined in Section 2.0, the WindPRO model was used to calculate shadow flicker for the receptors at the Project Site. Of the 135 known receptors that were modeled at the Project Site, 36 were observed to experience some duration of shadow flicker over the course of a year.

Appendix F presents the estimated shadow flicker results by occupied residence, including annual and daily results. Table F-1 and Table F-2 present estimated hours per year of shadow flicker by occupied residence, sorted by receptor name and total flicker time, respectively. Table F-3 and Table F-4 present maximum estimated minutes per day of shadow flicker by occupied residence, sorted by receptor name and total flicker time, respectively.

The following is a set of key observations from the results of the Study:

- 36 of the 135 known receptors were observed to experience shadow flicker over the course of a year.
- 2 of the 135 known receptors exceed the Bon Homme County limitation of up to 30 hours per year of shadow flicker on a specific residence, and 21 of the 135 known receptors exceed the Bon Homme County limitation of up to 30 minutes per day of shadow flicker on a specific residence.
- Receptor REC-32 is observed to have the most flicker with approximately 34 hours per year and up to 53 minutes in a given day.
- The majority of observed shadow flicker on each residence occurs during early morning and/or late afternoon and evening hours (see Appendix G). As a result, the intensity of flicker at these times is expected to be reduced.
- The Study was performed using a conservative modeling approach with Project Site-specific conditions. For example, the Study modeled each receptor as a “green house”, meaning each receptor was modeled as having windows on all sides and effectively causing the home to be susceptible to flicker effects in all directions. Further, the Project Site was modeled as if no obstacles were present, including trees or buildings, which may significantly reduce or eliminate the duration and/or intensity of shadow flicker at a receptor. Due to the conservative approach of the Study, the actual duration and intensity of shadow flicker experienced at each receptor is expected to be less than those reported in the Study.
- A flicker-related curtailment strategy was not considered. Many wind turbine manufacturers offer software to mitigate flicker by curtailing turbines during known periods of casting shadows. While this strategy was not considered for the Project, it may alleviate excessive flicker.

APPENDIX A - PROJECT SITE LAYOUT



LEGEND

- Occupied Residence
- Turbine Buffer (1160m)

REFERENCE

0 1 2 MILES

0 1 2 KILOMETERS

N

PREVAILING WINDS WIND FARM
Project Site Layout

LOCATION:	Charlex Mix and Bon Homme Counties, SD
CLIENT:	Prevailing Winds, LLC
PROJ. NO.:	91343
CREATED:	06/27/2016

BURNS McDONNELL
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Path: Z:\Clients\ESP\PrevailingWi\91343_Permitting\Studies\Geospatial\DataFiles\ArcDocs\91343_PrevailingWinds_Flicker_85x11P.mxd • Coordinate System: NAD 1983 StatePlane South Dakota South FIPS 4002 Feet • Units: Foot US

APPENDIX B - INFRASTRUCTURE COORDINATES

Table B-1: Receptor Coordinates

Receptor ID	Easting [m]	Northing [m]
REC-01	570,706	4,779,233
REC-02	568,955	4,779,050
REC-03	575,451	4,778,870
REC-04	570,834	4,777,924
REC-05	578,568	4,777,265
REC-06	578,579	4,777,228
REC-07	575,848	4,776,146
REC-08	Not Used	
REC-09	569,438	4,774,776
REC-10	568,000	4,773,684
REC-11	575,894	4,773,069
REC-12	568,870	4,772,838
REC-13	568,171	4,772,373
REC-14	574,123	4,771,642
REC-15	574,118	4,771,913
REC-16	583,527	4,771,509
REC-17	583,583	4,771,512
REC-18	567,115	4,771,132
REC-19	569,456	4,770,886
REC-20	582,410	4,770,691
REC-21	582,206	4,770,538
REC-22	575,769	4,770,370
REC-23	569,451	4,770,123
REC-24	578,916	4,770,107
REC-25	567,890	4,769,897
REC-26	574,058	4,769,738
REC-27	584,331	4,769,093
REC-28	571,038	4,769,100
REC-29	583,981	4,763,336
REC-30	579,595	4,768,434
REC-31	574,388	4,768,112
REC-32	575,857	4,767,969
REC-33	568,988	4,768,088
REC-34	574,140	4,767,903
REC-35	580,535	4,767,956
REC-36	569,571	4,767,694
REC-37	575,754	4,767,512
REC-38	575,854	4,767,409
REC-39	577,366	4,767,429
REC-40	580,535	4,768,650
REC-41	582,314	4,767,105
REC-42	582,518	4,766,647
REC-43	577,582	4,766,535
REC-44	580,460	4,766,528
REC-45	570,892	4,766,384
REC-46	576,072	4,766,099
REC-47	575,888	4,765,484
REC-48	579,136	4,765,004
REC-49	575,594	4,764,878
REC-50	577,015	4,764,806
REC-51	583,652	4,764,504
REC-52	571,035	4,764,976
REC-53	575,752	4,763,554
REC-54	579,261	4,763,509
REC-55	575,738	4,763,383
REC-56	578,784	4,763,423
REC-57	571,041	4,763,173
REC-58	575,729	4,763,021
REC-59	574,690	4,762,906
REC-60	571,059	4,762,772
REC-61	574,609	4,762,765
REC-62	574,556	4,762,431
REC-63	575,719	4,763,759
REC-64	571,187	4,762,047
REC-65	584,215	4,762,181
REC-66	578,907	4,762,093
REC-67	580,541	4,762,169
REC-68	574,569	4,761,969
REC-69	579,207	4,762,012
REC-70	579,069	4,761,501
REC-71	566,590	4,774,005
REC-72	566,795	4,771,446
REC-73	567,576	4,773,523
REC-74	568,170	4,775,222
REC-75	568,402	4,770,548
REC-76	569,475	4,776,605
REC-77	569,782	4,765,374
REC-78	570,301	4,776,152
REC-79	570,321	4,776,086
REC-80	570,931	4,767,169
REC-81	571,247	4,765,598
REC-82	571,575	4,763,967
REC-83	571,848	4,767,001
REC-84	572,712	4,764,371
REC-85	572,760	4,768,610
REC-86	572,501	4,762,365
REC-87	572,660	4,762,376
REC-88	572,875	4,775,184
REC-89	573,024	4,775,138
REC-90	573,104	4,767,559
REC-91	573,114	4,772,228
REC-92	573,830	4,762,742
REC-93	572,690	4,764,270
REC-94	572,840	4,766,532
REC-95	574,527	4,771,635
REC-96	574,606	4,772,084
REC-97	574,672	4,762,479
REC-98	575,690	4,761,883
REC-99	575,265	4,775,117
REC-100	575,384	4,771,696
REC-101	575,460	4,773,772
REC-102	576,210	4,770,611
REC-103	576,224	4,762,475
REC-104	576,538	4,765,598
REC-105	576,568	4,762,434
REC-106	576,971	4,770,447
REC-107	577,660	4,765,661
REC-108	577,747	4,768,860
REC-109	577,752	4,762,281
REC-110	577,878	4,764,079
REC-111	577,916	4,763,844

Table B-2: Receptor Coordinates [Cont.]

Receptor ID	Easting [m]	Northing [m]
REC-112	578,532	4,767,119
REC-113	578,576	4,778,619
REC-114	578,515	4,776,677
REC-115	578,804	4,764,275
REC-116	578,828	4,768,793
REC-117	578,943	4,770,455
REC-118	579,475	4,767,289
REC-119	579,721	4,762,442
REC-120	580,720	4,765,706
REC-121	580,992	4,762,541
REC-122	581,062	4,760,924
REC-123	581,560	4,763,175
REC-124	581,721	4,767,420
REC-125	581,794	4,770,381
REC-126	581,891	4,769,063
REC-127	581,883	4,766,984
REC-128	582,090	4,770,568
REC-129	582,148	4,764,102
REC-130	582,530	4,761,029
REC-131	582,610	4,767,583
REC-132	582,971	4,764,520
REC-133	583,963	4,770,430
REC-134	567,589	4,779,328
REC-135	582,578	4,767,332
REC-136	570,034	4,777,429

Notes:
[1] All coordinates presented in UTM NAD83 Zone 14 (meters)
[2] All turbine coordinates provided by Owner via "Prevailing Winds 6-23-16 GE-2.3 Shadow Flicker Array V1.xlsx"
[3] All receptor coordinates provided by Owner via “PW_OCCUPIED_FV_05-03-2016.xlsx”

APPENDIX C - ON-SITE FREQUENCY DISTRIBUTION

Table C-1: Onsite Frequency Distribution

Bin	Wind Direction [degrees]											
[m/s]	0	30	60	90	120	150	180	210	240	270	300	330
0	0.54	0.51	0.57	0.48	0.63	0.63	0.61	0.57	0.48	0.51	0.70	0.54
1	1.69	1.73	1.64	1.63	1.87	1.50	1.47	1.46	1.47	1.42	1.75	1.42
2	2.87	2.95	3.86	3.48	3.69	3.17	2.90	2.87	2.79	3.10	3.44	2.84
3	4.41	4.67	5.12	5.16	5.95	5.21	4.53	4.50	4.01	4.14	4.61	4.75
4	6.22	5.70	5.33	5.95	7.93	7.92	6.17	5.61	5.10	4.94	6.50	6.94
5	8.15	6.22	5.61	6.53	9.28	10.24	7.79	6.68	5.57	5.07	8.49	9.28
6	9.46	5.94	5.02	6.27	10.49	11.82	9.96	7.52	5.91	5.63	10.10	11.70
7	9.85	5.82	4.87	5.94	10.58	13.08	13.09	9.24	6.78	5.35	11.34	13.61
8	9.65	5.63	3.76	5.30	9.57	14.35	16.33	9.65	6.74	5.20	13.95	14.89
9	8.64	4.37	3.13	4.27	7.80	14.22	18.54	9.84	4.97	4.22	13.56	15.37
10	7.32	3.37	2.05	2.53	5.38	11.36	17.49	9.33	3.06	3.14	12.06	13.79
11	5.92	2.65	1.26	1.31	3.25	7.89	13.95	7.39	1.73	2.26	9.64	10.75
12	4.14	1.55	0.66	1.08	1.82	4.93	8.60	4.25	0.66	1.44	7.66	7.74
13	2.70	0.99	0.48	0.62	1.05	2.51	4.78	2.13	0.20	0.84	5.61	5.83
14	1.71	0.67	0.29	0.23	0.69	1.02	2.68	0.97	0.09	0.52	3.96	4.53
15	0.88	0.48	0.15	0.20	0.41	0.51	1.55	0.39	0.06	0.39	3.13	3.63
16	0.53	0.27	0.05	0.11	0.22	0.32	0.76	0.18	0.05	0.25	2.37	2.67
17	0.40	0.16	0.03	0.05	0.12	0.15	0.47	0.06	0.03	0.16	1.61	2.06
18	0.15	0.10	0.01	0.03	0.09	0.13	0.22	0.02	0.02	0.11	1.39	1.30
19	0.06	0.02	0.00	0.01	0.05	0.06	0.13	0.02	0.01	0.10	0.92	0.93
20	0.02	0.01	0.00	0.01	0.02	0.04	0.10	0.01	0.00	0.05	0.64	0.61
21	0.01	0.00	0.00	0.01	0.01	0.01	0.06	0.00	0.00	0.03	0.35	0.35
22	0.02	0.00	0.00	0.00	0.00	0.00	0.02	0.01	0.00	0.03	0.23	0.20
23	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.15	0.07
24	0.01	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.05
25	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.01
26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.01
27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00
28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sum	**85.4**	**53.8**	**43.9**	**51.2**	**80.9**	**111.1**	**132.2**	**82.7**	**49.7**	**48.9**	**124.3**	**135.9**

Notes:
[1] All data provided by Owner via "Prevailing Winds-All 10-min Data-B.tab"
[2] All data presented in milles (sum = 1000) for period from August 2009 to April 2016.
[3] All data presented at 80 magl.

APPENDIX D - SUNSHINE PROBABILITY DATA

Figure D-1: Monthly Sunshine Probability for Wagner, SD

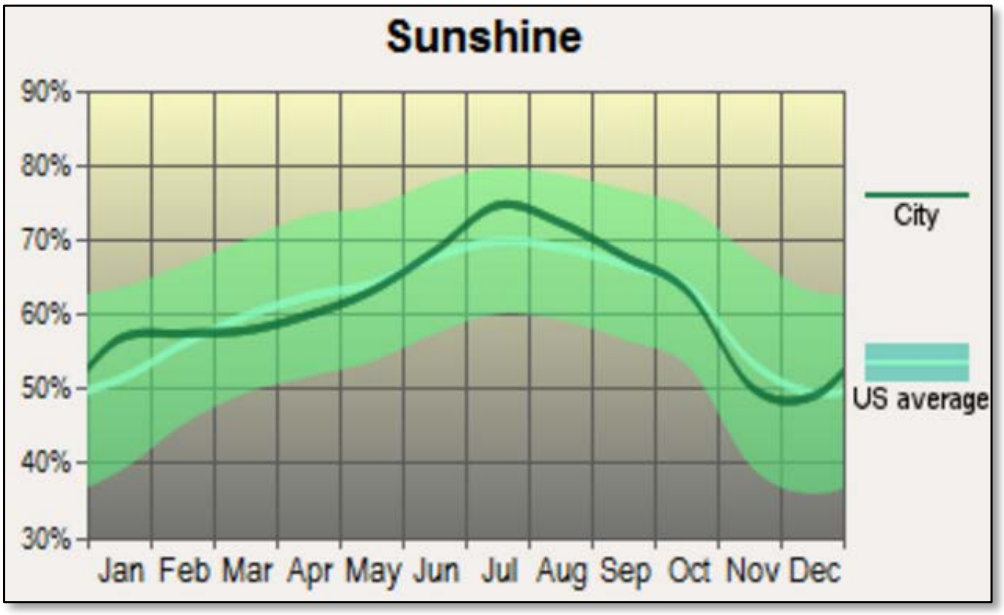

Table D-1: Monthly Sunshine Probability for Wagner, SD

Month	Avg Sunshine Probability
January	58%
February	58%
March	59%
April	60%
May	63%
June	69%
July	74%
August	72%
September	68%
October	65%
November	54%
December	50%

Notes:
[1] Data source: http://www.city-data.com/city/Wagner-South-Dakota.html
[2] Data location: Wagner, South Dakota
[3] Data in Table D-1 estimated from source data in Figure D-1

APPENDIX E - GE 2.3-116 POWER CURVE

Table E-1: GE 2.3-116 Power Curve Values

Wind Speed [m/s]	Power [kW]	Wind Speed [m/s]	Power [kW]
0.0	0	13.0	2,300
0.5	0	13.5	2,300
1.0	0	14.0	2,300
1.5	0	14.5	2,300
2.0	0	15.0	2,300
2.5	0	15.5	2,300
3.0	22	16.0	2,300
3.5	88	16.5	2,300
4.0	165	17.0	2,300
4.5	256	17.5	2,300
5.0	366	18.0	2,300
5.5	507	18.5	2,300
6.0	656	19.0	2,300
6.5	822	19.5	2,300
7.0	1,018	20.0	2,300
7.5	1,218	20.5	2,300
8.0	1,423	21.0	2,300
8.5	1,619	21.5	2,300
9.0	1,788	22.0	2,300
9.5	1,965	22.5	2,300
10.0	2,084	23.0	2,300
10.5	2,171	23.5	2,300
11.0	2,237	24.0	2,300
11.5	2,280	24.5	2,300
12.0	2,300	25.0	2,300
12.5	2,300		

Notes:
[1] Power curve for air density of 1.16 kg/m^3 and normal turbulence intensity.
[2] Values provided by Owner via "Power_Curve-NO_2 3-116-xxHz_1-2MW_EN_r01.pdf".

