SUMMARY OF SHADOW FLICKER STUDY RESULTS

Heritage Prairie Wind Project

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Introductions

STUDY LEAD

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- Education: B.S. Physics;
  B.S. Mechanical Engineering;
  B.S. Engineering Management
- Licensed professional engineer in multiple states, including Illinois
- 17+ years of wind industry experience
- Conducted > 100 shadow flicker studies, including > 10 in Illinois

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Shadow Flicker Overview

Flicker occurs when wind turbine blades pass in front of sun creating shadow

Requirements for flicker to occur:

- Sunny day
- Turbine in operation
- No obstructions
- Receptor in line of site

Most common during certain seasons and times of day

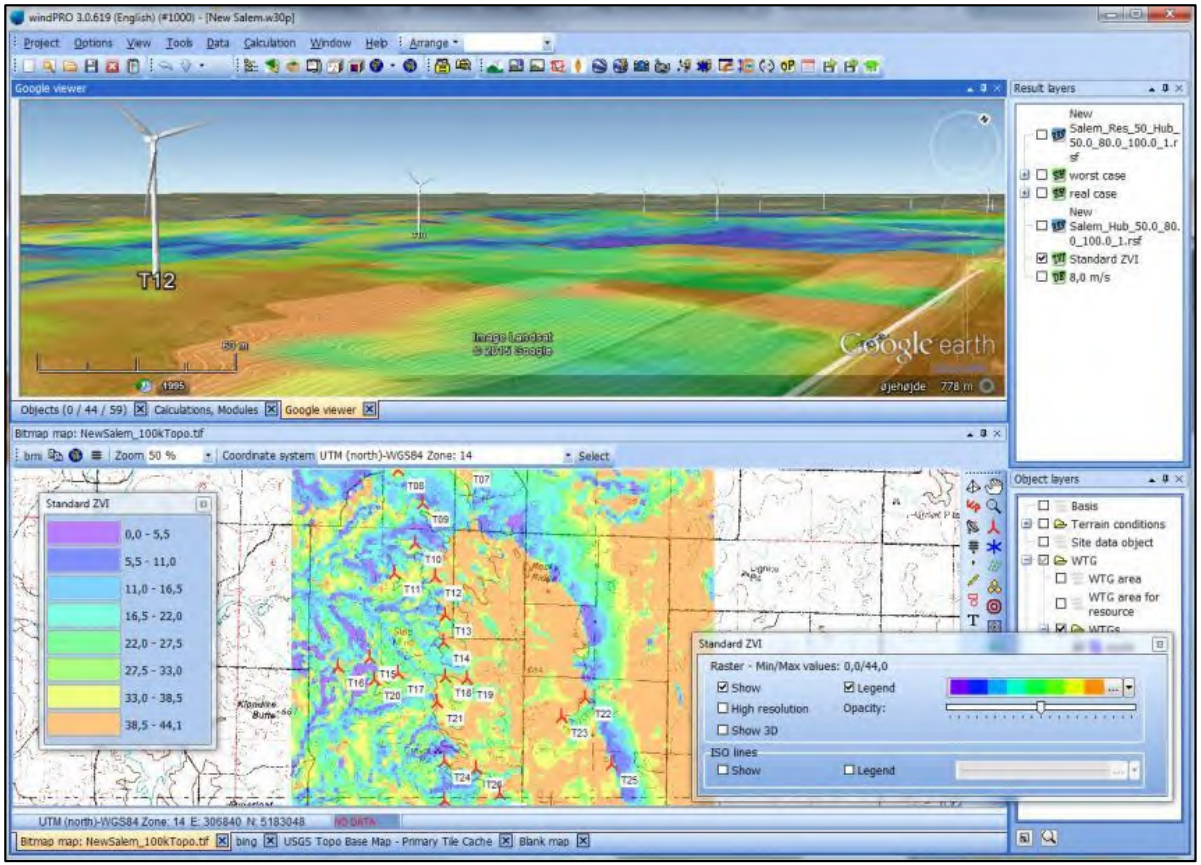
Ordinance Requirements

Federal	State	Local
Flicker is <u>not</u> currently regulated federally	**Senate Amendment 2 to HB 4412** requires the following: *…a wind tower of a commercial wind energy facility to be sited so that industry standard computer modeling indicates that any occupied community building or nonparticipating residence will not experience **more than 30 hours per year** of shadow flicker under planned operating conditions…*	**Section 56.619.E** of the Livingston County Zoning Ordinance requires: *Shadow flicker shall not affect an occupied building or non-participating residence **in excess of 30 hours per year** under planned operating conditions. Planned operating conditions is defined as those conditions that would exist if the sun were to shine every day of the year with no cloud cover.*

