

Subject: Shadow-Flicker Modeling
Dutch Hill, NY.

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Project type: Modeling

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1. Introduction

This Project Briefing provides a brief explanation of the shadow-flicker phenomenon, the modeling approach employed and relevant explanations and results.

2. Shadow-Flicker Background

Shadow-flicker from wind turbines is defined as alternating changes in light intensity caused by rotating blades casting shadows on the ground and stationary objects such as a window at a dwelling. No shadow will be cast when the sun is obscured by clouds/fog or when the turbine is not operating.

Shadow-flicker can occur in project area homes when the turbine is located near a home and is in a position where the blades interfere with very low-angle sunlight. The most typical effect is the visibility of an intermittent light reduction in the rooms of the home facing the wind turbines and subject to the shadow-flicker. Such locations are here referred to as shadow-flicker receptors. Obstacles such as terrain, trees, or buildings between the wind turbine and a potential shadow-flicker receptor significantly reduce or eliminate shadow-flicker effects.

The spatial relationships between a wind turbine and receptor, as well as wind direction are key factors related to shadow-flicker time (hours per year). General industry practices place turbines at least 1000 ft from receptors. At this distance shadow flicker usually only occurs at sunrise or sunset when the cast shadows are sufficiently long.

Shadow flicker intensity is defined as the difference in brightness at a given location in the presence and absence of a shadow. Shadow flicker intensity diminishes with greater receptor-to-turbine separation distance and low visibility weather conditions, such as haze or fog.

The analysis performed for this report does not evaluate the shadow flicker intensity, but rather focuses on the total amount of time (hours and minutes/year) that shadow flicker can potentially occur at receptors regardless of whether the shadow flicker is barely noticeable or

clearly distinct. Consequently, it is likely that receptors will experience less shadow-flicker impact than modeled and reported, especially those that are further away from turbines. It is very likely that marginally affected receptors may not be able to identify shadow-flicker at all.

The shadow-flicker frequency is related to the rotor speed and number of blades on the rotor. The modeling results presented are based on a wind turbine with a 3-bladed, 96 meter diameter rotor, 80 meter hub height and a nominal rotor speed of 15.5 RPM which translates to a blade pass frequency of 0.8 Hz (less than 1 alternation per second). Health wise, such low frequencies are harmless. Frequencies higher than 3 Hz but below 10 Hz are widely used in discotheques and the Epilepsy Foundation has made statements that frequencies below 10 Hz are not likely to trigger epileptic seizures.

3. Modeling Approach

A near worst case approach has been adopted for reporting the shadow-flicker results. Additional general site and receptor-specific assessments such as obstacles, diurnal and seasonal cloud and fog patterns may further reduce the reported shadow flicker impacts. The analysis assumes windows are situated in direct alignment with the turbine to sun line of sight. Even when windows are so aligned, the analysis does not account for the difference between windows in rooms with primary use and enjoyment (e.g. living rooms) and other less frequently occupied or un-occupied rooms or garages.

The shadow-flicker model uses the following input:

- Turbine locations (coordinates)
- Shadow Flicker receptor (residence) locations (coordinates)
- USGS 1:24,000 topographic and USGS DEM (height contours)
- Turbine rotor diameter
- Turbine hub height
- Joint wind speed and direction frequency distribution
- Sunshine hours (long term monthly reference data)

The model calculates detailed shadow-flicker results at each assessed receptor location and the amount of shadow-flicker time (hours/year) everywhere surrounding the project (on an iso-line plot). A receptor in the model is defined as a 1 m² area 1 meter above ground level. This omni-directional approach produces shadow-flicker results at a receptor regardless of the direction of windows and provides similar results as a model with windows on various sides of the receptor.

The sun's path with respect to each turbine location is calculated by the software to determine the cast shadow paths every 2 minutes, every day over a full year.

The turbine run-time and direction (seen from the receptor) are calculated from the site's long-term wind speed and direction distribution.

Finally, the effects of cloud cover are calculated using long term reference data (monthly average sunshine hours) to arrive at the projected annual flicker time at each receptor.

Output from the model includes the following information:

- Calculated shadow-flicker time at selected receptors
- Tabulated and plotted time of day with shadow flicker at selected receptors
- Map showing turbine locations, selected shadow-flicker receptors and iso-line contours indicating projected shadow-flicker time (hours per year).

4. Conclusion

The shadow-flicker model assumptions applied to this project are very conservative and as such, the analysis is expected to over-predict the impacts. Additionally, many of the modeled shadow flicker hours are expected to be of very low intensity.

The results are therefore prudent projections of the anticipated shadow flicker levels that would be experienced at the nearby residences. Of the 126 modeled receptors (126 receptors being within approximately 1,500 meter of a wind turbine), only four receptor potentially receive shadow flicker for more than 25 hours per year. All other modeled receptors potentially receive little or no shadow flicker.

The overall statistics are outlined below:

Cumulative shadow-flicker time	Number of receptors
Total	126
>0 hours	90
>10 hours	15
>15 hours	9
>20 hours	5
>25 hours	4

Fig. 1. Overall statistics, all modeled receptors.

The number of shadow-flicker hours calculated and reported above in the table is common and significantly lower than at other wind power projects installed in the state of New York and around the USA.

For clarifications and eventual detailed analyses of expected influence at selected receptors please contact:

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