

# Appendix C-8: Shadow Flicker Analysis (June 4, 2013)

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C-8.1: GE 1.7-100 Shadow Flicker Analysis (June 4, 2013)

C-8.2: Vestas 2.0-110 Shadow Flicker Analysis (June 4, 2013)

C-8.3: Siemens SWT-2.3-108 Shadow Flicker Analysis (June 4, 2013)

C-8.4: Siemens SWT-3.2-113 Shadow Flicker Analysis (June 4, 2013)

# Memorandum



Date: June 4, 2013

To: EDF Energy Renewables (EDF)

From: Kory Sandven, Burns & McDonnell

Subject: Stoneray Wind Farm – Worst-Case Shadow Flicker Analysis using Vestas 2.0-110 Turbines.(v1)  
BMcD Project No. 62823

Burns & McDonnell performed a worst-case analysis of shadow flicker at the proposed Stoneray Wind Farm in Minnesota. Shadow flicker occurs when moving wind turbine blades cast shadows upon stationary objects, such as occupied residences. Such shadows occur only under very specific conditions, including sun position, wind direction, time of day, and other similar factors.

The analysis was modeled using WindPRO, an industry-leading software package for the design and planning of wind energy projects. The following is a brief summary of the assumptions and inputs utilized in shadow the flicker analysis:

### **Turbine Layout**

A quantity of 50 Vestas 2.0-110 turbines were modeled at the project site, using the coordinates shown in Attachment A, Table 1. All coordinates were furnished by EDF. Each turbine was modeled with a hub height of 95 meters, a rotor diameter of 100 meters, and maximum rotor speed of 14.9 rpm.

### **Occupied Residences**

A quantity of 139 occupied residences was modeled at the project site, using the coordinates shown in Attachment A, Table 2. All coordinates were furnished by EDF. Each receptor was modeled as a “greenhouse”, i.e. a worst-case approach wherein every home is modeled as having windows on all sides.

### **Terrain**

The terrain data was provided by EDF using privately flown data from 2011 composed by Westwood Engineering.

Using the aforementioned assumptions and inputs, WindPRO was used to calculate how often and during what periods each receptor would be affected by shadows generated by one or more wind turbines. To produce a conservative output, the model was run under a worst-case scenario, including the following:

- The sun was assumed to always be shining from sunrise to sunset (i.e., no cloud cover, no rainy days, etc. that would reduce flicker effects);