Modeling Overview

WindPRO modeling software

- Models the sun's path during every minute of the year
- Results aggregated by the receptor for an entire year



Modeling Parameters/Inputs

A conservative modeling approach was used to model the two turbine scenarios.

Turbine Coordinates

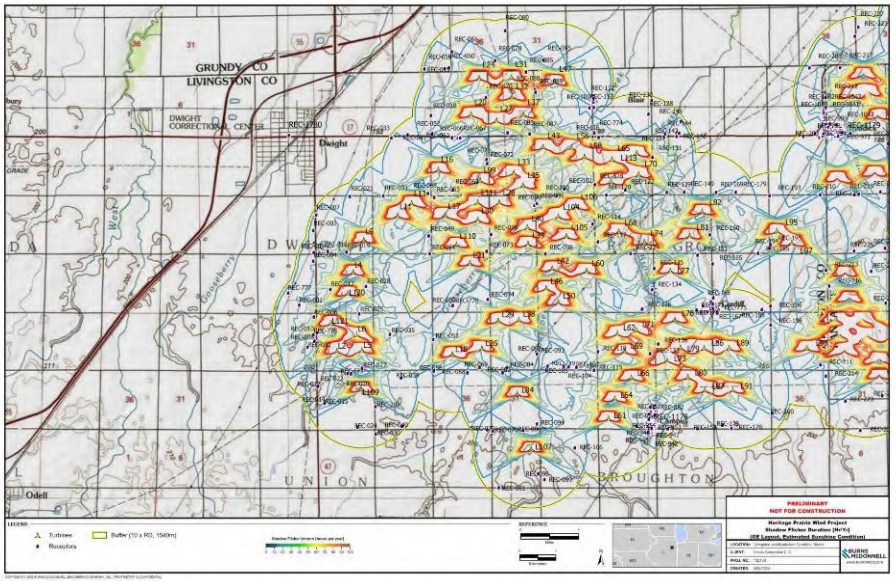
145 GE 3.8-154 turbines analyzed (71 turbines in Livingston County)

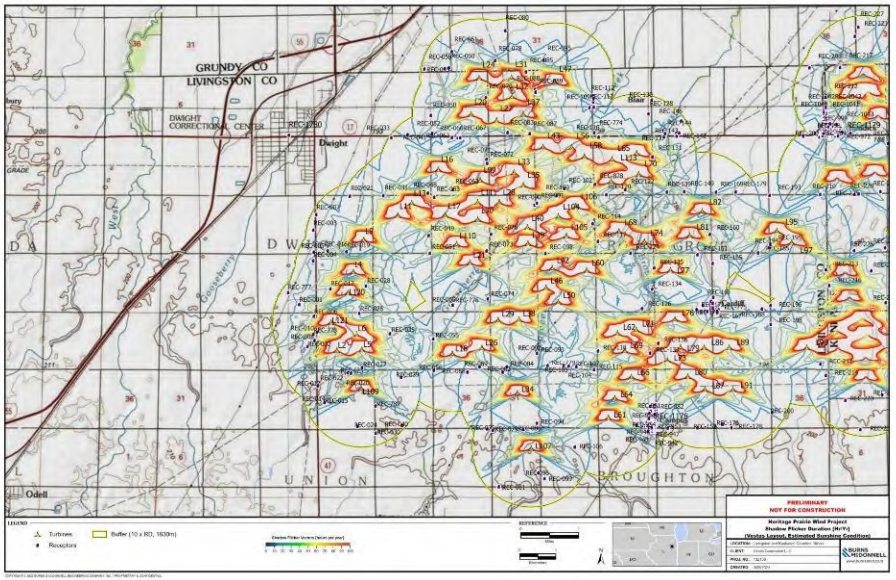
137 V163-4.5 turbines analyzed (71 turbines in Livingston County)

