Appendix G
Shadow Flicker Analysis for the University of Delaware

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Shadow Flicker Analysis for the University of Delaware

The University of Delaware has proposed the installation of a wind turbine at their College of Marine & Earth Studies campus in Lewes, DE to act as an educational and research tool for on-site and offshore wind turbine development in Delaware, as well as provide electricity cost savings for University of Delaware. A feasibility study was commissioned to evaluate numerous areas to site the wind turbine utilizing wind industry best practices, setbacks from residential and/or sensitive environmental areas. Shadow flicker is one effect of wind turbines that requires additional investigation, particularly as it relates to nearby residential areas.

Shadow flicker occurs when wind turbine blades cast a shadow on the surrounding area when the blades pass in front of the sun. The location and occurrence of the shadow effect depends on the time of year, time of day and the position of the sun in the sky. The shadow effects' main disturbance area is any unshaded windows of buildings, especially residential areas where people would be most likely to experience these effects. Generally, the discernable shadow flicker effect only occurs on properties within ten turbine rotor diameters from the wind turbine[1]. In the case of the University of Delaware wind turbine this would equal a radius of 900 meters from the wind turbine.
Shadow flicker effects will only occur under certain conditions:

- During daylight hours
- When the sun is shining, no overcast or foggy conditions
- Within 10 rotor diameters of turbine
- When wind turbine is in operation or spinning

Receptors

The wind turbine to be installed is a Gamesa G90 2.0MW wind turbine with an 80 meter hub height and a 90 meter rotor diameter. This turbine will be located to the southwest of the main campus off of Pilottown Road in the City of Lewes, adjacent to an existing dredge spoils area. SED identified six receptor areas to evaluate the shadow flicker impacts from the UD wind turbine. The receptors are representative of areas that could

[1] http://www.meridianenergy.co.nz

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be impacted by shadow flicker or have been identified as sites of particular concern. These areas were selected based on several criteria:

- Distance to wind turbine location - within 10 rotor diameters of site or 900 meters (2950')
- Areas most likely to be effected by shadow effects related to position of sun in the sky – locations to the east, west, and north of wind turbine
- Current use of facility (residence, classroom, overnight lodging)
- Areas of cultural and historical significance
- Line of site to wind turbine from windows at site

Shadows will be cast on specific days of the year and will move from one point to another relatively quickly. And certain areas are more susceptible to shadow effects at certain times of the day. Areas to the west of the wind turbine would experience these effects as the sun rises. Areas to the north would experience the effects during the day. Areas to the east would experience these as the sun sets. The shadows cast by the wind turbine blades will be narrow, be of low intensity and move rapidly at the receptor. The closer a receptor is to the wind turbine, the more intense the shadows, as a greater proportion of the sun is blocked by the rotating wind turbine blades.

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An image showing the proposed turbine location as well as the receptor sites used for this analysis is shown below:

Methodology

SED used the Shadow Flicker module of the software program Wind Farm version 4.1.1, as well as a digital elevation model and dimensions of the G90 wind turbine assumed to represent the impact of shadow flicker on 6 receptor sites. Each receptor site was assumed to be a residence with a single bay window 3 meters wide by 2 meters high (9.84 x 6.56 ft.), and elevated 2 meters off above ground level. For the purposes of this analysis, SED assumed that each of these windows is directly facing the wind turbine. The results of the shadow flicker analysis are attached to this document in the form of