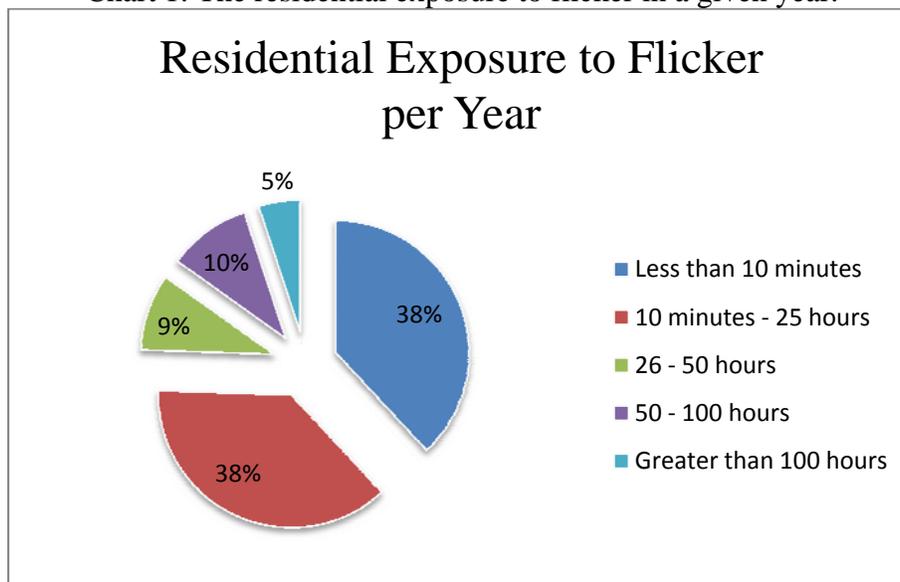
June 4, 2013

Page 2

- The turbines were assumed to always be operating (i.e., constantly spinning, and no downtime due to very low or very high wind speeds);
- The turbine rotors were assumed to always be perpendicular to the individual homes;
- A conservative distance of 2,000 meters was estimated as the maximum distance at which flicker was considered relevant (i.e., shadows cast beyond this distance were considered immaterial); and
- A value of three (3) degrees was utilized for the height below which the sun would not cause noticeable flicker (due to atmospheric diffusion, low radiation, sheltering, etc.).

The results of the worst-case flicker analysis are included in Attachment A, Table 2 by residence. This information was produced directly from the WindPRO model, and using the aforementioned inputs and assumptions. The following chart describes the results from the worst-case flicker analysis:

Chart 1: The residential exposure to flicker in a given year.



A summary of the results from the worse-case flicker analysis are described below:

- 86 of the 139 homes considered (61.9%) experienced at least 10 total minutes of worst-case flicker over the course of a year.
- 105 of the 139 homes considered (75.5%) experienced less than 25 total hours of worst-case flicker over the course of a year.

## Memorandum *(continued)*



June 4, 2013

Page 3

- 118 of the 139 homes considered (84.9%) experienced less than 50 total hours of worst-case flicker over the course of a year.
- 132 of the 139 homes considered (95%) experienced less than 100 total hours of worst-case flicker over the course of a year.
- Only 7 of the 139 homes considered (5%) experienced more than 100 total hours of worst-case flicker over the course of a year.

KPS

cc: Robert Everard, BMcD  
Aaron Anderson, BMcD

June 4, 2013

Page 4

**Attachment A**

**Table 1: Wind Turbine Coordinates**

Turbine Number	Easting [m]	Northing [m]	Elevation [masl]	Turbine Number	Easting [m]	Northing [m]	Elevation [masl]
V WTG-1	728057	4882900	539.5	V WTG-26	737898	4872017	534.5
V WTG-2	727319	4883374	539.5	V WTG-27	727281	4881996	529.3
V WTG-3	730942	4875716	533.5	V WTG-28	728312	4883510	542.5
V WTG-4	726608	4876419	511	V WTG-29	733520	4871695	539.5
V WTG-5	729929	4882900	545.6	V WTG-30	727496	4882674	536.4
V WTG-6	738294	4873242	539.6	V WTG-31	728464	4878997	530.4
V WTG-7	729326	4876005	523.8	V WTG-32	727640	4877629	527.3
V WTG-8	736710	4872344	545.6	V WTG-33	726407	4877055	512.1
V WTG-9	727746	4883491	544.4	V WTG-34	734596	4872724	542.4
V WTG-10	737875	4872933	544.7	V WTG-35	727555	4878695	530.4
V WTG-11	732319	4882053	553.6	V WTG-36	733924	4882411	573
V WTG-12	734268	4872766	537.3	V WTG-37	728057	4881331	536.4
V WTG-13	733142	4879822	553.9	V WTG-38	730679	4882356	551.7
V WTG-14	729115	4879569	530.4	V WTG-39	732977	4874274	527.7
V WTG-15	727441	4877375	527.3	V WTG-40	732419	4880855	554.7
V WTG-16	727813	4878794	530.4	V WTG-41	732560	4874606	533.4
V WTG-17	727735	4881953	533.4	V WTG-42	733102	4875747	548.6
V WTG-18	734863	4872787	543.7	V WTG-43	730801	4876640	540.9
V WTG-19	734049	4875766	551.7	V WTG-44	727084	4877272	526.1
V WTG-20	736266	4871778	548.6	V WTG-45	731276	4875703	539.5
V WTG-21	735942	4870979	546.5	V WTG-46	735217	4872585	551.1
V WTG-22	731122	4882748	551.7	V WTG-47	735944	4872388	551.7
V WTG-23	726553	4883797	538.3	V WTG-48	736382	4872386	544.7
V WTG-24	726844	4877135	521.8	V WTG-49	728219	4878847	530.4
V WTG-25	727494	4884246	542.5	V WTG-50	737652	4872772	545.4