Receptor Coordinates

289 occupied residences in Livingston County

"Green house" mode





Modeling Parameters/Inputs

General Electric 3.8-154

Hub height [m]: **98**

Rotor diameter [m]: **154**

Vestas V163-4.5

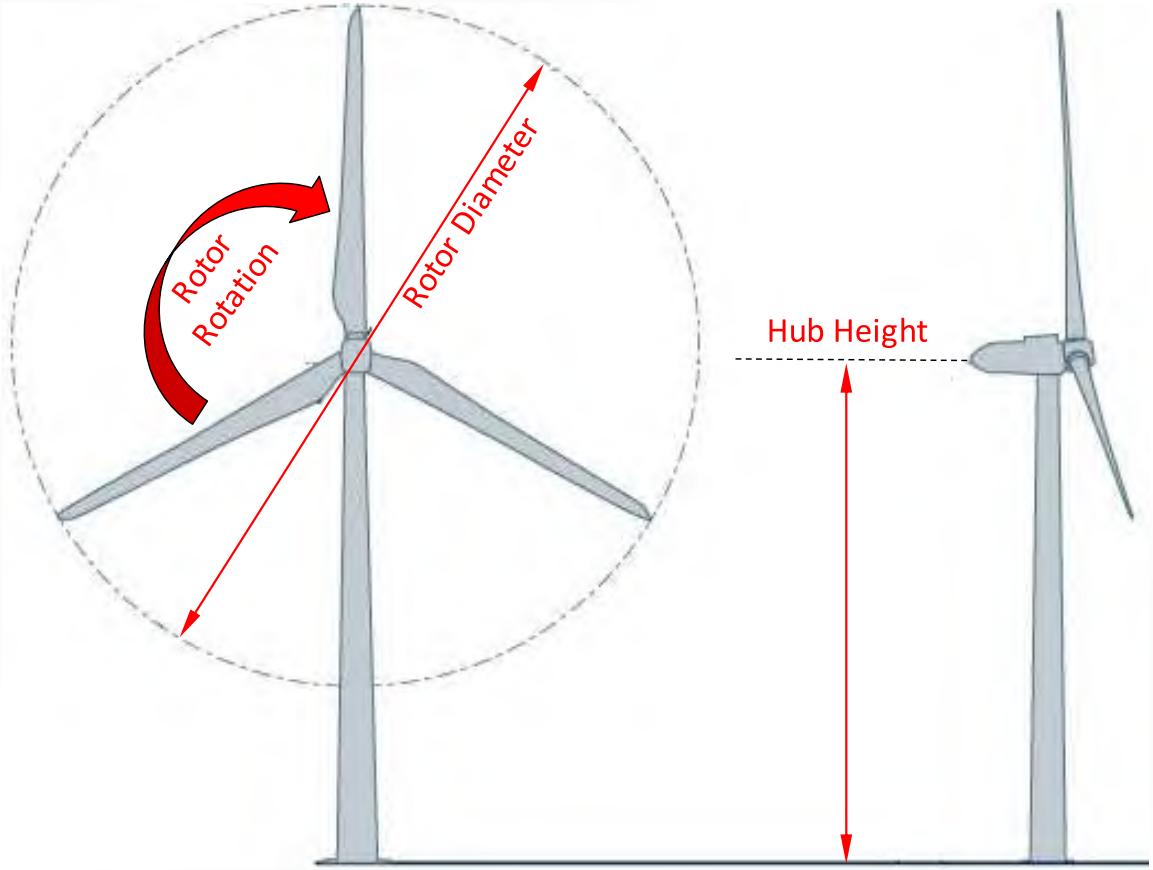
Hub height [m]: **113**

Rotor diameter [m]: **163**

Turbine Operation

Wind speed data