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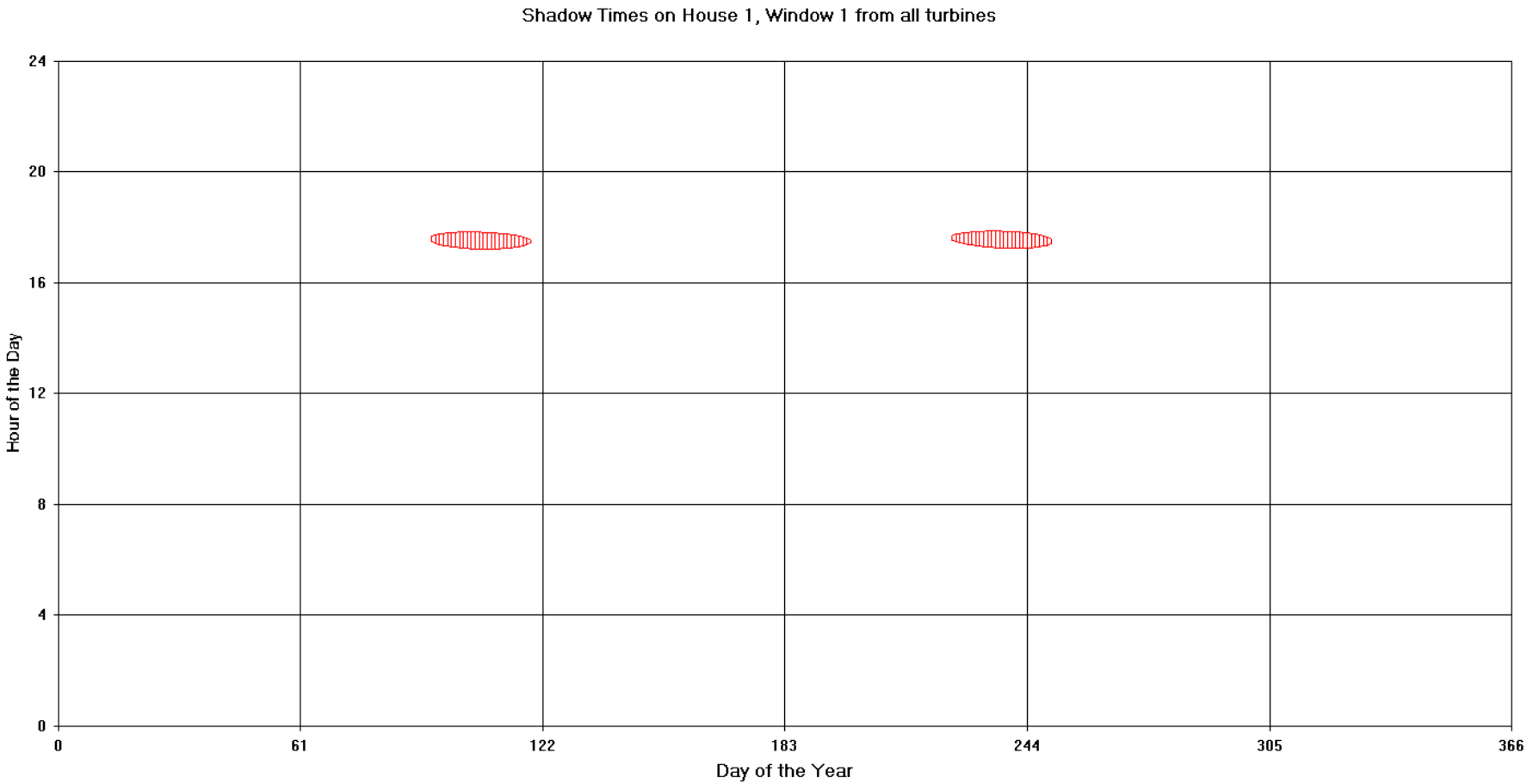
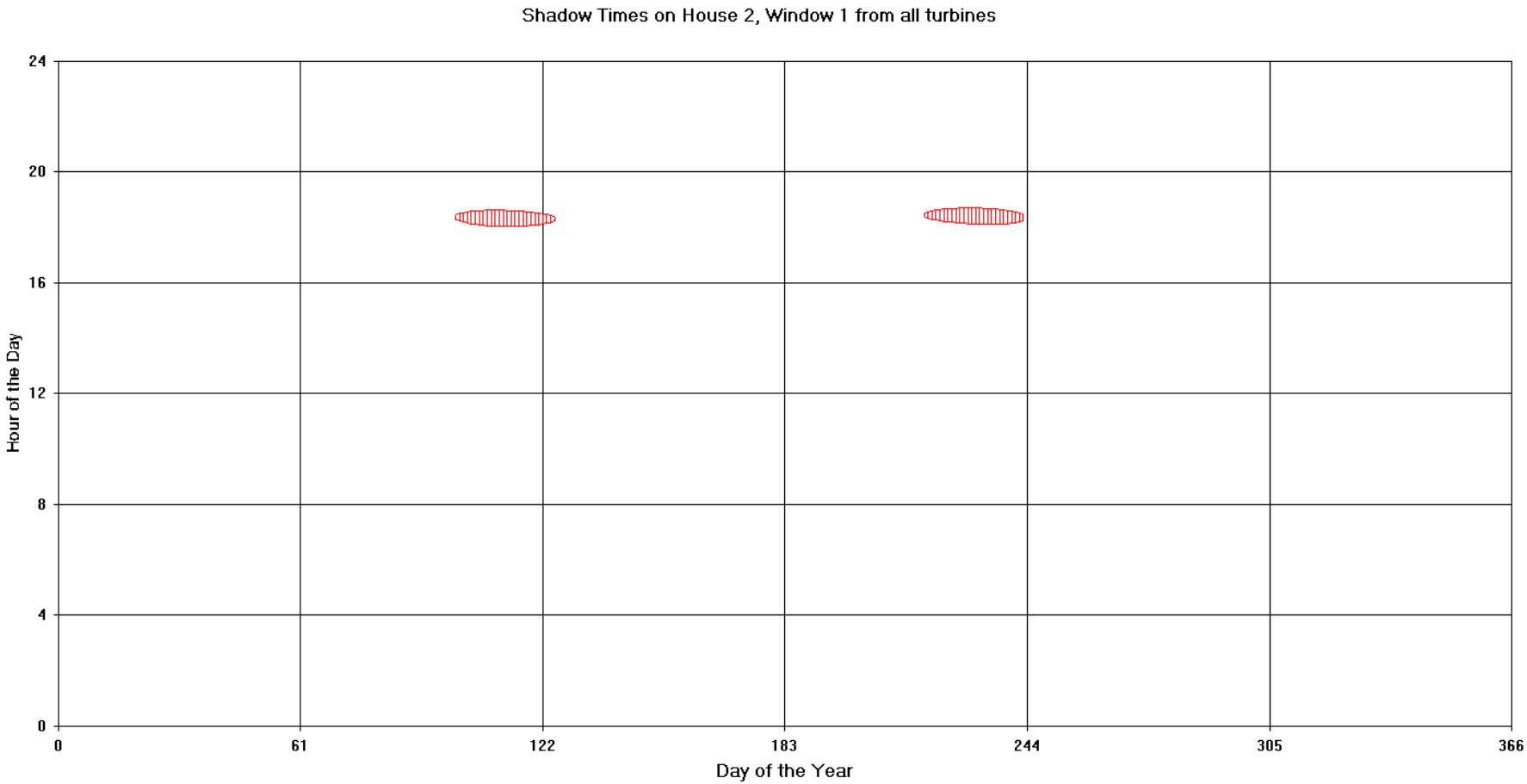
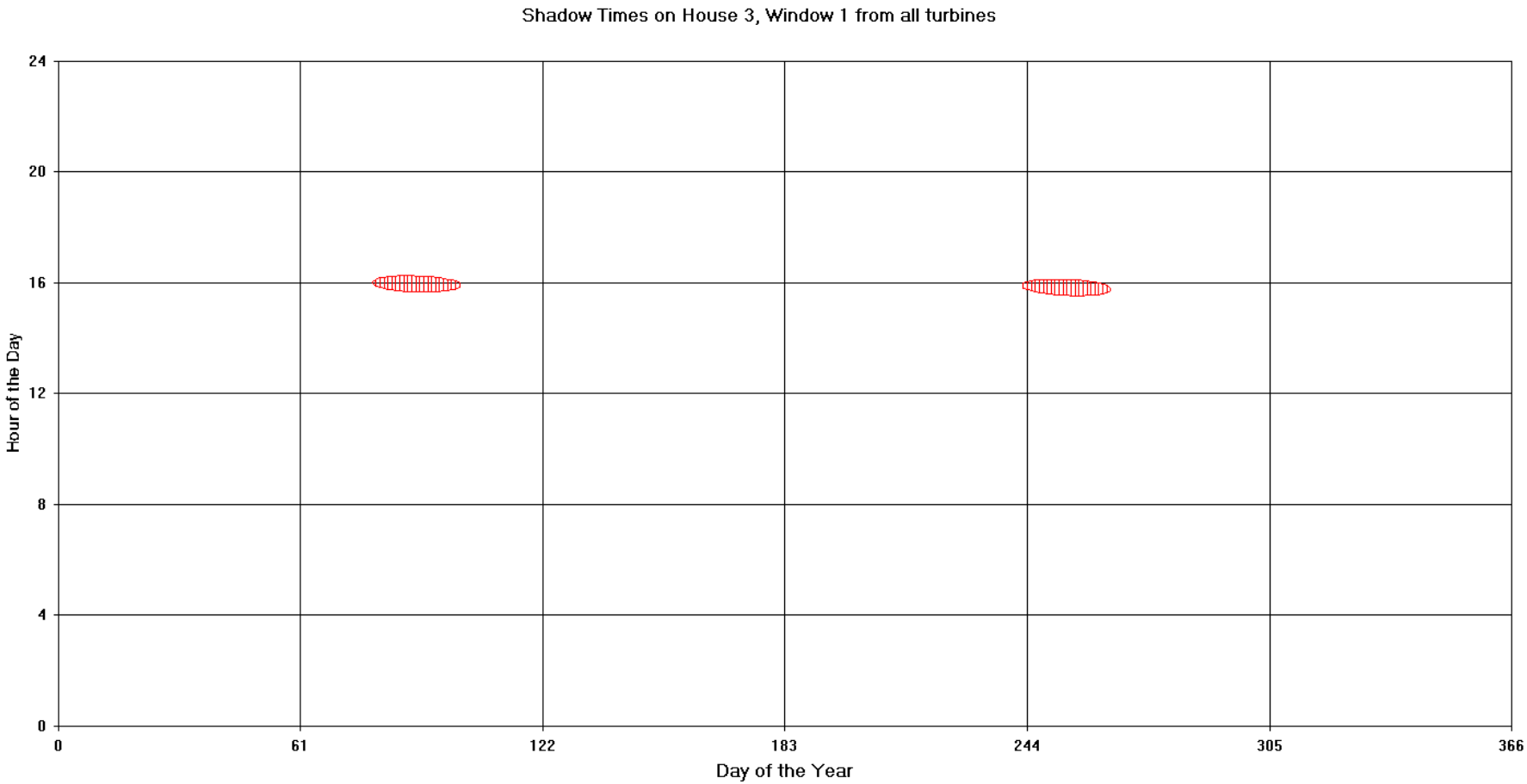
"shadow calendars." These shadow calendars offer a graphical representation of when each receptor site might be impacted by shadow flicker assuming that the wind turbine is constantly spinning, the rotor is always facing the sun, and that the sun shines during every daytime hour of a given year. Because these conservative assumptions were used for the purposes of this analysis, it is likely that the impact of shadow flicker on these receptor sites will be significantly less than the model predicts. Shadow calendars show the times of year as well as the time of day that shadow flicker may be visible at each receptor sites. Note that these graphical representations refer to receptor sites as "houses."