APPENDIX F - FLICKER RESULTS BY RECEPTOR

Table F-1: Hours per Year of Shadow Flicker (Sorted by Receptor ID)

Receptor ID	Flicker [hrs/yr]	Receptor ID	Flicker [hrs/yr]	Receptor ID	Flicker [hrs/yr]	Receptor ID	Flicker [hrs/yr]
REC-01	0.0	REC-35	6.9	REC-69	0.0	REC-103	0.0
REC-02	0.0	REC-36	0.0	REC-70	0.0	REC-104	0.0
REC-03	0.0	REC-37	24.8	REC-71	0.0	REC-105	0.0
REC-04	0.0	REC-38	19.5	REC-72	0.0	REC-106	0.0
REC-05	0.0	REC-39	23.5	REC-73	0.0	REC-107	0.0
REC-06	0.0	REC-40	6.5	REC-74	0.0	REC-108	14.2
REC-07	7.5	REC-41	0.0	REC-75	0.0	REC-109	0.0
REC-08	Not Used	REC-42	0.0	REC-76	0.0	REC-110	0.0
REC-09	3.1	REC-43	6.8	REC-77	0.0	REC-111	0.0
REC-10	14.9	REC-44	9.7	REC-78	14.7	REC-112	0.0
REC-11	0.0	REC-45	18.5	REC-79	15.3	REC-113	0.0
REC-12	3.6	REC-46	11.7	REC-80	31.4	REC-114	0.0
REC-13	5.6	REC-47	7.2	REC-81	0.0	REC-115	0.0
REC-14	0.0	REC-48	19.9	REC-82	0.0	REC-116	0.0
REC-15	0.0	REC-49	0.0	REC-83	0.0	REC-117	0.0
REC-16	0.0	REC-50	0.0	REC-84	0.0	REC-118	3.5
REC-17	0.0	REC-51	0.0	REC-85	7.7	REC-119	0.0
REC-18	0.0	REC-52	0.0	REC-86	0.0	REC-120	0.0
REC-19	9.8	REC-53	0.0	REC-87	0.0	REC-121	0.0
REC-20	0.0	REC-54	0.0	REC-88	4.3	REC-122	0.0
REC-21	0.0	REC-55	0.0	REC-89	3.1	REC-123	0.0
REC-22	0.0	REC-56	0.0	REC-90	0.0	REC-124	0.0
REC-23	4.9	REC-57	0.0	REC-91	12.6	REC-125	0.0
REC-24	0.0	REC-58	0.0	REC-92	0.0	REC-126	0.0
REC-25	0.0	REC-59	0.0	REC-93	0.0	REC-127	0.0
REC-26	22.0	REC-60	0.0	REC-94	7.9	REC-128	0.0
REC-27	0.0	REC-61	0.0	REC-95	0.0	REC-129	0.0
REC-28	19.6	REC-62	0.0	REC-96	0.0	REC-130	0.0
REC-29	0.0	REC-63	0.0	REC-97	0.0	REC-131	0.0
REC-30	0.0	REC-64	0.0	REC-98	0.0	REC-132	0.0
REC-31	8.7	REC-65	0.0	REC-99	23.9	REC-133	0.0
REC-32	33.7	REC-66	0.0	REC-100	0.0	REC-134	0.0
REC-33	4.8	REC-67	0.0	REC-101	13.0	REC-135	0.0
REC-34	6.3	REC-68	0.0	REC-102	0.0	REC-136	0.0

Table F-2: Hours per Year of Shadow Flicker (Sorted by Flicker Time)

Receptor ID	Flicker [hrs/yr]	Receptor ID	Flicker [hrs/yr]	Receptor ID	Flicker [hrs/yr]	Receptor ID	Flicker [hrs/yr]
REC-32	33.7	REC-09	3.1	REC-58	0.0	REC-102	0.0
REC-80	31.4	REC-89	3.1	REC-59	0.0	REC-103	0.0
REC-37	24.8	REC-01	0.0	REC-60	0.0	REC-104	0.0
REC-99	23.9	REC-02	0.0	REC-61	0.0	REC-105	0.0
REC-39	23.5	REC-03	0.0	REC-62	0.0	REC-106	0.0
REC-26	22.0	REC-04	0.0	REC-63	0.0	REC-107	0.0
REC-48	19.9	REC-05	0.0	REC-64	0.0	REC-109	0.0
REC-28	19.6	REC-06	0.0	REC-65	0.0	REC-110	0.0
REC-38	19.5	REC-11	0.0	REC-66	0.0	REC-111	0.0
REC-45	18.5	REC-14	0.0	REC-67	0.0	REC-112	0.0
REC-79	15.3	REC-15	0.0	REC-68	0.0	REC-113	0.0
REC-10	14.9	REC-16	0.0	REC-69	0.0	REC-114	0.0
REC-78	14.7	REC-17	0.0	REC-70	0.0	REC-115	0.0
REC-108	14.2	REC-18	0.0	REC-71	0.0	REC-116	0.0
REC-101	13.0	REC-20	0.0	REC-72	0.0	REC-117	0.0
REC-91	12.6	REC-21	0.0	REC-73	0.0	REC-119	0.0
REC-46	11.7	REC-22	0.0	REC-74	0.0	REC-120	0.0
REC-19	9.8	REC-24	0.0	REC-75	0.0	REC-121	0.0
REC-44	9.7	REC-25	0.0	REC-76	0.0	REC-122	0.0
REC-31	8.7	REC-27	0.0	REC-77	0.0	REC-123	0.0
REC-94	7.9	REC-29	0.0	REC-81	0.0	REC-124	0.0
REC-85	7.7	REC-30	0.0	REC-82	0.0	REC-125	0.0
REC-07	7.5	REC-36	0.0	REC-83	0.0	REC-126	0.0
REC-47	7.2	REC-41	0.0	REC-84	0.0	REC-127	0.0
REC-35	6.9	REC-42	0.0	REC-86	0.0	REC-128	0.0
REC-43	6.8	REC-49	0.0	REC-87	0.0	REC-129	0.0
REC-40	6.5	REC-50	0.0	REC-90	0.0	REC-130	0.0
REC-34	6.3	REC-51	0.0	REC-92	0.0	REC-131	0.0
REC-13	5.6	REC-52	0.0	REC-93	0.0	REC-132	0.0
REC-23	4.9	REC-53	0.0	REC-95	0.0	REC-133	0.0
REC-33	4.8	REC-54	0.0	REC-96	0.0	REC-134	0.0
REC-88	4.3	REC-55	0.0	REC-97	0.0	REC-135	0.0
REC-12	3.6	REC-56	0.0	REC-98	0.0	REC-136	0.0
REC-118	3.5	REC-57	0.0	REC-100	0.0	REC-08	Not Used

Table F-3: Worst-Case Minutes per Day of Shadow Flicker (Sorted by Receptor ID)

Receptor ID	Flicker [min/day]	Receptor ID	Flicker [min/day]	Receptor ID	Flicker [min/day]	Receptor ID	Flicker [min/day]
REC-01	0	REC-35	33	REC-69	0	REC-103	0
REC-02	0	REC-36	0	REC-70	0	REC-104	0
REC-03	0	REC-37	61	REC-71	0	REC-105	0
REC-04	0	REC-38	46	REC-72	0	REC-106	0
REC-05	0	REC-39	45	REC-73	0	REC-107	0
REC-06	0	REC-40	27	REC-74	0	REC-108	38
REC-07	33	REC-41	0	REC-75	0	REC-109	0
REC-08	Not Used	REC-42	0	REC-76	0	REC-110	0
REC-09	29	REC-43	34	REC-77	0	REC-111	0
REC-10	34	REC-44	33	REC-78	40	REC-112	0
REC-11	0	REC-45	32	REC-79	39	REC-113	0
REC-12	25	REC-46	35	REC-80	41	REC-114	0
REC-13	30	REC-47	28	REC-81	0	REC-115	0
REC-14	0	REC-48	51	REC-82	0	REC-116	0
REC-15	0	REC-49	0	REC-83	0	REC-117	0
REC-16	0	REC-50	0	REC-84	0	REC-118	24
REC-17	0	REC-51	0	REC-85	35	REC-119	0
REC-18	0	REC-52	0	REC-86	0	REC-120	0
REC-19	29	REC-53	0	REC-87	0	REC-121	0
REC-20	0	REC-54	0	REC-88	29	REC-122	0
REC-21	0	REC-55	0	REC-89	24	REC-123	0
REC-22	0	REC-56	0	REC-90	0	REC-124	0
REC-23	21	REC-57	0	REC-91	30	REC-125	0
REC-24	0	REC-58	0	REC-92	0	REC-126	0
REC-25	0	REC-59	0	REC-93	0	REC-127	0
REC-26	74	REC-60	0	REC-94	28	REC-128	0
REC-27	0	REC-61	0	REC-95	0	REC-129	0
REC-28	38	REC-62	0	REC-96	0	REC-130	0
REC-29	0	REC-63	0	REC-97	0	REC-131	0
REC-30	0	REC-64	0	REC-98	0	REC-132	0
REC-31	31	REC-65	0	REC-99	63	REC-133	0
REC-32	53	REC-66	0	REC-100	0	REC-134	0
REC-33	28	REC-67	0	REC-101	23	REC-135	0
REC-34	22	REC-68	0	REC-102	0	REC-136	0

Table F-4: Worst-Case Minutes per Day of Shadow Flicker (Sorted by Flicker Time)

Receptor ID	Flicker [min/day]	Receptor ID	Flicker [min/day]	Receptor ID	Flicker [min/day]	Receptor ID	Flicker [min/day]
REC-26	74	REC-34	22	REC-58	0	REC-102	0
REC-99	63	REC-23	21	REC-59	0	REC-103	0
REC-37	61	REC-01	0	REC-60	0	REC-104	0
REC-32	53	REC-02	0	REC-61	0	REC-105	0
REC-48	51	REC-03	0	REC-62	0	REC-106	0
REC-38	46	REC-04	0	REC-63	0	REC-107	0
REC-39	45	REC-05	0	REC-64	0	REC-109	0
REC-80	41	REC-06	0	REC-65	0	REC-110	0
REC-78	40	REC-11	0	REC-66	0	REC-111	0
REC-79	39	REC-14	0	REC-67	0	REC-112	0
REC-28	38	REC-15	0	REC-68	0	REC-113	0
REC-108	38	REC-16	0	REC-69	0	REC-114	0
REC-46	35	REC-17	0	REC-70	0	REC-115	0
REC-85	35	REC-18	0	REC-71	0	REC-116	0
REC-10	34	REC-20	0	REC-72	0	REC-117	0
REC-43	34	REC-21	0	REC-73	0	REC-119	0
REC-07	33	REC-22	0	REC-74	0	REC-120	0
REC-35	33	REC-24	0	REC-75	0	REC-121	0
REC-44	33	REC-25	0	REC-76	0	REC-122	0
REC-45	32	REC-27	0	REC-77	0	REC-123	0
REC-31	31	REC-29	0	REC-81	0	REC-124	0
REC-13	30	REC-30	0	REC-82	0	REC-125	0
REC-91	30	REC-36	0	REC-83	0	REC-126	0
REC-09	29	REC-41	0	REC-84	0	REC-127	0
REC-19	29	REC-42	0	REC-86	0	REC-128	0
REC-88	29	REC-49	0	REC-87	0	REC-129	0
REC-33	28	REC-50	0	REC-90	0	REC-130	0
REC-47	28	REC-51	0	REC-92	0	REC-131	0
REC-94	28	REC-52	0	REC-93	0	REC-132	0
REC-40	27	REC-53	0	REC-95	0	REC-133	0
REC-12	25	REC-54	0	REC-96	0	REC-134	0
REC-89	24	REC-55	0	REC-97	0	REC-135	0
REC-118	24	REC-56	0	REC-98	0	REC-136	0
REC-101	23	REC-57	0	REC-100	0	REC-08	NA

APPENDIX G - SHADOW FLICKER CALENDAR

Project:
PrevailingWinds_Shadow_Flicker_Study

Description:
The purpose of the analysis is to identify the number of hours at which each receptor experiences shadow flickering from the turbines and turbine locations specified for this project. This model is the second revision of the original case.

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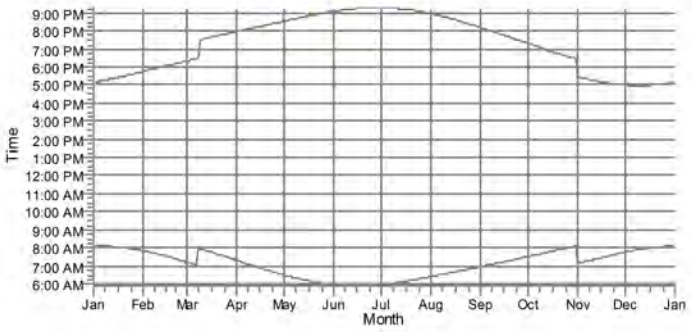
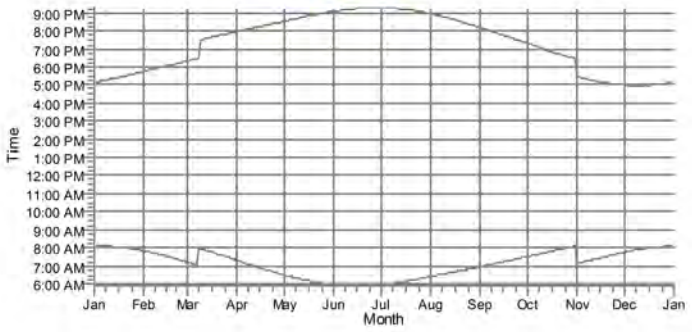
SHADOW - Calendar, graphical

Calculation: Shadow Flicker Analysis v2-WTGs (06.27.2016)

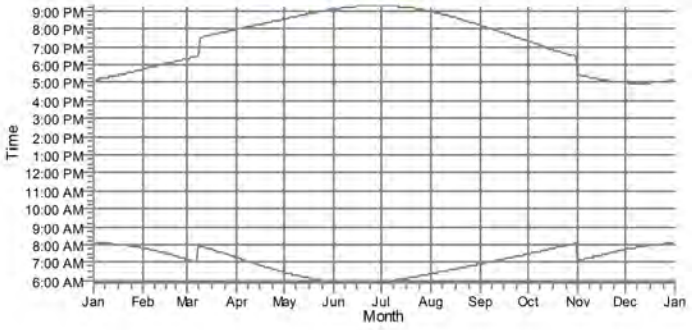
A: REC-01



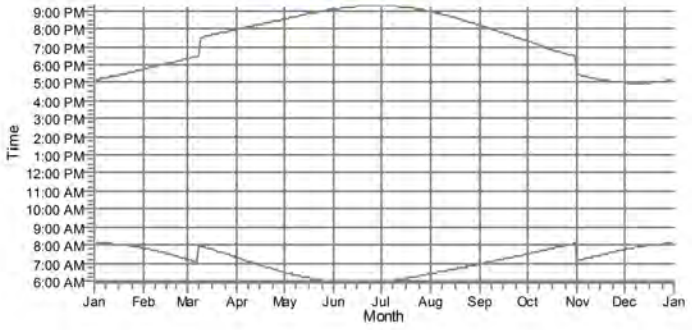
B: REC-02



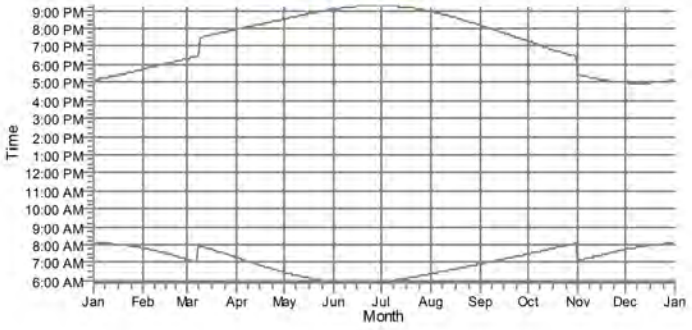
C: REC-03



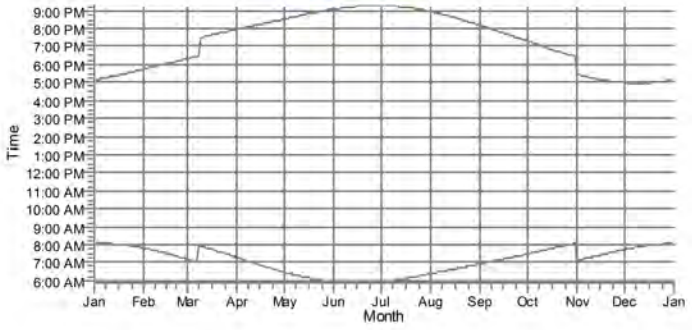
D: REC-04



E: REC-05



F: REC-06



WTGs

Project:
PrevailingWinds_Shadow_Flicker_Study

Description:
The purpose of the analysis is to identify the number of hours at which each receptor experiences shadow flickering from the turbines and turbine locations specified for this project. This model is the second revision of the original case.