*Note: all coordinates provided as UTM NAD83 Zone 14*

June 4, 2013

Page 5

**Table 2: Occupied Residence Coordinates and Flicker Results**

Residence Number	Easting [m]	Northing [m]	Elevation [masl]	Worst-Case Flicker [Hours/Year]
A	728,693	4,885,001	549	5
B	728,356	4,885,174	550	0
C	731,819	4,884,542	564	0
D	730,190	4,884,446	561	0
E	727,056	4,884,807	545	0
F	726,222	4,884,788	543	5
G	728,602	4,884,373	546	14
H	727,334	4,883,949	540	57
I	730,186	4,884,037	556	1
J	731,788	4,884,082	553	0
K	731,963	4,883,685	564	0
L	729,179	4,883,057	543	54
M	730,868	4,883,327	548	10
N	733,480	4,883,419	579	0
O	734,503	4,883,422	573	0
P	730,411	4,882,660	552	147
Q	730,273	4,882,808	552	168
R	726,763	4,882,365	529	110
S	727,355	4,882,324	531	106
T	736,438	4,881,885	567	0
U	736,640	4,881,829	563	0
V	733,270	4,881,978	559	11
W	730,792	4,881,735	544	7
X	728,754	4,881,851	531	38
Y	725,455	4,881,848	533	1
Z	726,987	4,881,298	524	9
AA	728,658	4,881,401	536	36
AB	730,302	4,881,628	544	0
AC	731,919	4,881,473	539	0
AD	732,037	4,881,304	546	31
AE	733,626	4,881,077	563	5
AF	733,323	4,881,089	564	11
AG	728,812	4,880,750	536	0
AH	735,711	4,880,265	574	0
AI	733,187	4,880,244	563	0
AJ	731,518	4,880,132	541	3
AK	730,052	4,880,248	537	13
AL	729,522	4,879,989	537	57
AM	727,390	4,880,003	533	2
AN	733,651	4,879,589	549	36
AO	734,411	4,878,603	555	0
AP	734,743	4,878,619	556	0
AQ	736,990	4,878,109	572	0
AR	732,924	4,877,907	549	0
AS	732,125	4,877,854	552	0

# Memorandum *(continued)*



June 4, 2013

Page 6

AT	732,021	4,877,692	552	6
AU	730,412	4,877,912	540	0
AV	732,084	4,877,289	555	3
AW	733,741	4,877,520	559	0
AX	736,253	4,877,010	564	0
AY	733,393	4,876,851	558	0
AZ	731,644	4,876,898	549	13
BA	732,164	4,876,828	555	3
BB	732,219	4,876,820	555	6
BC	732,417	4,876,820	554	7
BD	732,553	4,876,901	555	3
BE	732,345	4,876,895	555	4
BF	732,103	4,876,825	555	4
BG	732,628	4,876,899	555	1
BH	732,805	4,876,902	558	2
BI	732,687	4,876,814	555	7
BJ	732,909	4,876,904	558	0
BK	732,914	4,876,941	558	0
BL	732,960	4,876,926	558	0
BM	736,865	4,876,103	556	0
BN	732,423	4,875,998	551	34
BO	730,522	4,875,871	528	75
BP	734,558	4,875,781	560	44
BQ	737,391	4,875,467	550	0
BR	738,558	4,875,126	566	0
BS	732,250	4,875,212	545	33
BT	731,084	4,875,277	536	5
BU	731,016	4,875,274	535	5
BV	731,686	4,875,129	549	22
BW	730,869	4,875,304	531	7
BX	730,488	4,875,292	524	31
BY	730,145	4,875,262	520	34
BZ	730,539	4,874,777	527	0
CA	738,438	4,874,473	551	0
CB	735,472	4,874,184	552	0
CC	735,499	4,873,706	555	6
CD	739,080	4,873,799	552	17
CE	737,183	4,873,265	543	59
CF	733,838	4,873,138	533	97
CG	733,953	4,873,213	535	64
CH	735,444	4,873,106	555	60
CI	739,172	4,872,304	548	20
CJ	737,183	4,872,549	533	188
CK	735,601	4,872,363	549	157
CL	733,962	4,872,115	543	65
CM	733,973	4,871,931	541	60
CN	735,597	4,871,471	540	47
CO	737,246	4,871,752	538	79
CP	737,139	4,871,614	543	56