Rotational speed



Modeling Parameters/Inputs

Obstacles

Example: trees, buildings

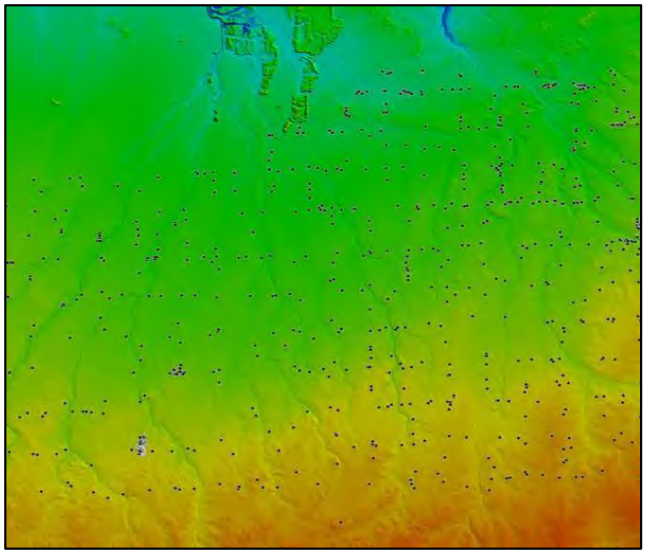
Disregarded (worst case)

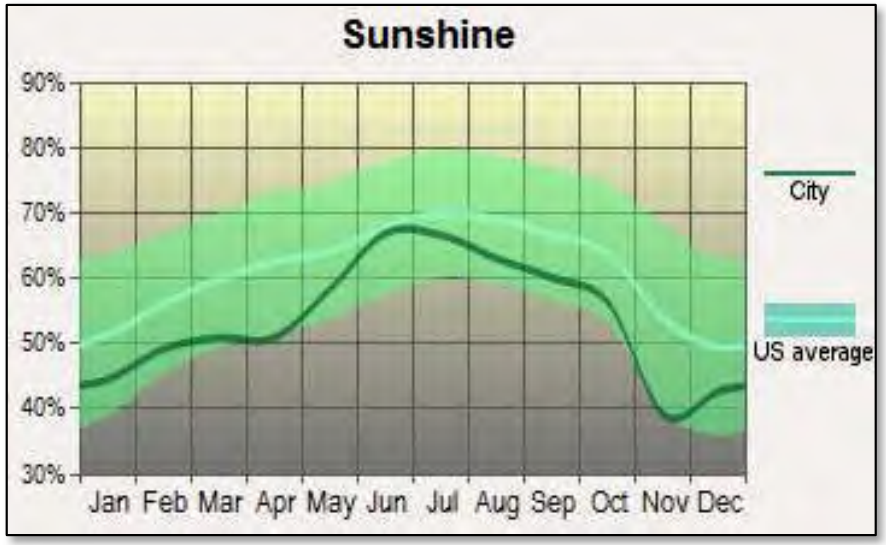
Terrain

10-foot contours
Source: USGS NED

Flicker Relevance

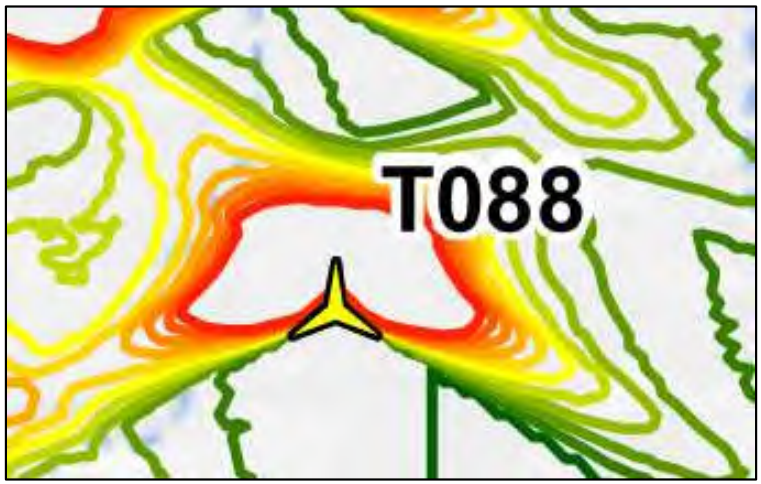
10 x rotor diameter
(1540 meters, 1630 meters)