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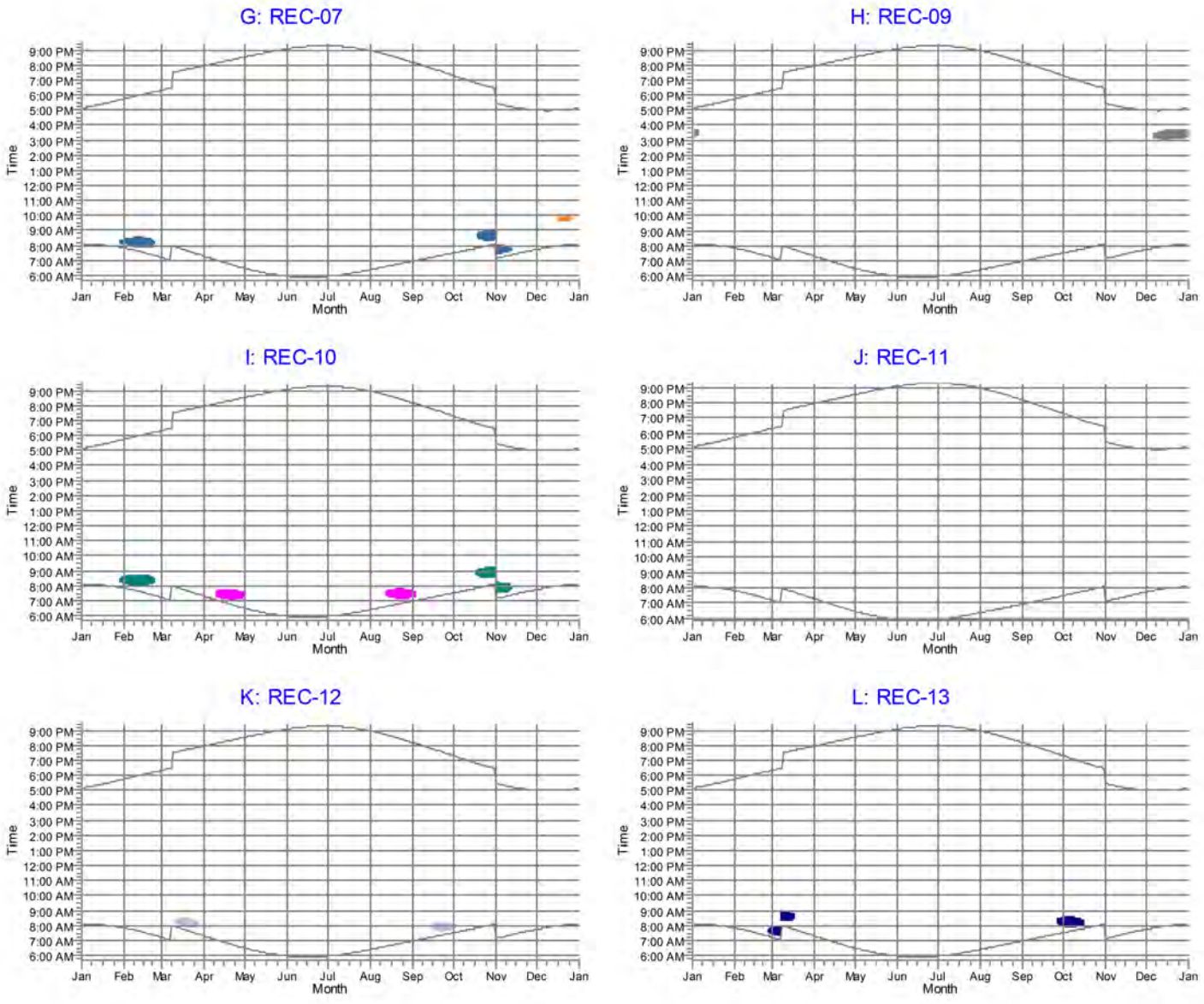
SHADOW - Calendar, graphical

Calculation: Shadow Flicker Analysis v2-WTGs (06.27.2016)



Project:
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Description:
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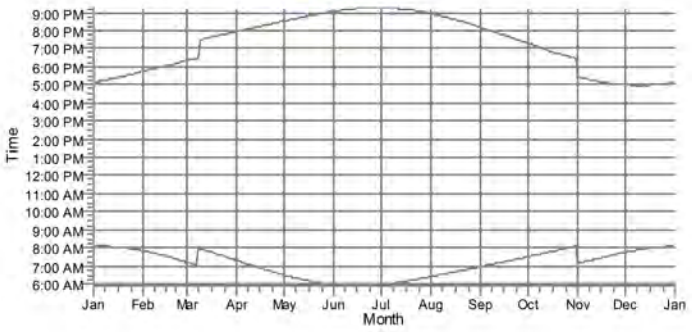
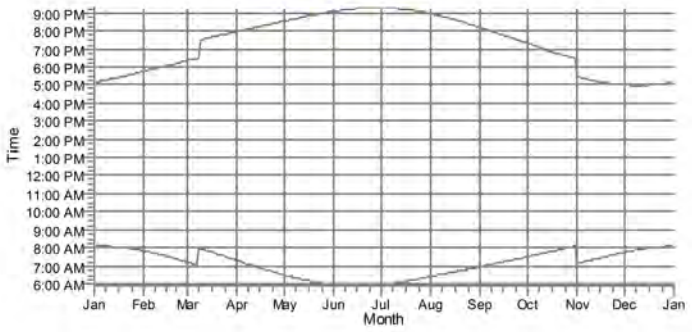
SHADOW - Calendar, graphical

Calculation: Shadow Flicker Analysis v2-WTGs (06.27.2016)

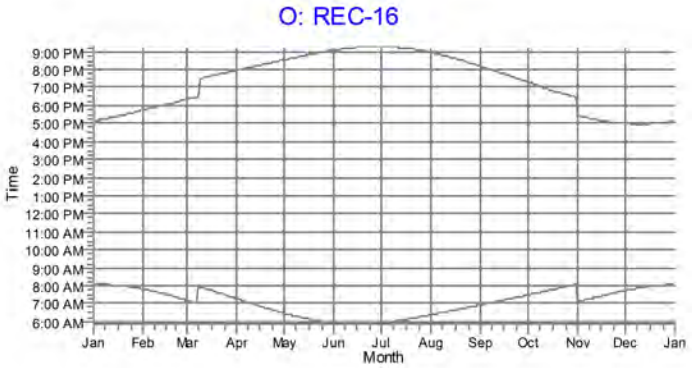
M: REC-14



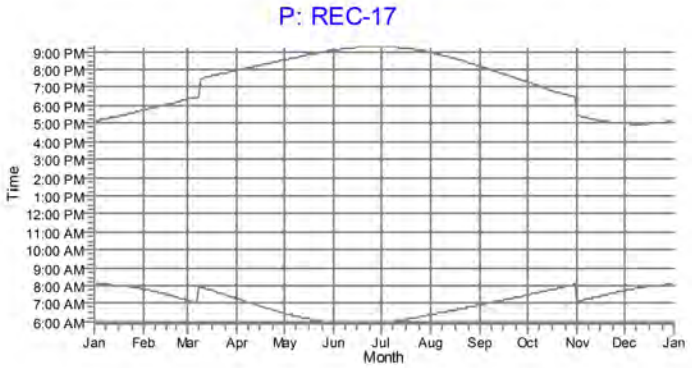
N: REC-15



O: REC-16



P: REC-17



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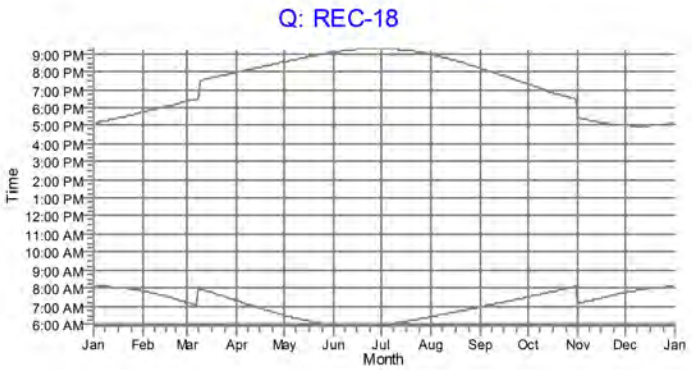
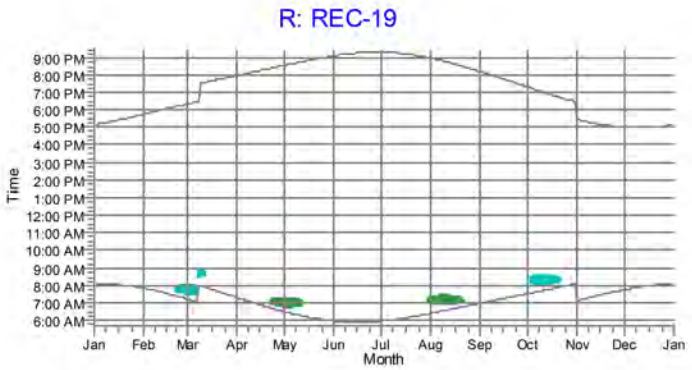


R: REC-19



WTGs

20: 23 21: 24

Project:
PrevailingWinds_Shadow_Flicker_Study

Description:
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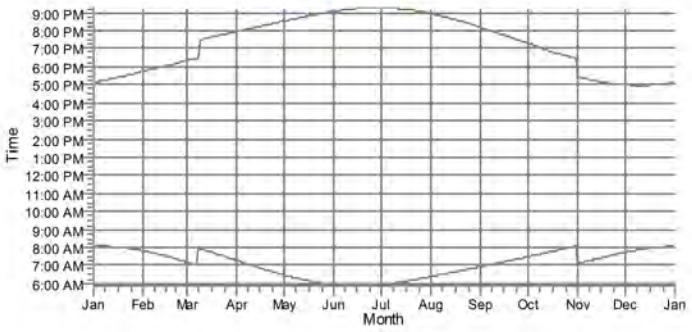
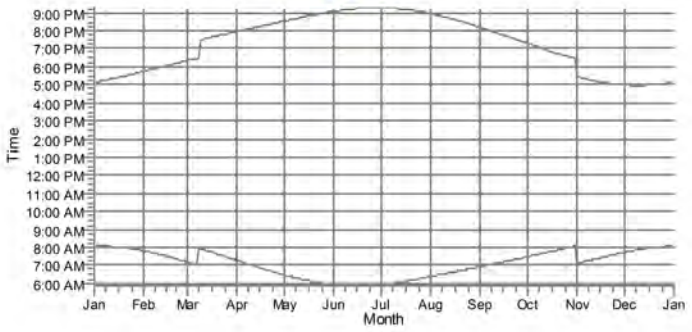
SHADOW - Calendar, graphical

Calculation: Shadow Flicker Analysis v2-WTGs (06.27.2016)

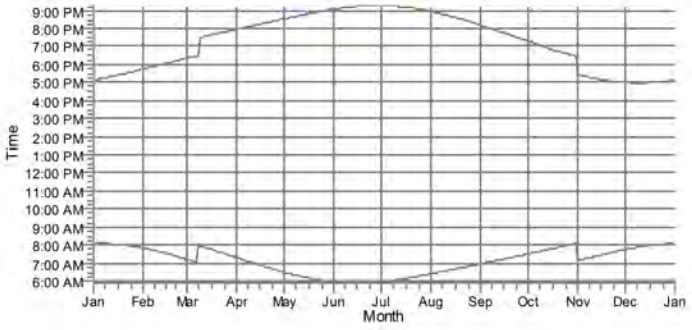
S: REC-20



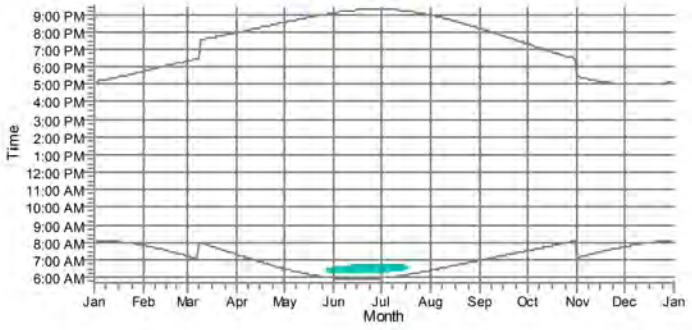
T: REC-21



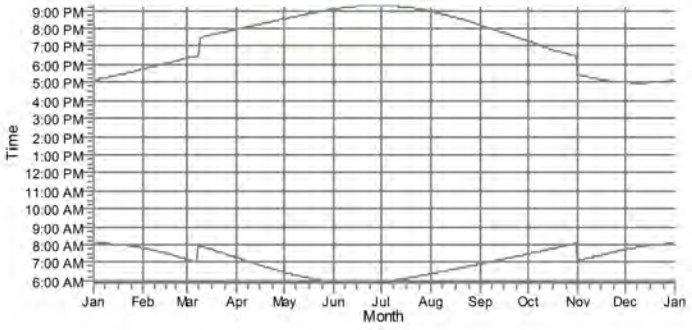
U: REC-22



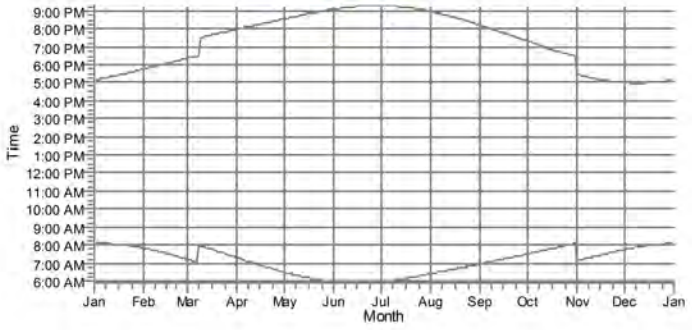
V: REC-23



W: REC-24



X: REC-25



WTGs

21: 24

Project:
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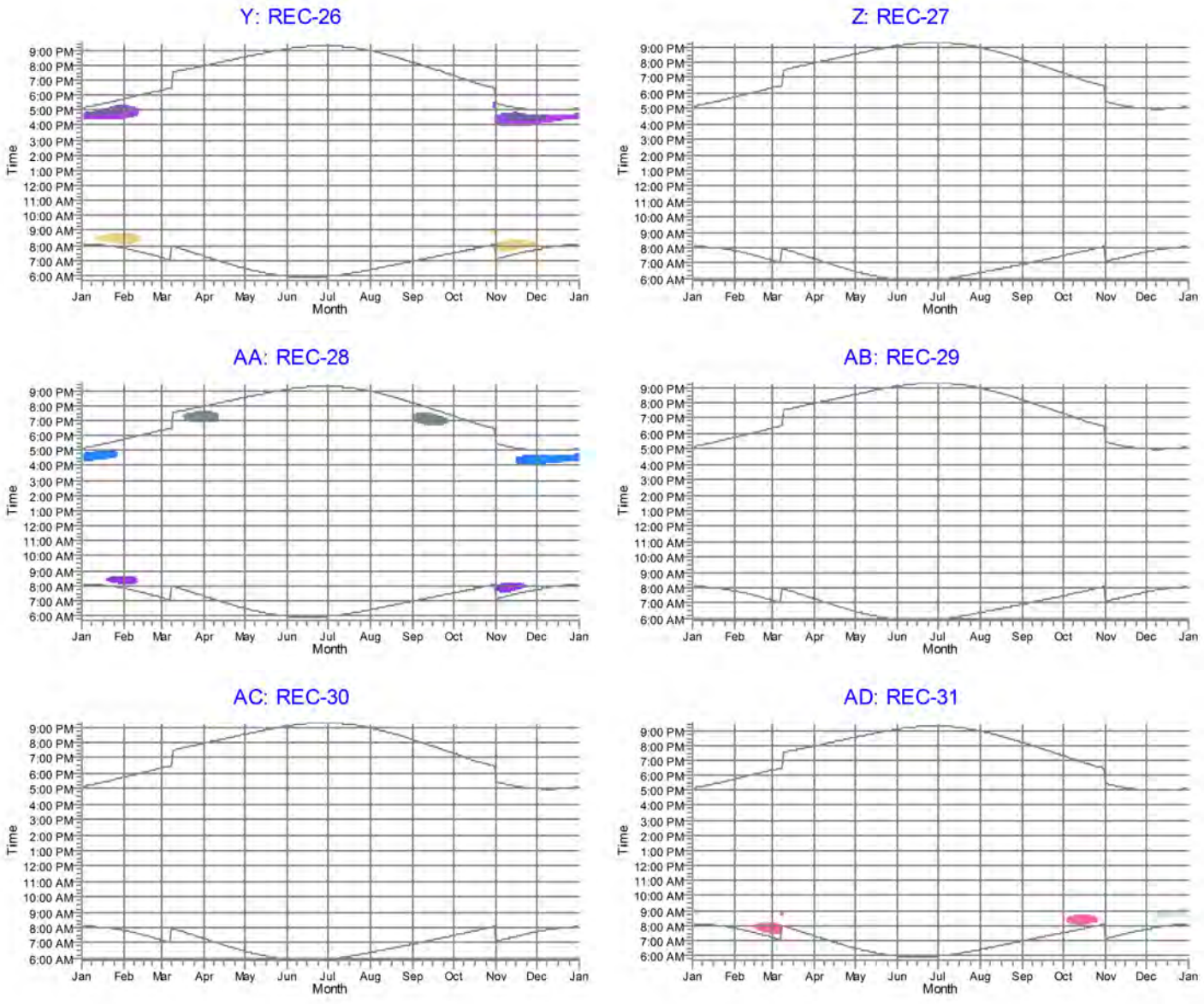
SHADOW - Calendar, graphical

Calculation: Shadow Flicker Analysis v2-WTGs (06.27.2016)



Project:
PrevailingWinds_Shadow_Flicker_Study

Description:
The purpose of the analysis is to identify the number of hours at which each receptor experiences shadow flickering from the turbines and turbine locations specified for this project. This model is the second revision of the original case.