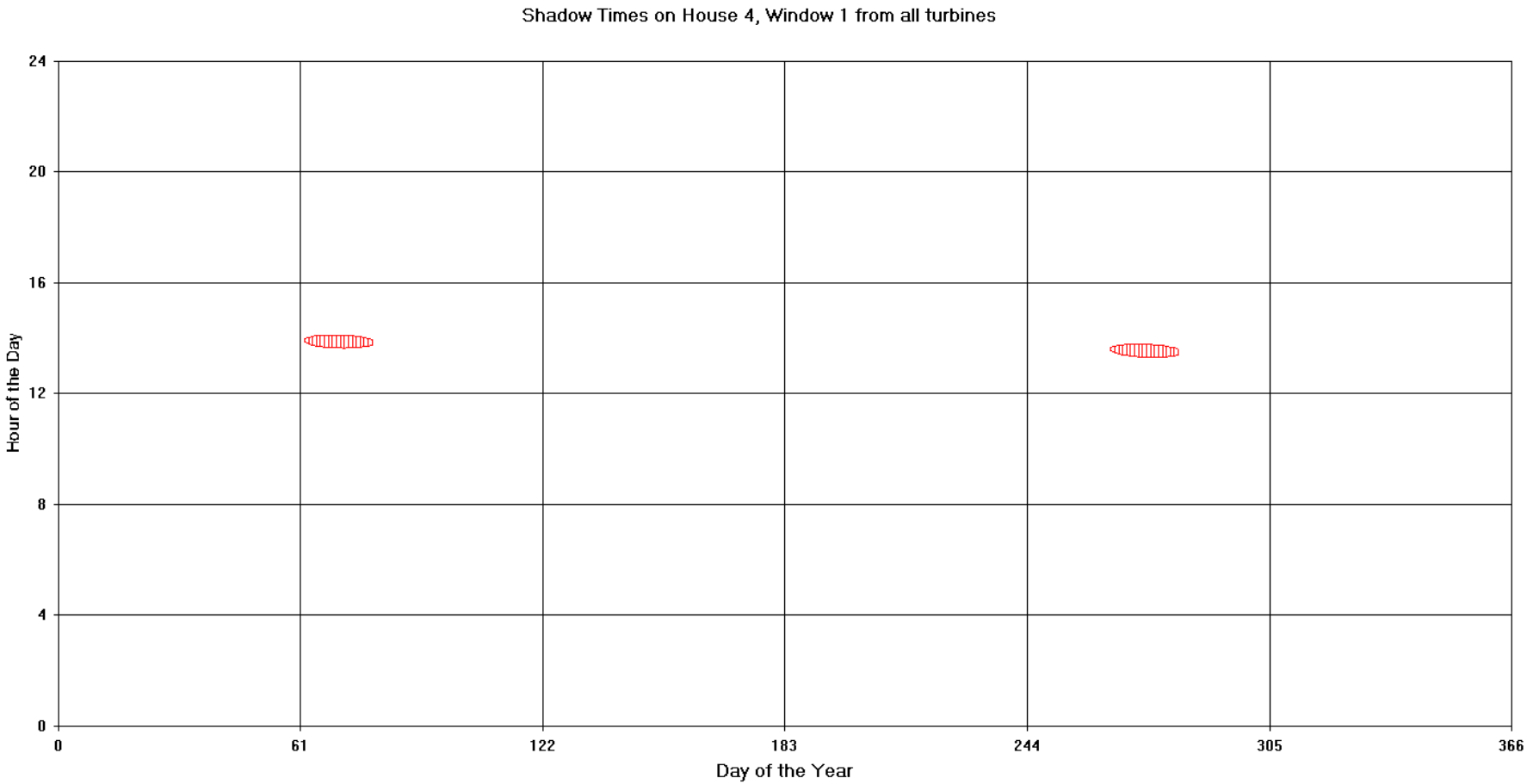
Conclusion

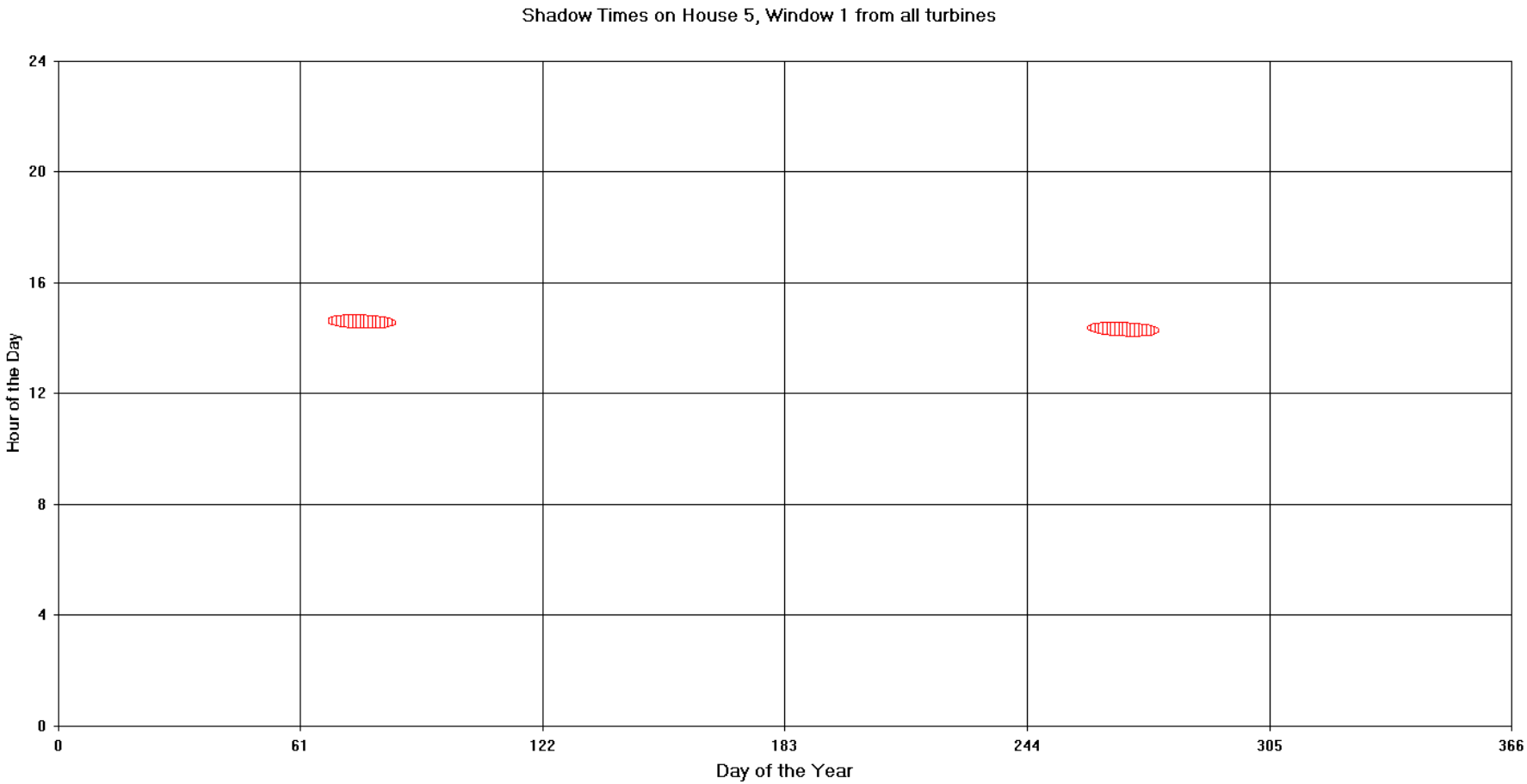
In Delaware there are no specific regulations relating to acceptable degrees of shadow flicker impact at a specific location. Based on the results presented in this assessment, SED does not consider that the proposed wind turbine will have any adverse shadow flicker impacts to the surrounding area. The most impacted receptor would be the University buildings, but the majority of the windows face away from where the wind turbine would be located. While all 6 receptor sites may experience some shadow flicker, it will occur only during brief periods on any given day, and will not occur at any sites for the vast majority of the year.