# Memorandum *(continued)*



June 4, 2013

Page 7

CQ	734,000	4,870,899	529	2
CR	736,444	4,870,583	546	0
CS	736,255	4,870,427	547	0
CT	734,252	4,870,392	522	4
CU	733,915	4,870,268	520	0
CV	726,286	4,884,670	542	6
CW	734,729	4,883,355	575	0
CX	728,915	4,877,901	521	9
CY	737,359	4,877,097	564	0
CZ	737,097	4,872,205	539	132
DA	736,560	4,870,047	544	0
DB	728,918	4,877,351	525	11
DC	732,155	4,877,165	555	3
DD	732,093	4,877,183	555	4
DE	729,402	4,875,186	517	7
DF	729,971	4,875,213	518	34
DG	725,128	4,883,188	536	5
DH	725,325	4,877,837	518	19
DI	725,339	4,876,614	530	15
DJ	726,386	4,876,720	512	99
DK	727,255	4,876,534	521	24
DL	727,579	4,876,747	524	32
DM	727,247	4,875,176	509	0
DN	726,791	4,875,160	509	0
DO	726,359	4,875,131	521	0
DP	733,797	4,874,196	539	23
DQ	732,278	4,874,316	533	22
DR	732,341	4,873,597	524	0
DS	732,034	4,873,693	524	11
DT	729,080	4,873,567	514	0
DU	729,099	4,873,450	515	0
DV	728,751	4,874,291	514	0
DW	728,704	4,875,076	515	0
DX	728,689	4,875,171	516	0
DY	727,493	4,874,116	507	0
DZ	727,529	4,873,362	505	0
EA	727,780	4,872,070	502	0
EB	728,851	4,872,688	513	0
EC	727,738	4,876,680	523	29
ED	729,178	4,876,706	522	6
EE	726,304	4,875,021	524	0
EF	727,800	4,875,160	513	8
EG	732,024	4,874,344	536	65
EH	732,407	4,872,671	520	2
EI	732,173	4,872,460	519	6