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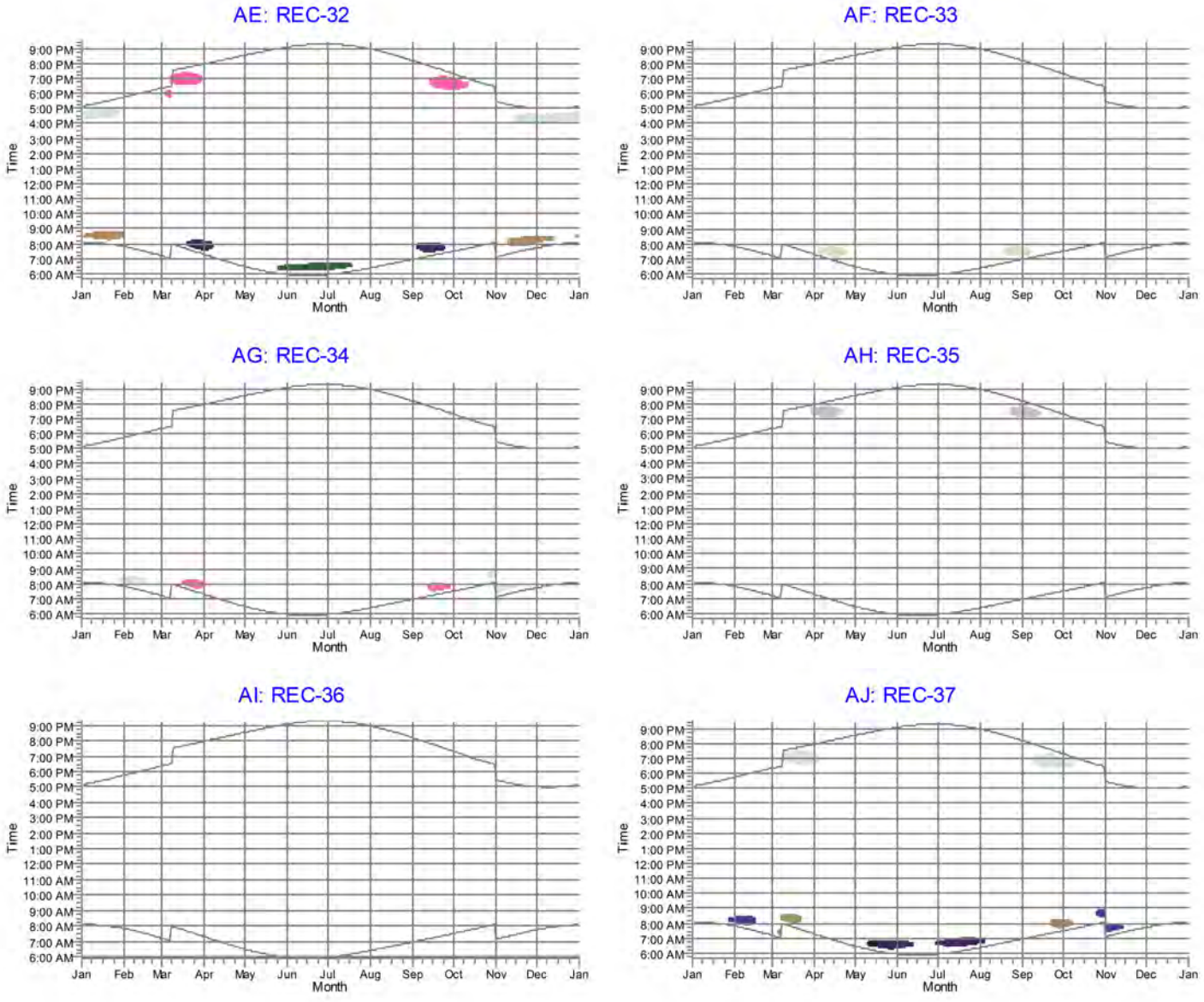
SHADOW - Calendar, graphical

Calculation: Shadow Flicker Analysis v2-WTGs (06.27.2016)



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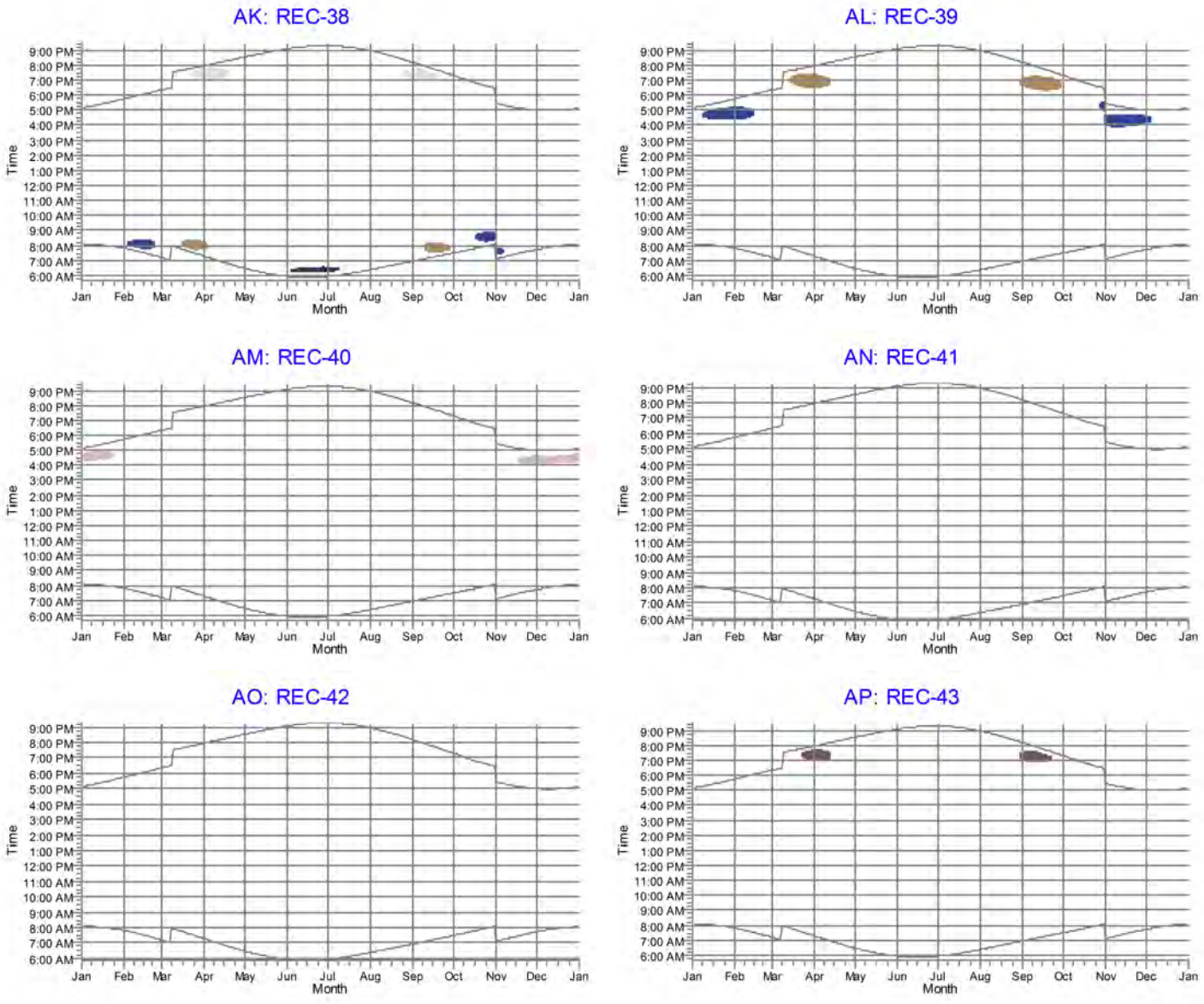
SHADOW - Calendar, graphical

Calculation: Shadow Flicker Analysis v2-WTGs (06.27.2016)



Project:
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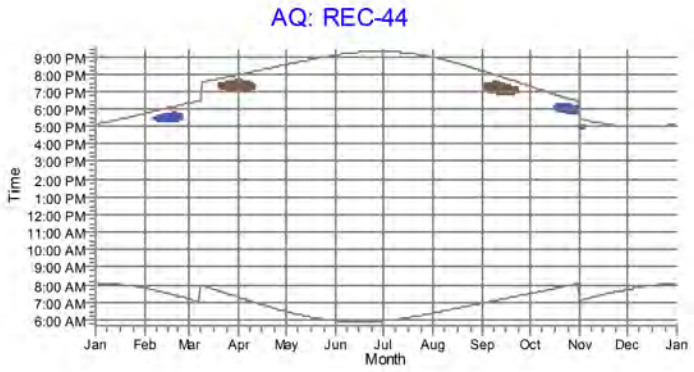
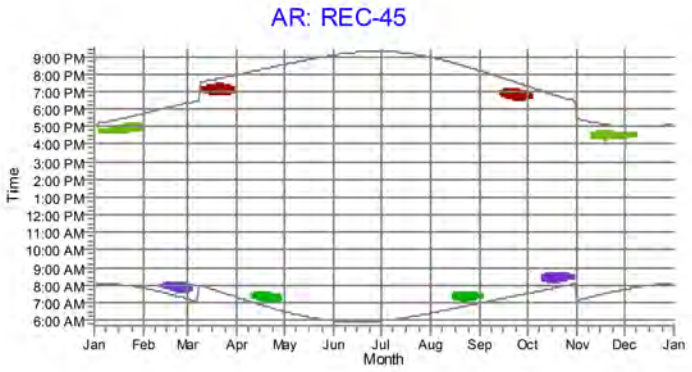
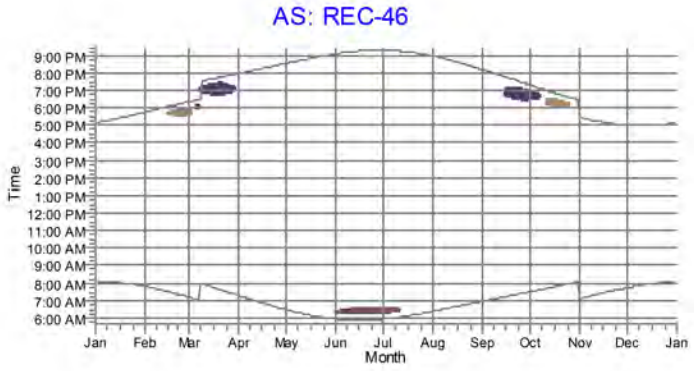
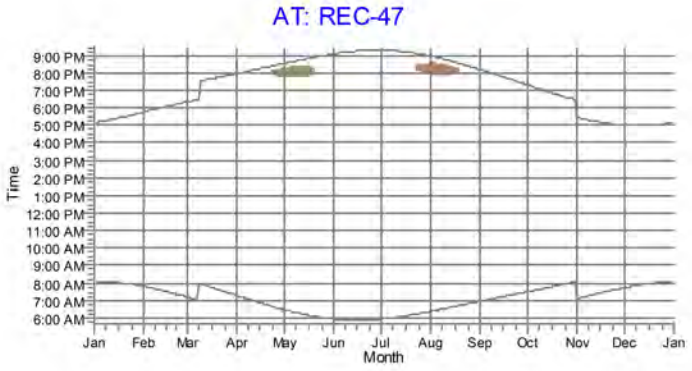
SHADOW - Calendar, graphical

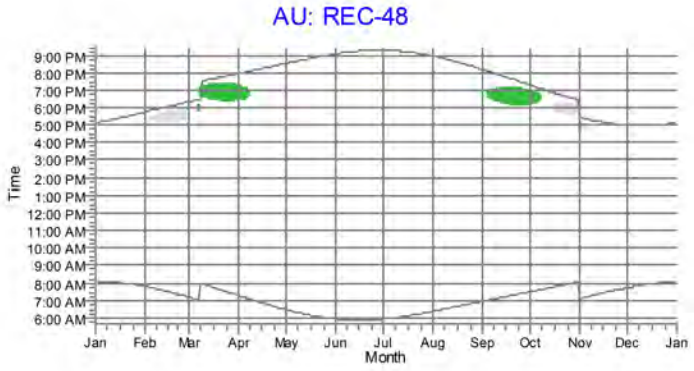
Calculation: Shadow Flicker Analysis v2-WTGs (06.27.2016)

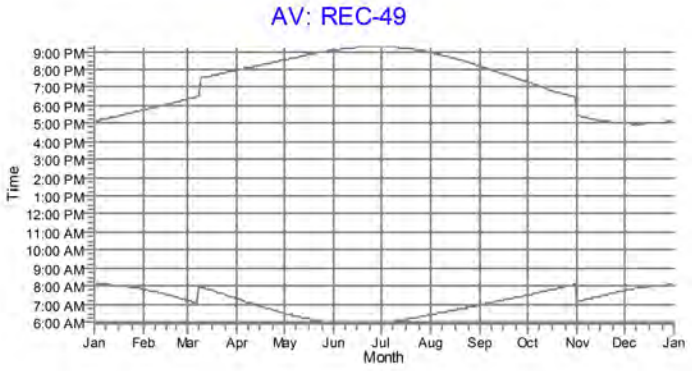












WTGs

51: 58	54: 61a	63: 70	79: 88a	83: 92a	86: 95	
52: 59	55: 62a	64: 71	82: 91	85: 94		

Project:
PrevailingWinds_Shadow_Flicker_Study

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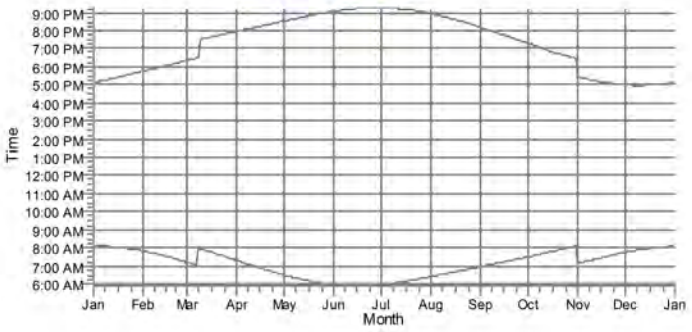
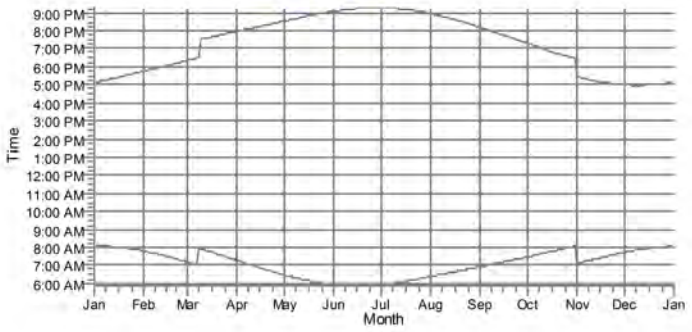
SHADOW - Calendar, graphical

Calculation: Shadow Flicker Analysis v2-WTGs (06.27.2016)