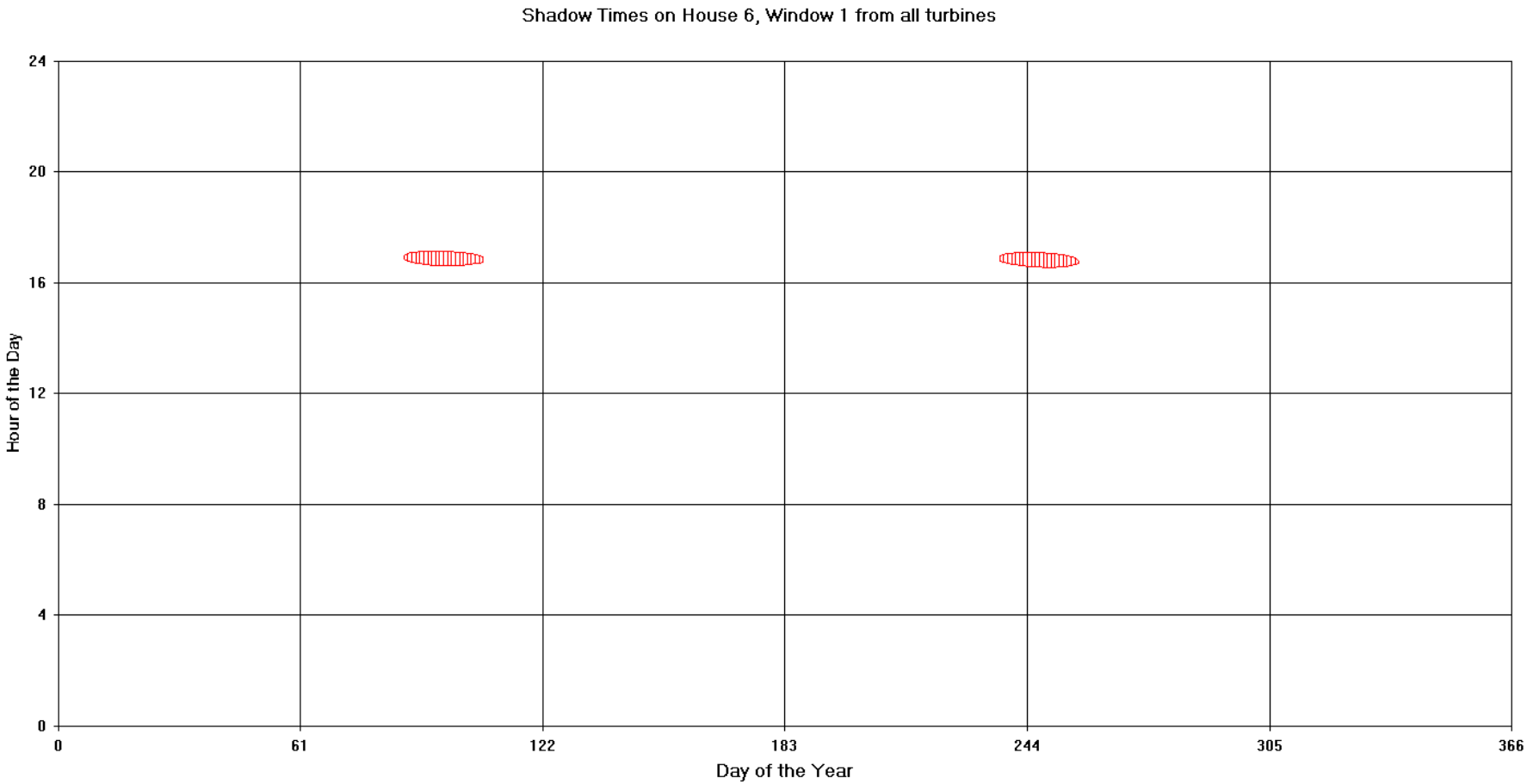

Shadow Times on House 1, Window 1 from all turbines
Hour of the Day
24
20
16
12
8
4
0
0
61
122
183
244
305
366
Day of the Year


Shadow Times on House 2, Window 1 from all turbines
Hour of the Day
24
20
16
12
8
4
0
0
61
122
183
244
305
366
Day of the Year


Shadow Times on House 3, Window 1 from all turbines
Hour of the Day
24
20
16
12
8
4
0
0
61
122
183
244
305
366
Day of the Year


Shadow Times on House 4, Window 1 from all turbines
Hour of the Day
24
20
16
12
8
4
0
0
61
122
183
244
305
366
Day of the Year


Shadow Times on House 5, Window 1 from all turbines
Hour of the Day
24
20
16
12
8
4
0
0
61
122
183
244
305
366
Day of the Year


Shadow Times on House 6, Window 1 from all turbines
Hour of the Day
24
20
16
12
8
4
0
0
61
122
183
244
305
366
Day of the Year

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Title :
Time : 13:17:30, 23 Feb 2010

SUMMARY OF SHADOW TIMES ON EACH WINDOW

House/ Window	Easting	Northing	Width (m)	Depth (m)	Height (m)	Degrees from North	Tilt angle	Days per year	Max hours per day	Mean hours per day	Total hours
1/ 1	486273	4292543	3.0	2.0	2.0	285.0	0.0	51	0.59	0.46	23.3
2/ 1	486259	4292401	3.0	2.0	2.0	295.0	0.0	50	0.57	0.44	22.2
3/ 1	486308	4292819	3.0	2.0	2.0	260.0	0.0	44	0.56	0.44	19.5
4/ 1	486256	4293267	3.0	2.0	2.0	225.0	0.0	35	0.46	0.36	12.5
5/ 1	486336	4293127	3.0	2.0	2.0	237.0	0.0	36	0.47	0.36	13.1
6/ 1	486378	4292651	3.0	2.0	2.0	270.0	0.0	42	0.52	0.41	17.1