*Note: all coordinates provided as UTM NAD83 Zone 14*

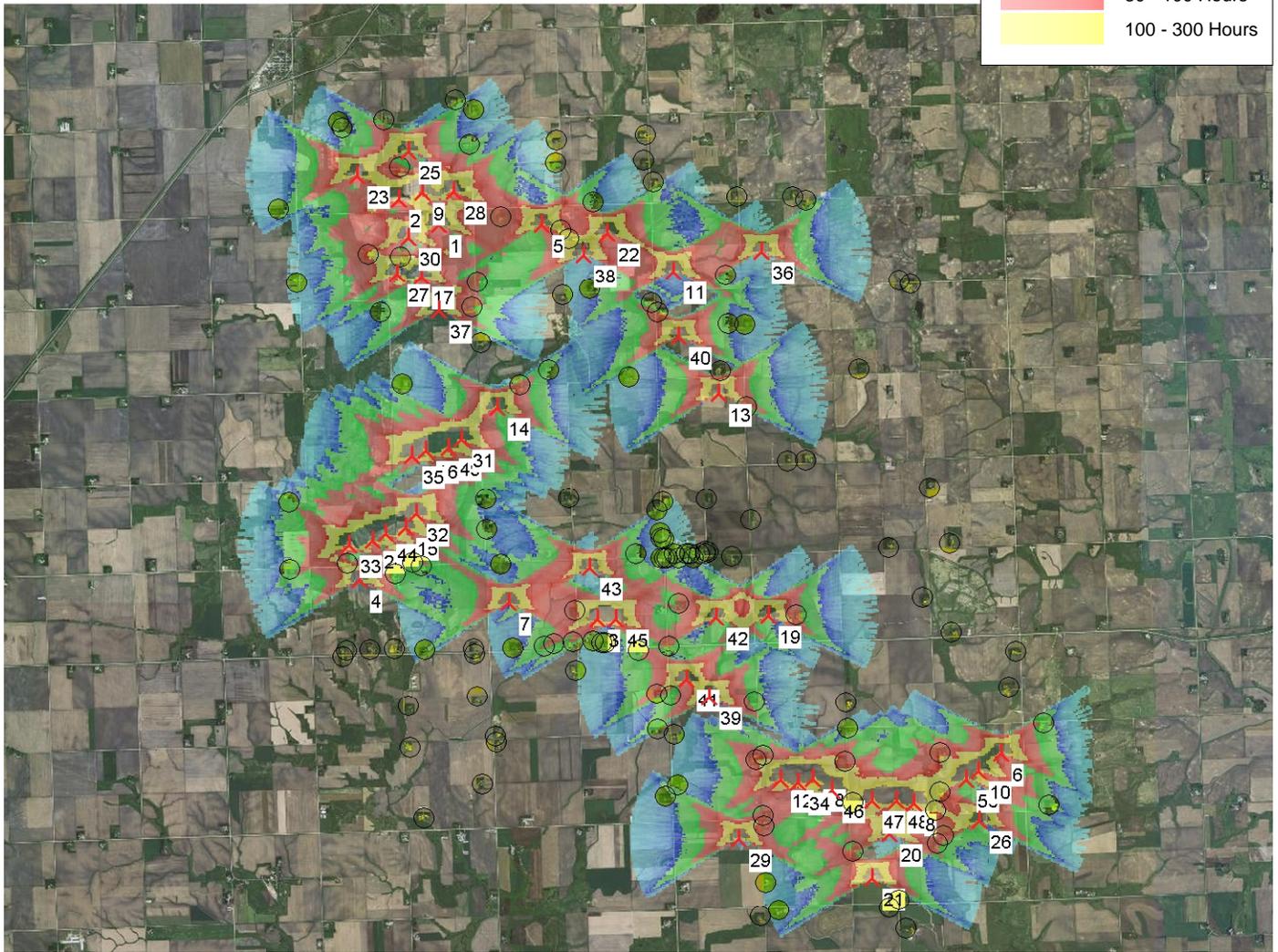
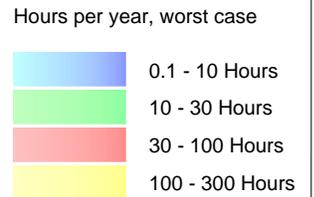
Project:  
**Stoneray Wind Project**

Description:  
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Calculated:  
6/5/2013 12:24 PM/2.9.207

**SHADOW - Map**

Calculation: Turbine Layout Vestas 2000-110



Map: Aerial , Print scale 1:125,000, Map center UTM (north)-NAD83 (US+CA) Zone: 14 East: 731,680 North: 4,878,320

New WTG      Shadow receptor

Flicker map level: Height Contours: 10ft Contours from NED 30m.wpo (1)