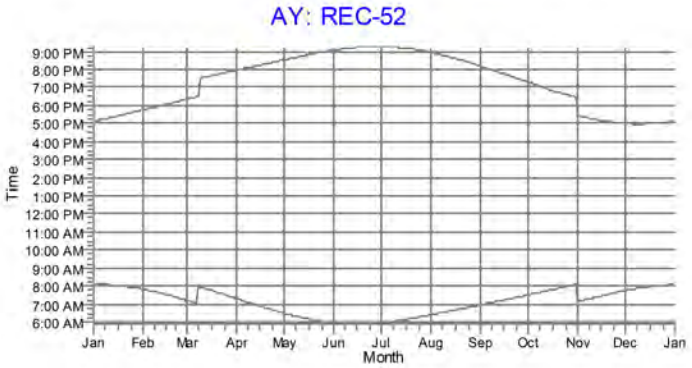
AW: REC-50



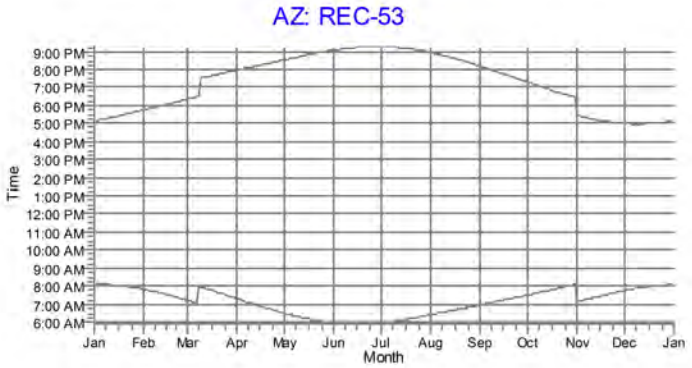
AX: REC-51



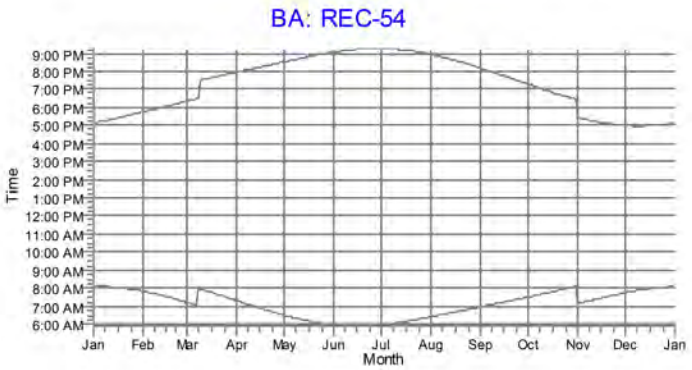
AY: REC-52



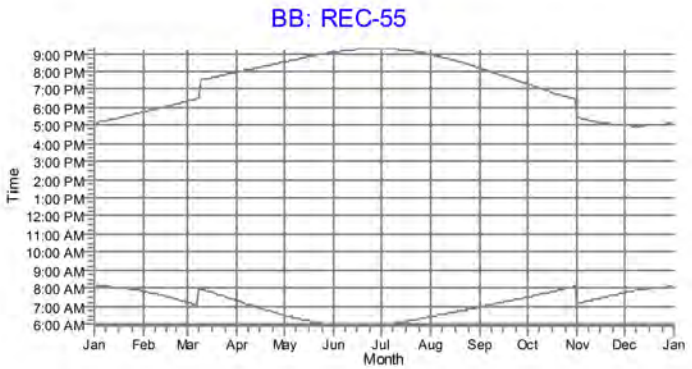
AZ: REC-53



BA: REC-54



BB: REC-55



WTGs

Project:
PrevailingWinds_Shadow_Flicker_Study

Description:
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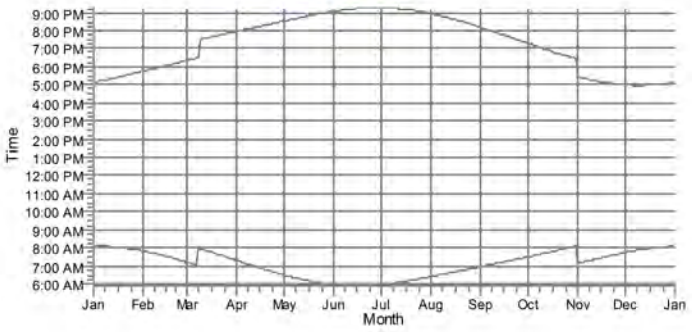
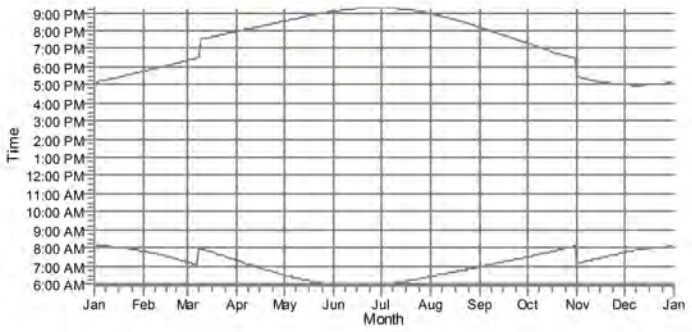
SHADOW - Calendar, graphical

Calculation: Shadow Flicker Analysis v2-WTGs (06.27.2016)

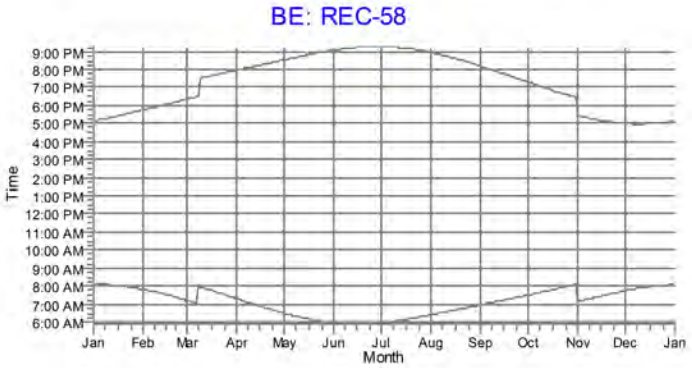
BC: REC-56



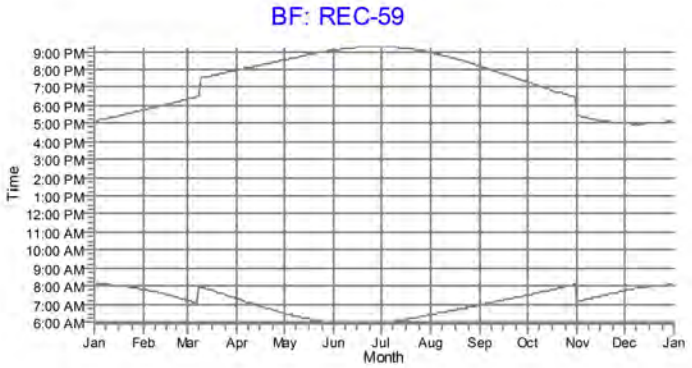
BD: REC-57



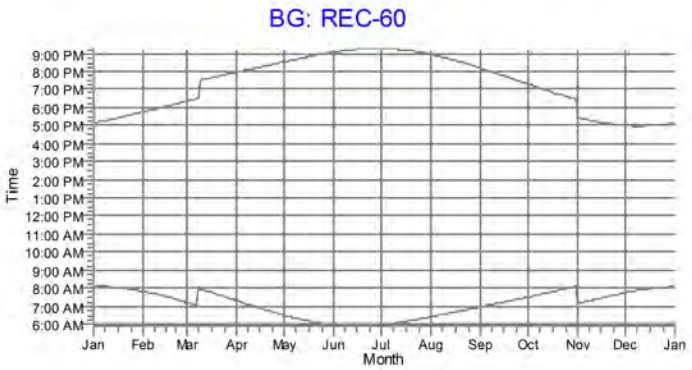
BE: REC-58



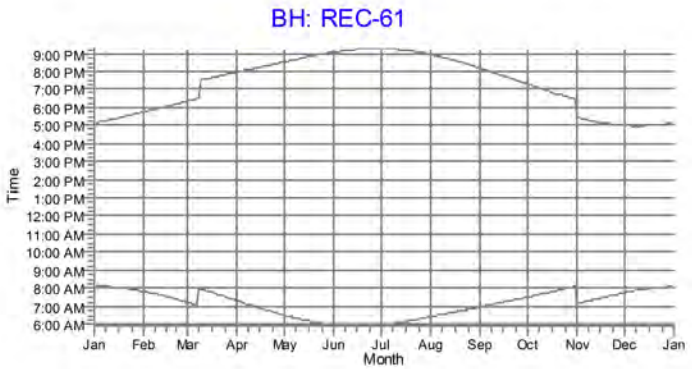
BF: REC-59



BG: REC-60



BH: REC-61



WTGs

Project:
PrevailingWinds_Shadow_Flicker_Study

Description:
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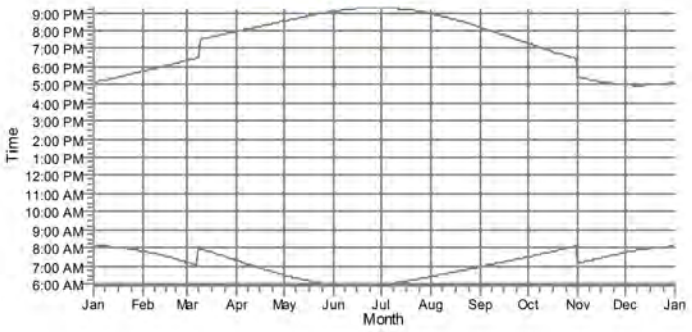
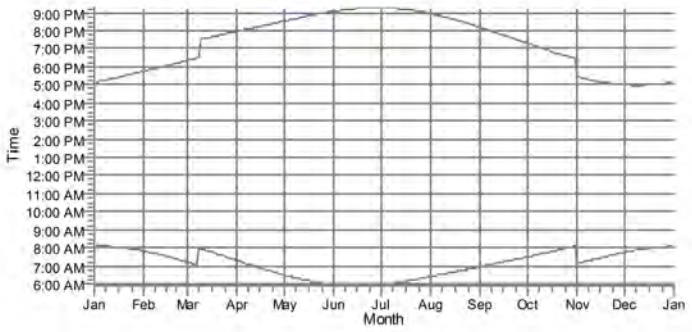
SHADOW - Calendar, graphical

Calculation: Shadow Flicker Analysis v2-WTGs (06.27.2016)

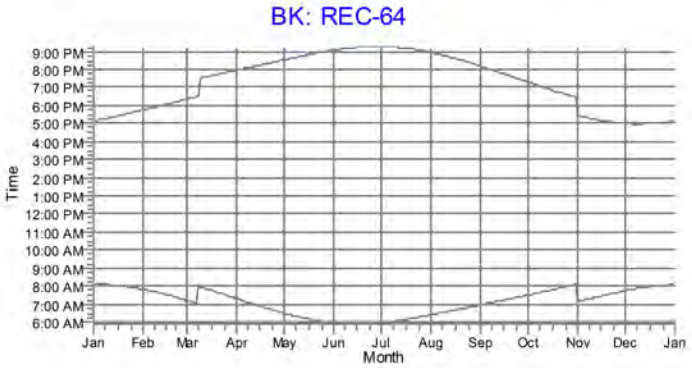
BI: REC-62



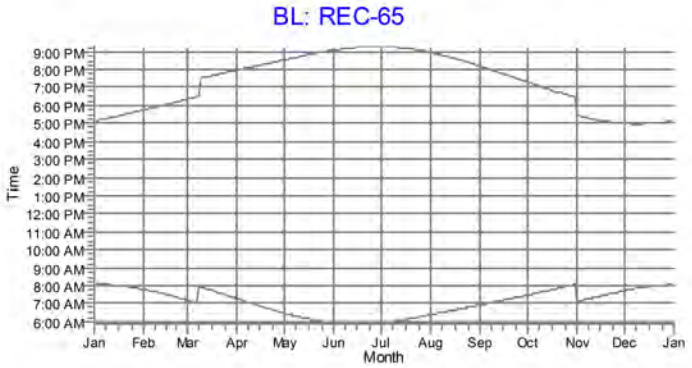
BJ: REC-63



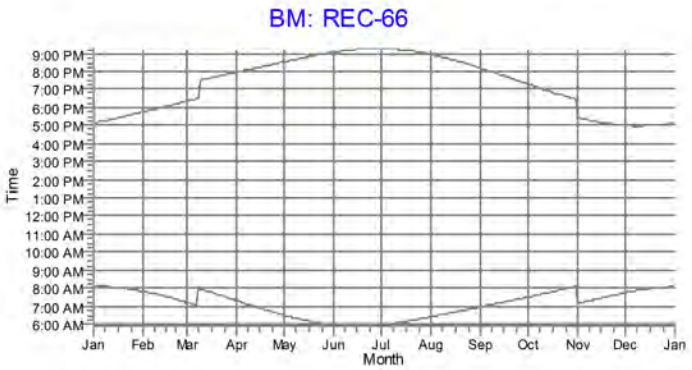
BK: REC-64



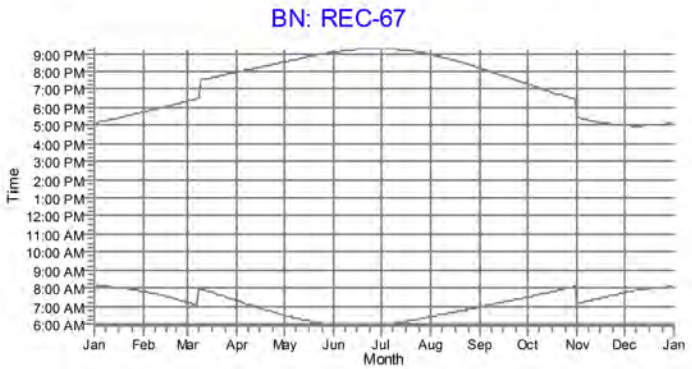
BL: REC-65



BM: REC-66



BN: REC-67



WTGs

Project:
PrevailingWinds_Shadow_Flicker_Study

Description:
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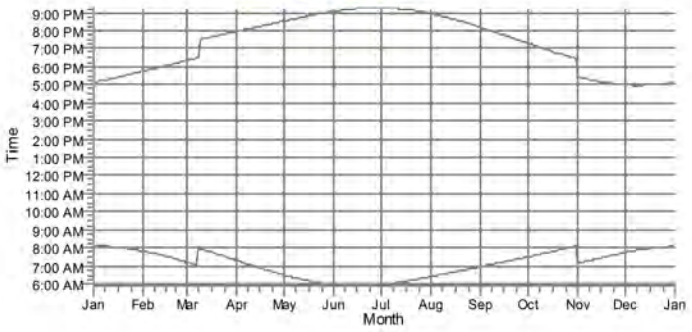
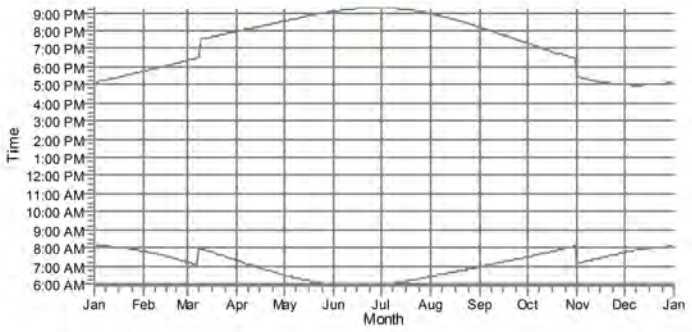
SHADOW - Calendar, graphical

Calculation: Shadow Flicker Analysis v2-WTGs (06.27.2016)