Modeling Results

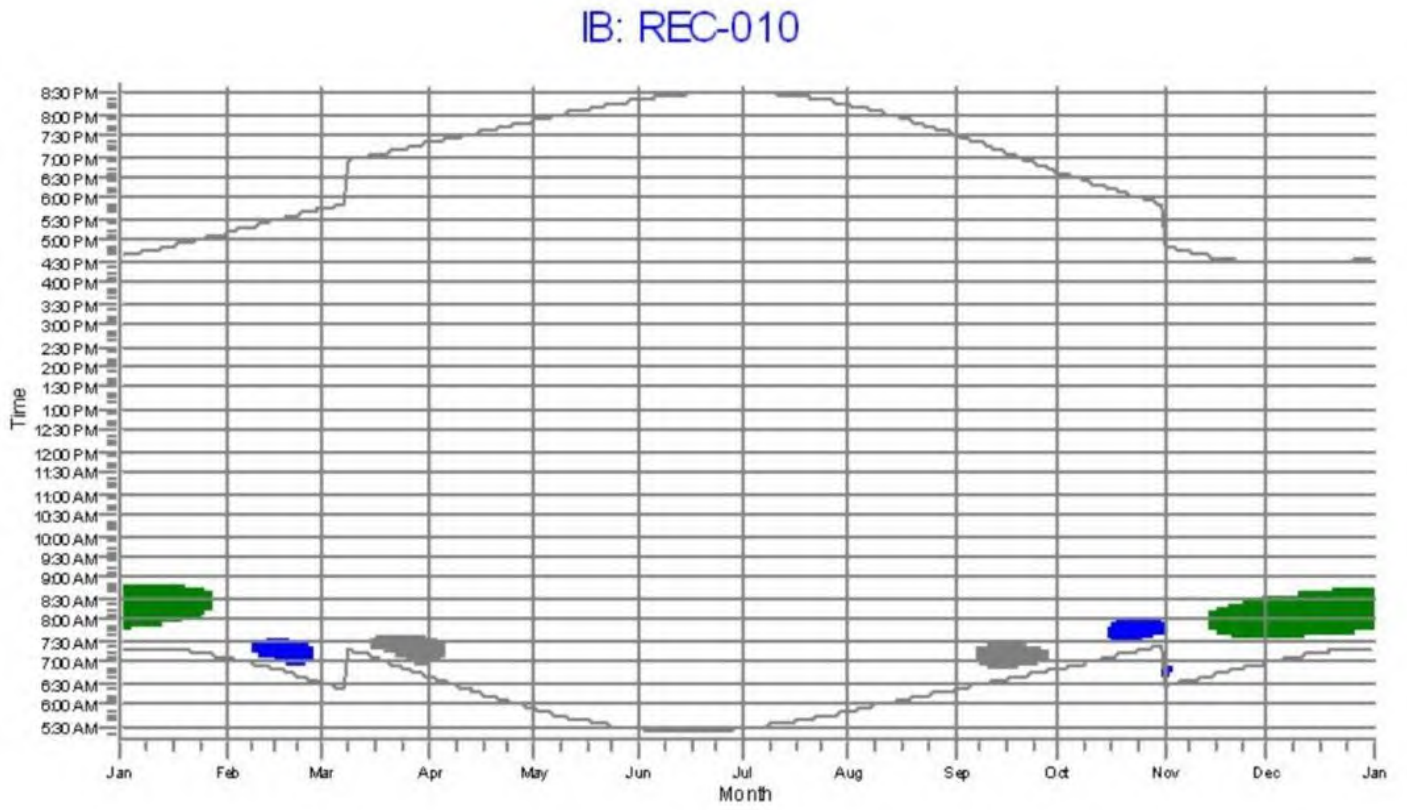
- Inputs aggregated in WindPRO
- Results expressed visually and numerically (hours/year)
- “Butterfly” shape caused by the position of sun + predominant wind direction
- Flicker impacts vary greatly based on the house’s location relative to the turbine



Modeling Results

CALENDAR

Describes the time of day, time of year, and duration that a receptor is predicted to experience shadow flicker



Modeling Results

FULL PROJECT RESULTS				
Turbine Model	No. of Turbines	No. of Receptors	No. of Participating Receptors, Flicker ≥ 30 hr/yr	No. of Non-Participating Receptors, Flicker ≥ 30 hr/yr
145 x GE 3.8-154	71	289	3	14
137 x V163-4.5	71	289	5	19

Mitigation

Common mitigation techniques

- Blinds/curtains
- Awnings
- Trees/vegetation
- Existing obstructions (e.g., barn)
- Regulated turbine operation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