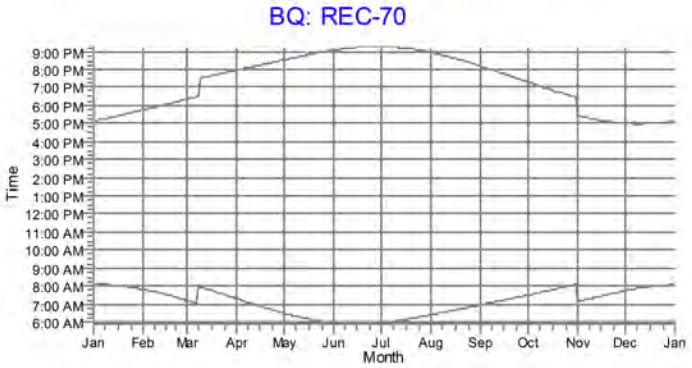
BO: REC-68



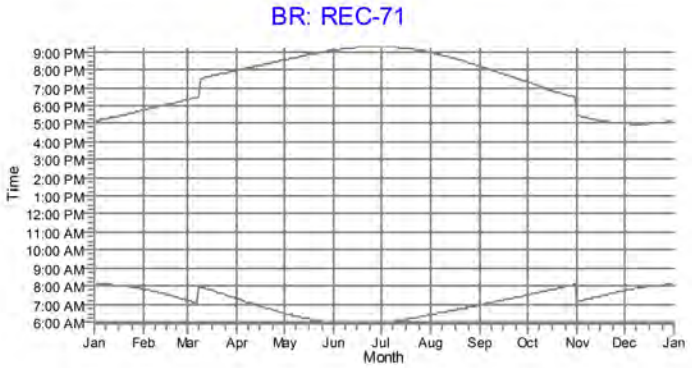
BP: REC-69



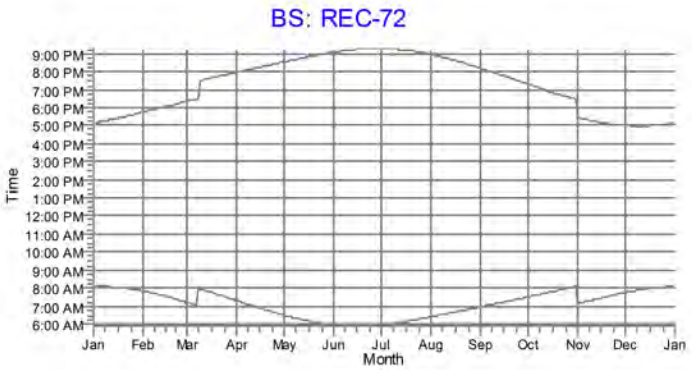
BQ: REC-70



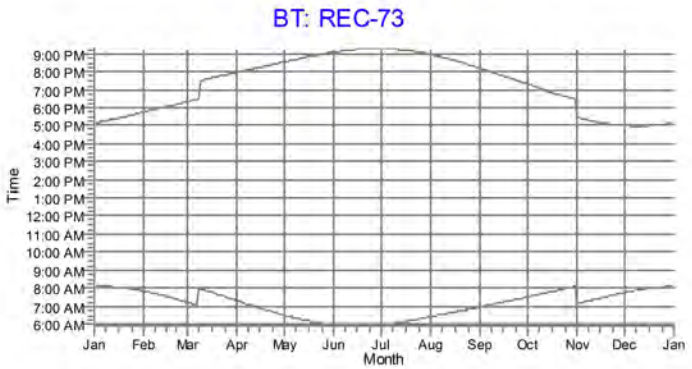
BR: REC-71



BS: REC-72



BT: REC-73



WTGs

Project:
PrevailingWinds_Shadow_Flicker_Study

Description:
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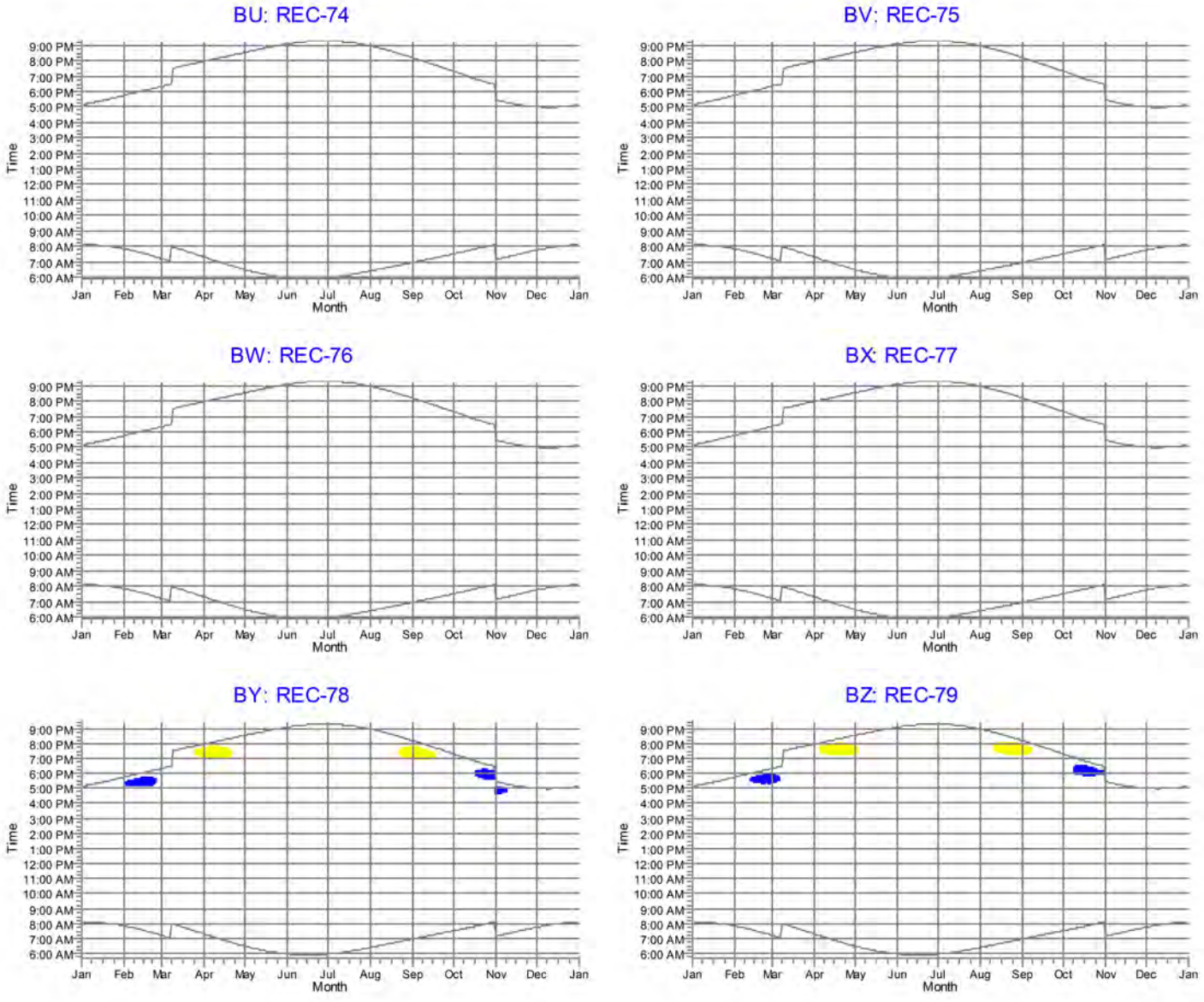
SHADOW - Calendar, graphical

Calculation: Shadow Flicker Analysis v2-WTGs (06.27.2016)



Project:
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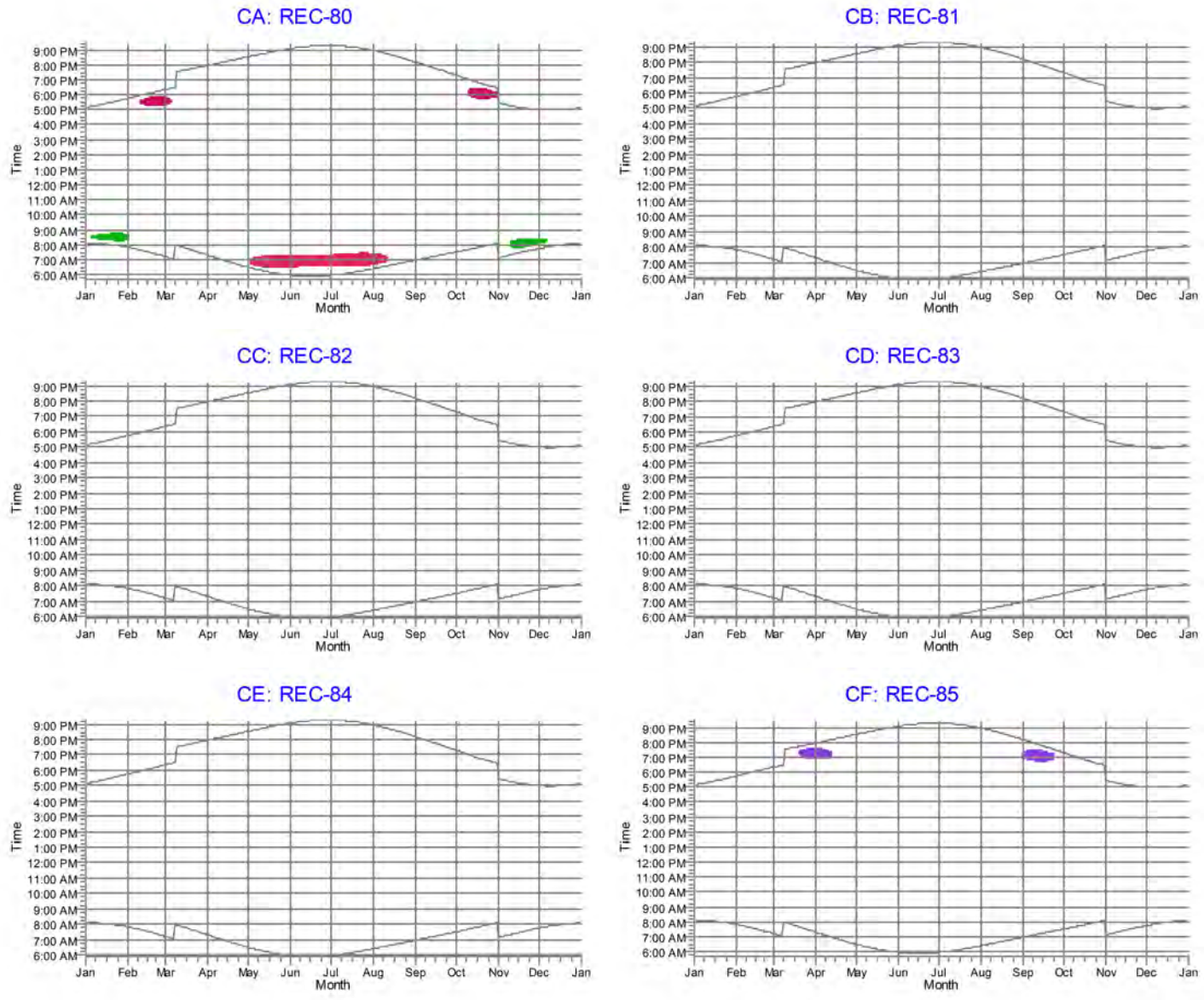
SHADOW - Calendar, graphical

Calculation: Shadow Flicker Analysis v2-WTGs (06.27.2016)



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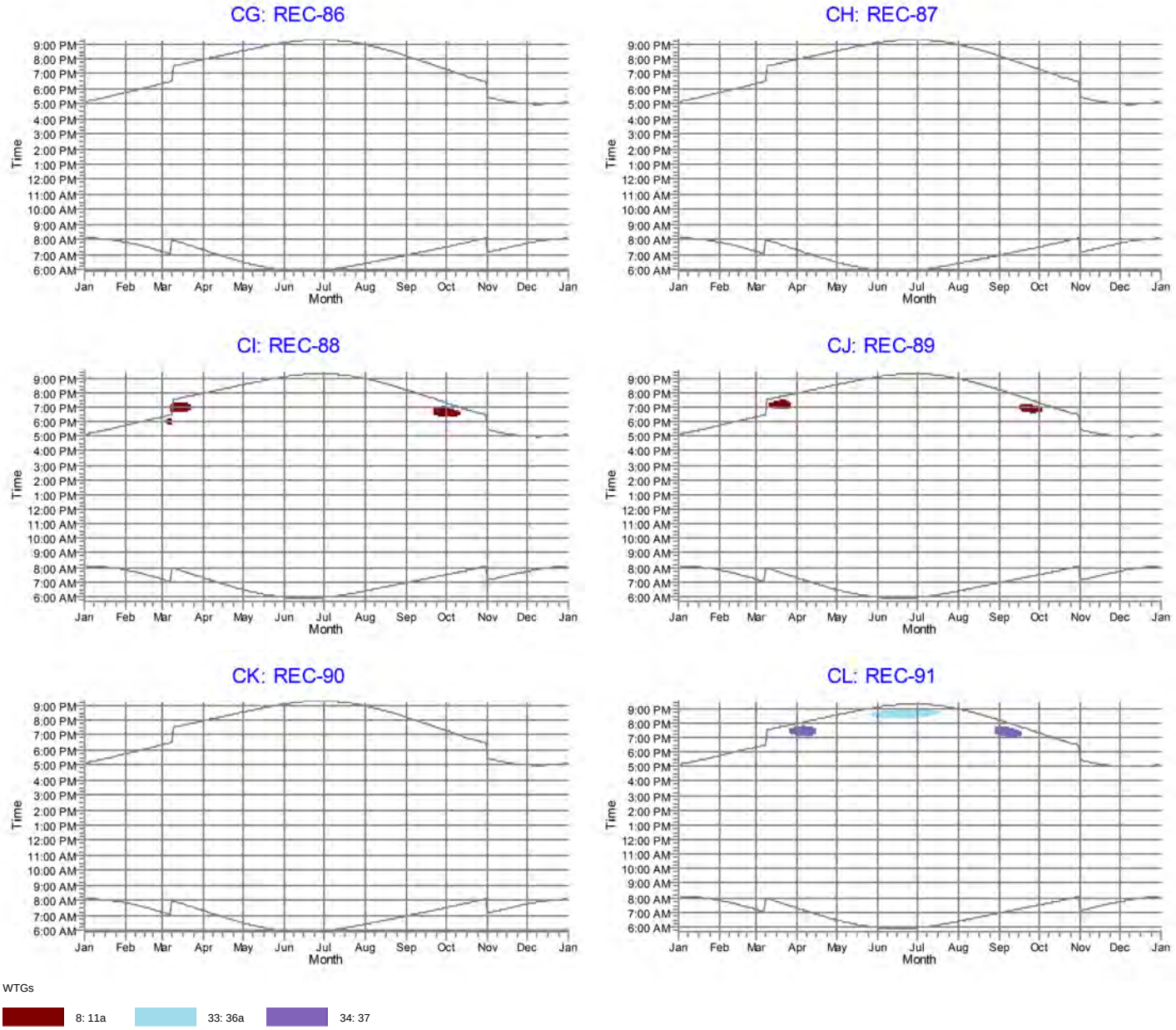
SHADOW - Calendar, graphical

Calculation: Shadow Flicker Analysis v2-WTGs (06.27.2016)



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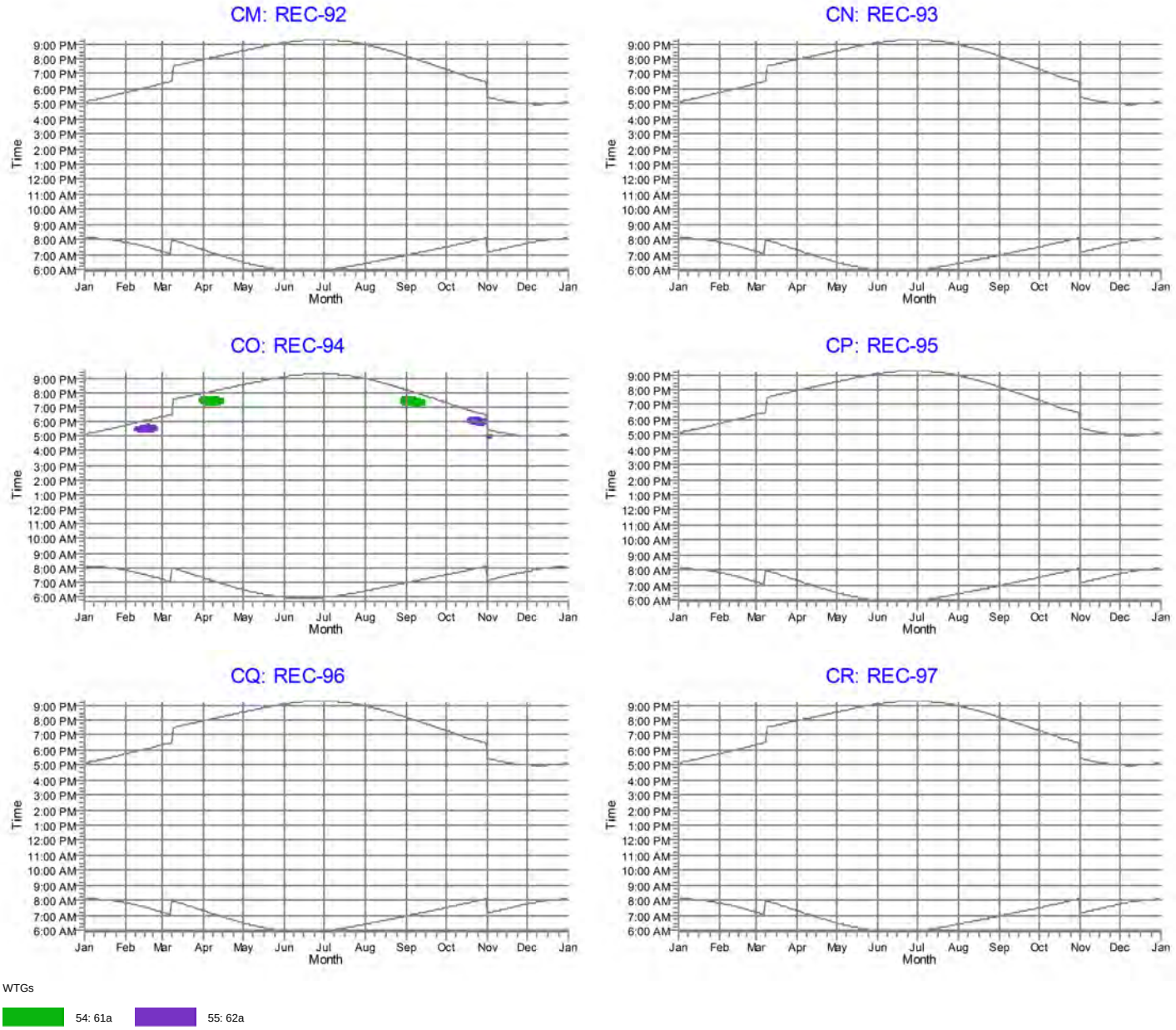
SHADOW - Calendar, graphical

Calculation: Shadow Flicker Analysis v2-WTGs (06.27.2016)



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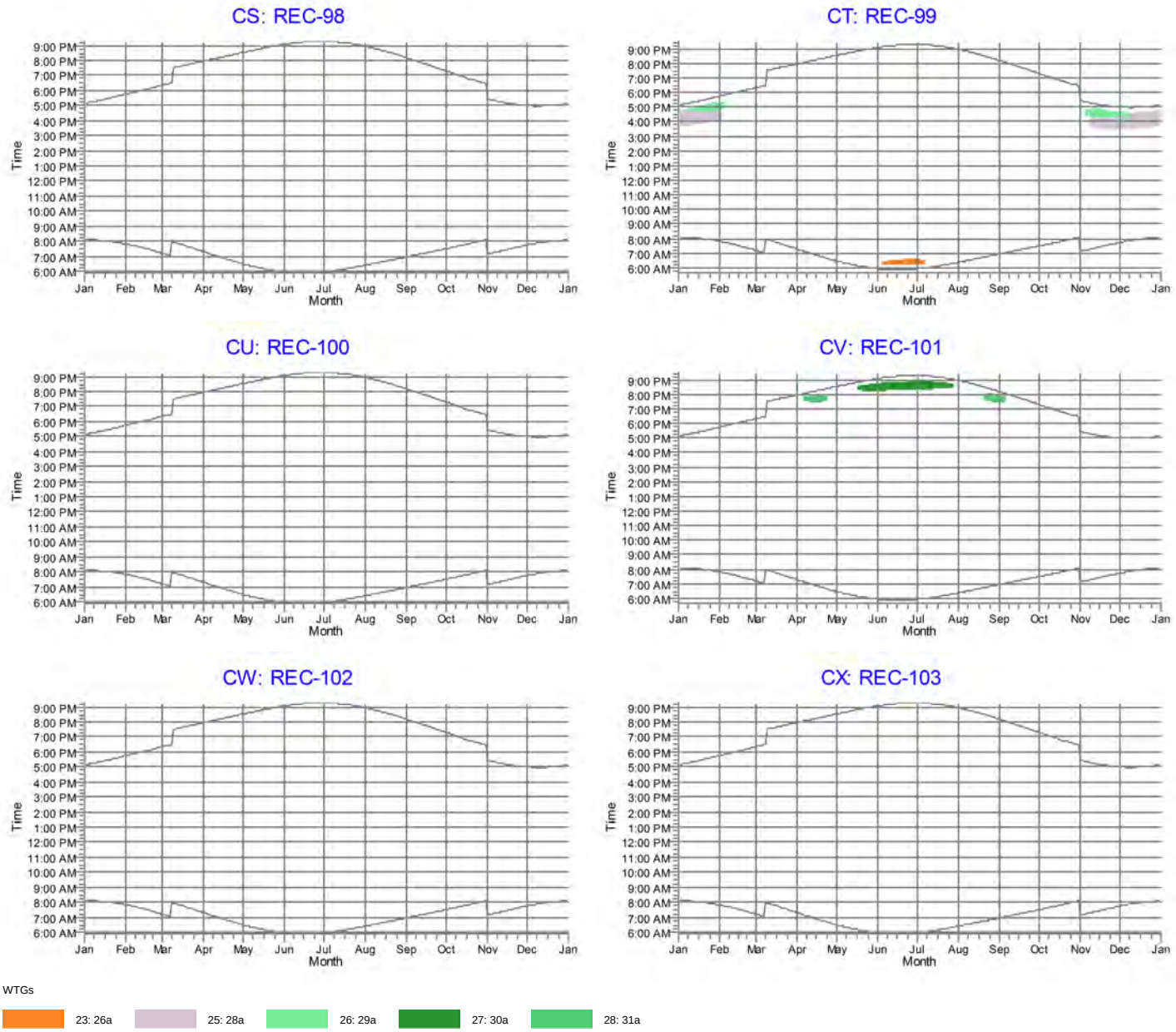
SHADOW - Calendar, graphical

Calculation: Shadow Flicker Analysis v2-WTGs (06.27.2016)



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PrevailingWinds_Shadow_Flicker_Study

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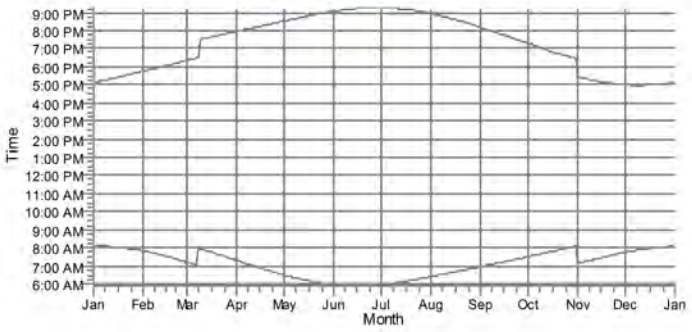
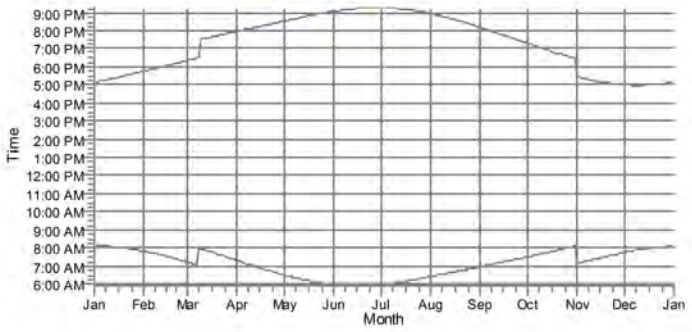
SHADOW - Calendar, graphical

Calculation: Shadow Flicker Analysis v2-WTGs (06.27.2016)

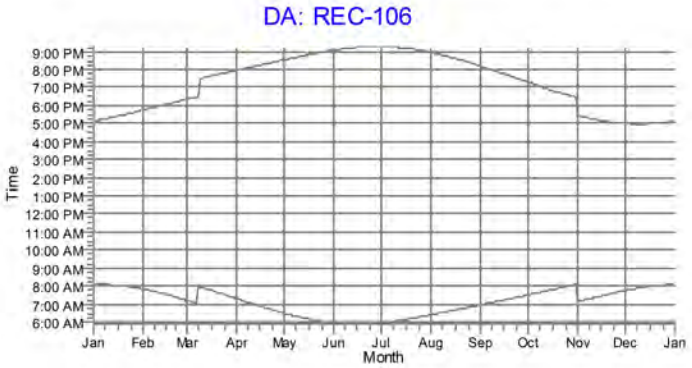
CY: REC-104



CZ: REC-105



DA: REC-106



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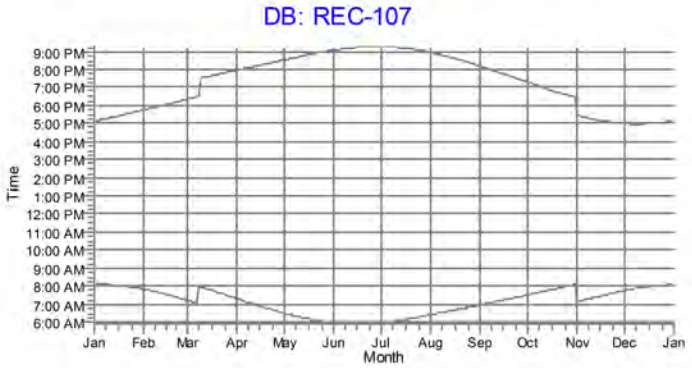
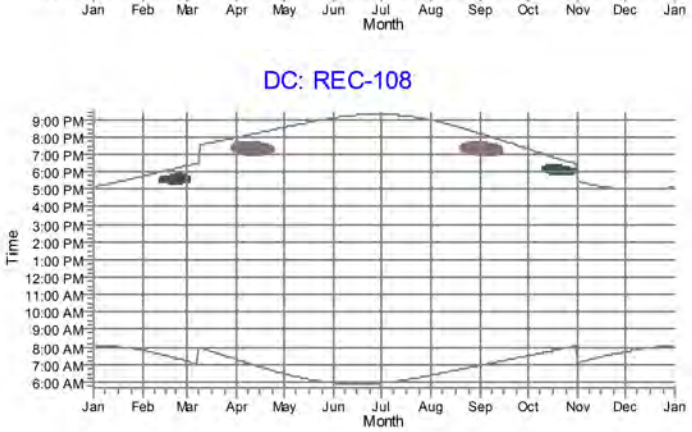
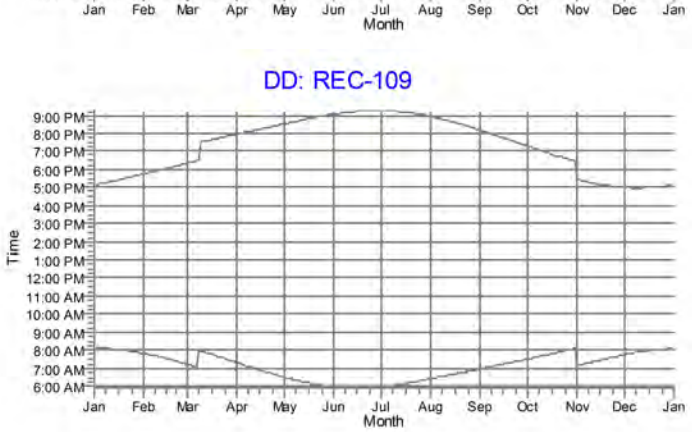


DC: REC-108



DD: REC-109



WTGs

70: 77a 73: 82a

Project:
PrevailingWinds_Shadow_Flicker_Study

Description:
The purpose of the analysis is to identify the number of hours at which each receptor experiences shadow flickering from the turbines and turbine locations specified for this project. This model is the second revision of the original case.

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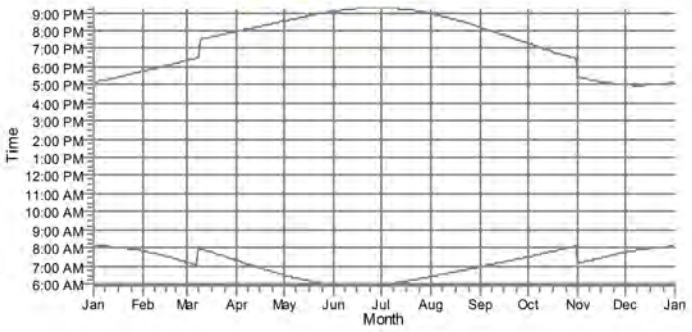
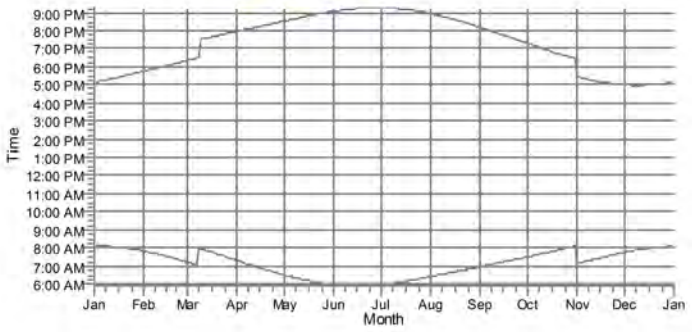
SHADOW - Calendar, graphical

Calculation: Shadow Flicker Analysis v2-WTGs (06.27.2016)

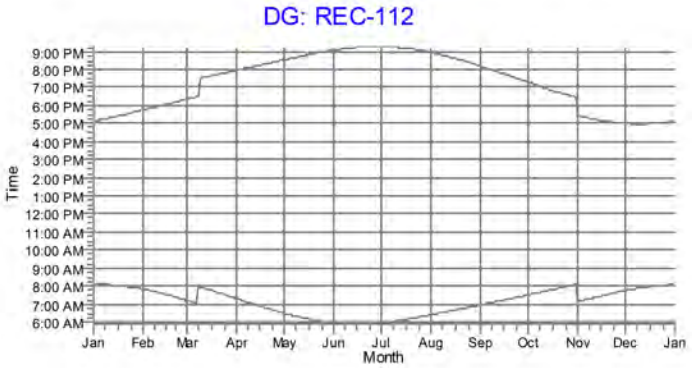
DE: REC-110



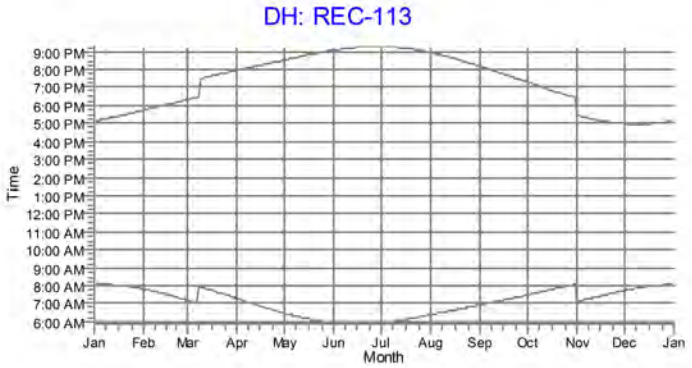
DF: REC-111



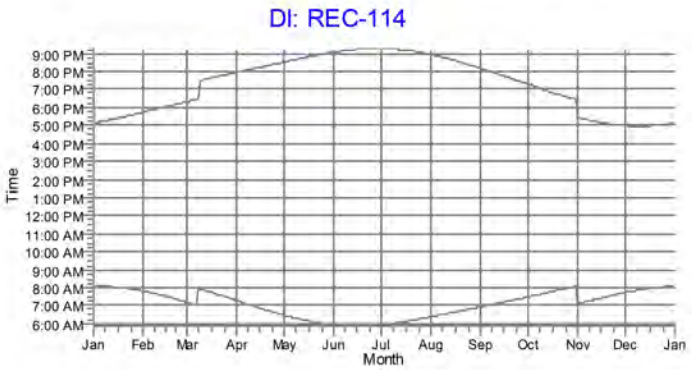
DG: REC-112



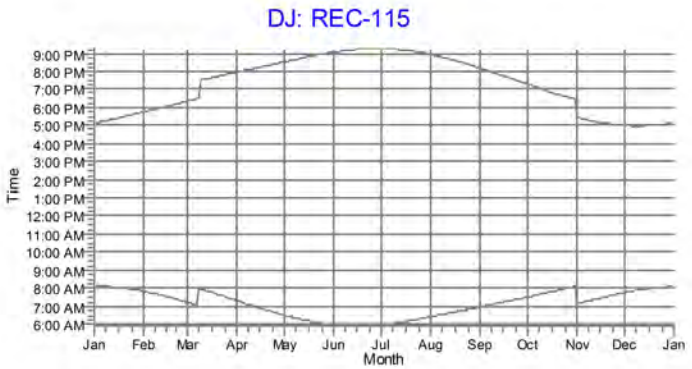
DH: REC-113



DI: REC-114



DJ: REC-115



WTGs

Project:
PrevailingWinds_Shadow_Flicker_Study

Description:
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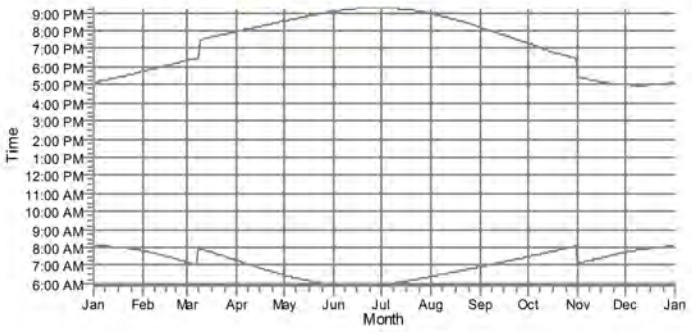
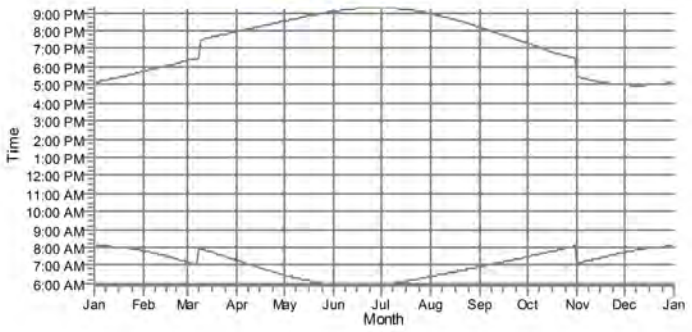
SHADOW - Calendar, graphical

Calculation: Shadow Flicker Analysis v2-WTGs (06.27.2016)

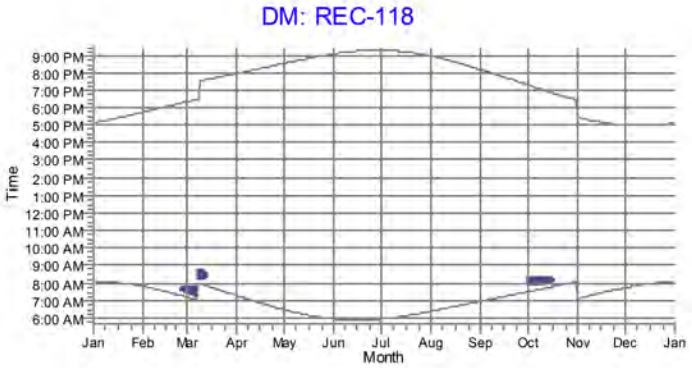
DK: REC-116



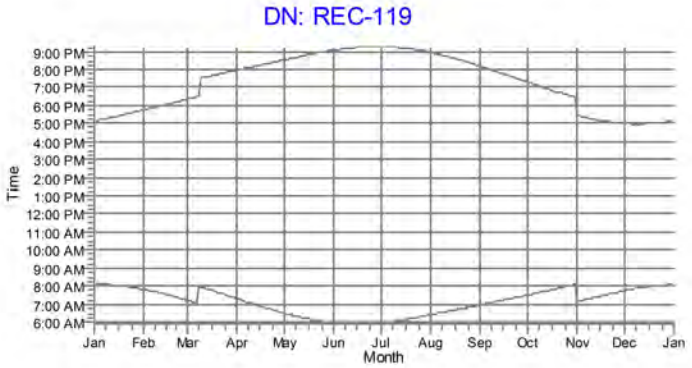
DL: REC-117



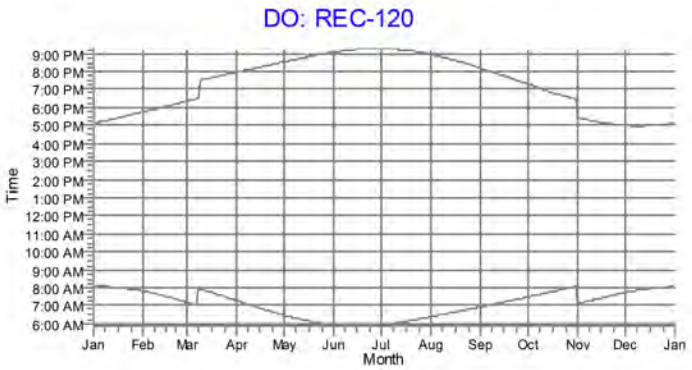
DM: REC-118



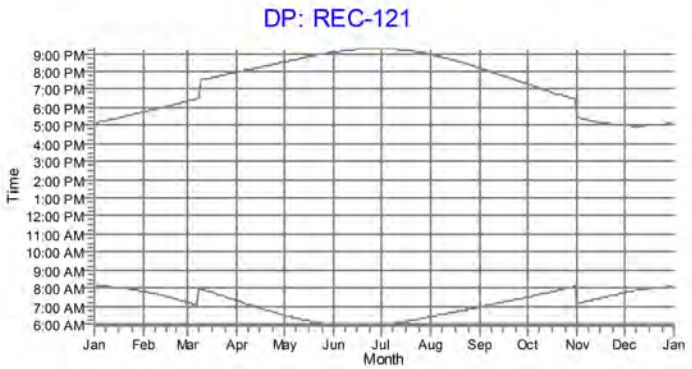
DN: REC-119



DO: REC-120



DP: REC-121



WTGs

81: 90a

Project:
PrevailingWinds_Shadow_Flicker_Study

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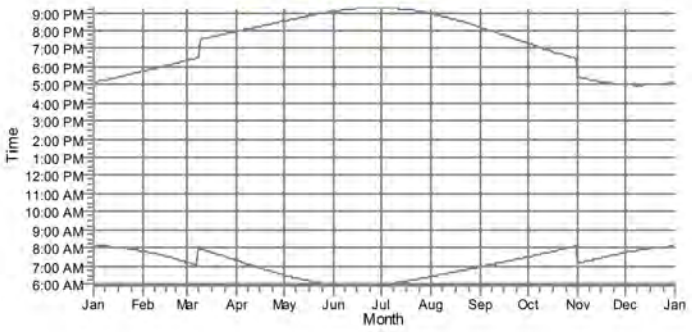
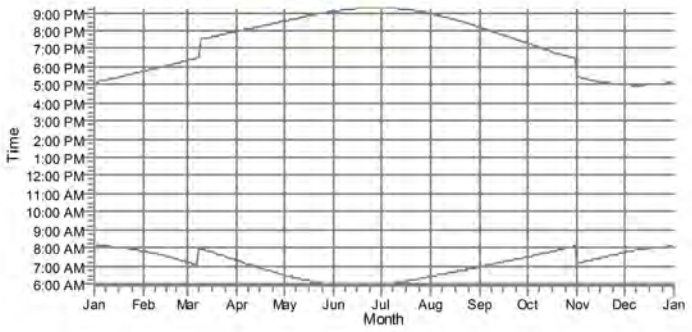
SHADOW - Calendar, graphical

Calculation: Shadow Flicker Analysis v2-WTGs (06.27.2016)

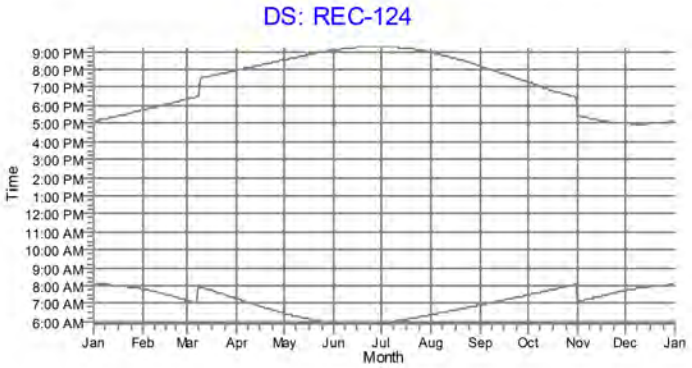
DQ: REC-122



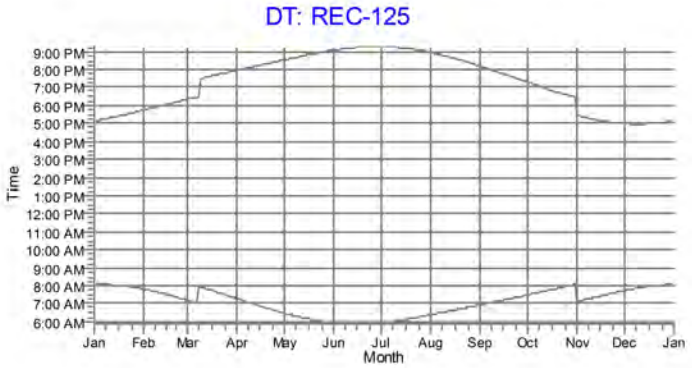
DR: REC-123



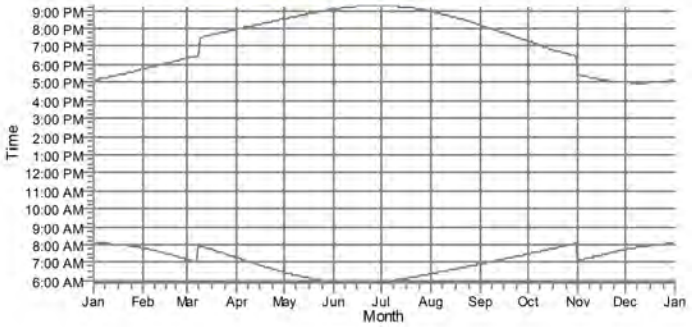
DS: REC-124



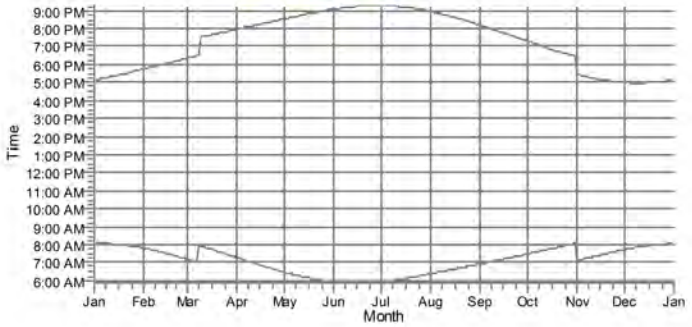
DT: REC-125



DU: REC-126



DV: REC-127



WTGs

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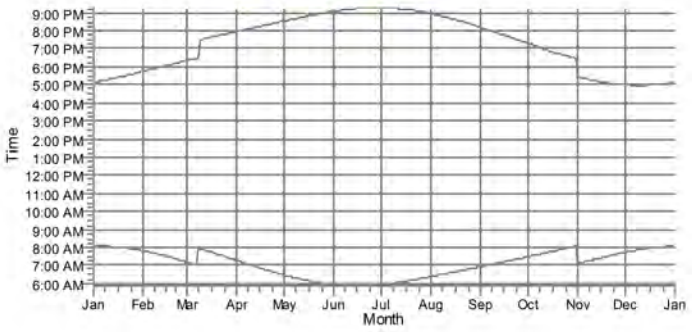
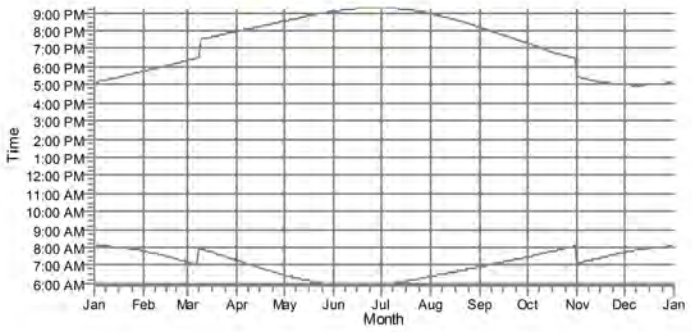
SHADOW - Calendar, graphical

Calculation: Shadow Flicker Analysis v2-WTGs (06.27.2016)

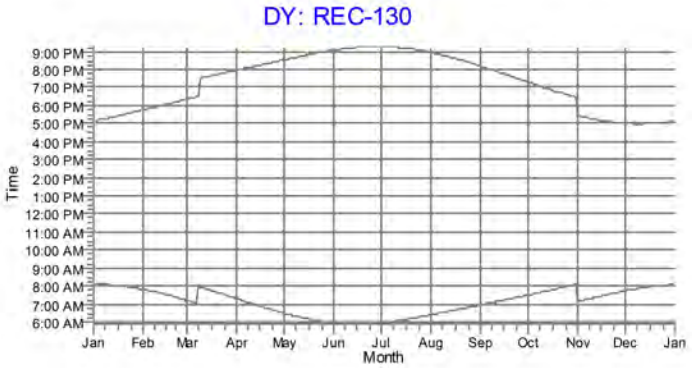
DW: REC-128



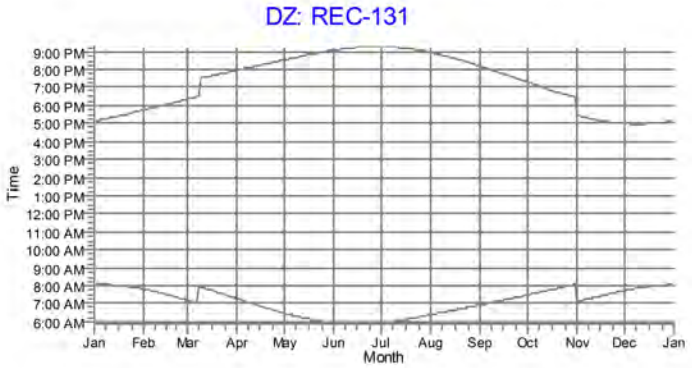
DX: REC-129



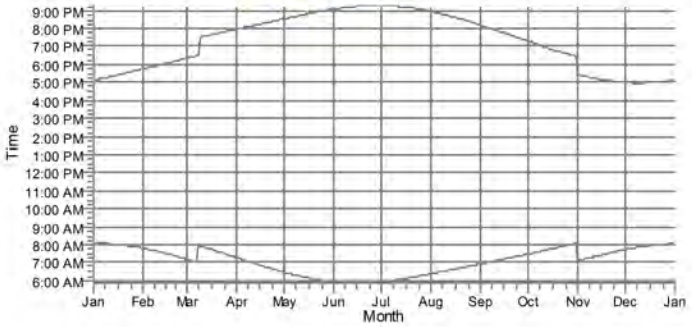
DY: REC-130



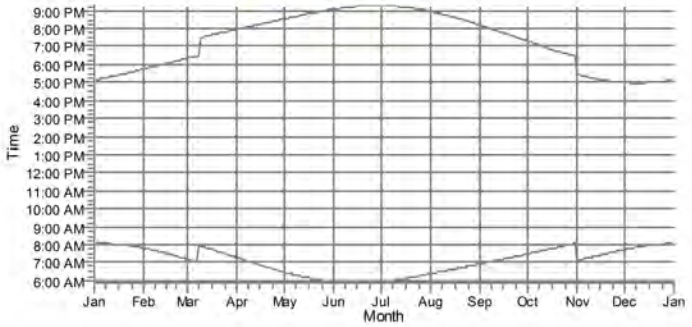
DZ: REC-131



EA: REC-132



EB: REC-133



WTGs

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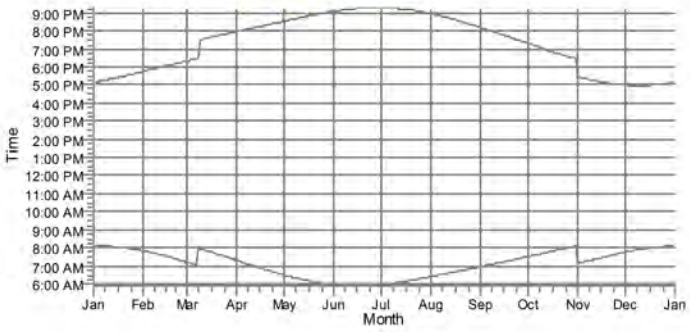
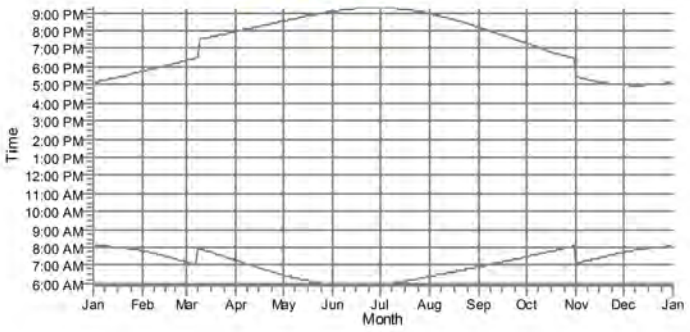
SHADOW - Calendar, graphical

Calculation: Shadow Flicker Analysis v2-WTGs (06.27.2016)

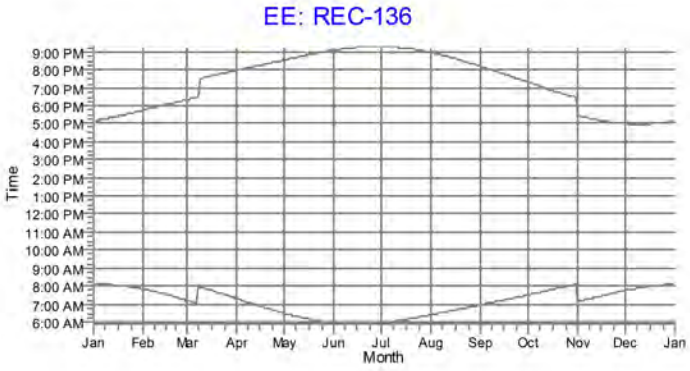
EC: REC-134



ED: REC-135



EE: REC-136



WTGs

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