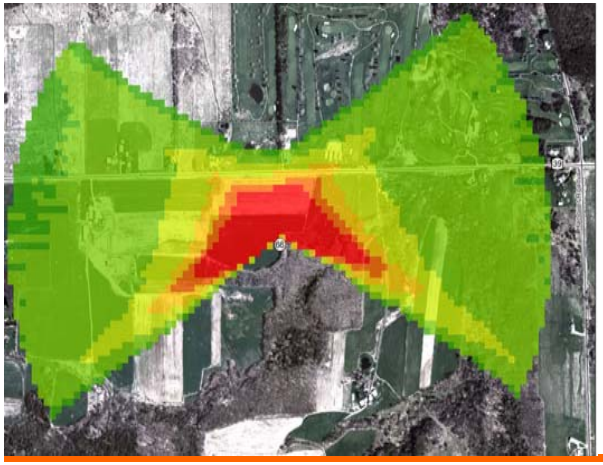

New England Wind Energy Education Project

Understanding the Current Science, Regulation and Mitigation of Shadow Flicker

Community Concerns and Mitigation Methods

February 10, 2011

SARATOGA ASSOCIATES

Presented by:

Matthew W. Allen, RLA

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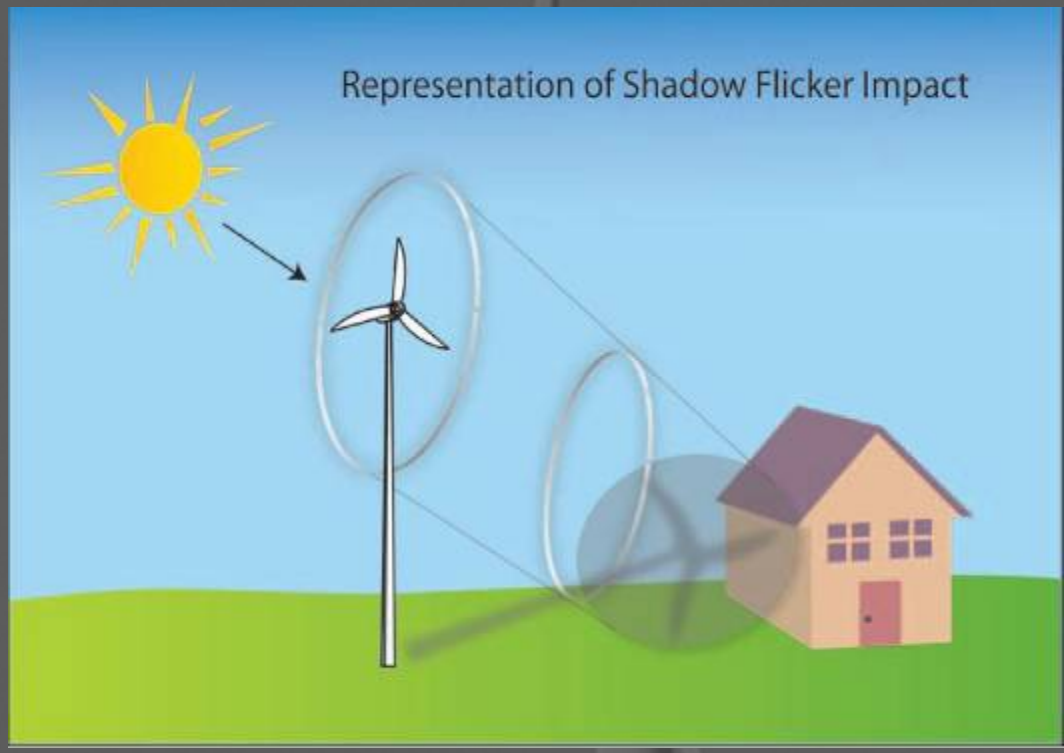
What is Shadow Flicker?

> Rotating turbine blades cast shadows upon stationary objects

> Shadow Flicker is limited in time and location

> Does not occur simply because the sun is out



What is Shadow Flicker?

> Potential health impacts

- Real or rhetoric?
  - Anti-wind sources cite issues ranging from headaches to seizures
  - Pro wind sources cite research concluding there is no basis for concern

> Nuisance/Annoyance

- Pulsating shadows enter personal space

What Can be Done to Minimize Flicker?

Play Video

Indoor Shadow.avi

What Constitutes an Impact?

> Worst-case Values:

- Maximum possible impact
  - Always sunny, always windy, wind always on axis with receptor
- Unrealistic condition

> Real-case Values:

- Weather statistics
  - Cloudy days (no shadow)
  - Calm winds (no flicker)
  - Aligned rotor plane (full /partial shadow profile)

Aligned Rotor Plane

Perpendicular Rotor Plane

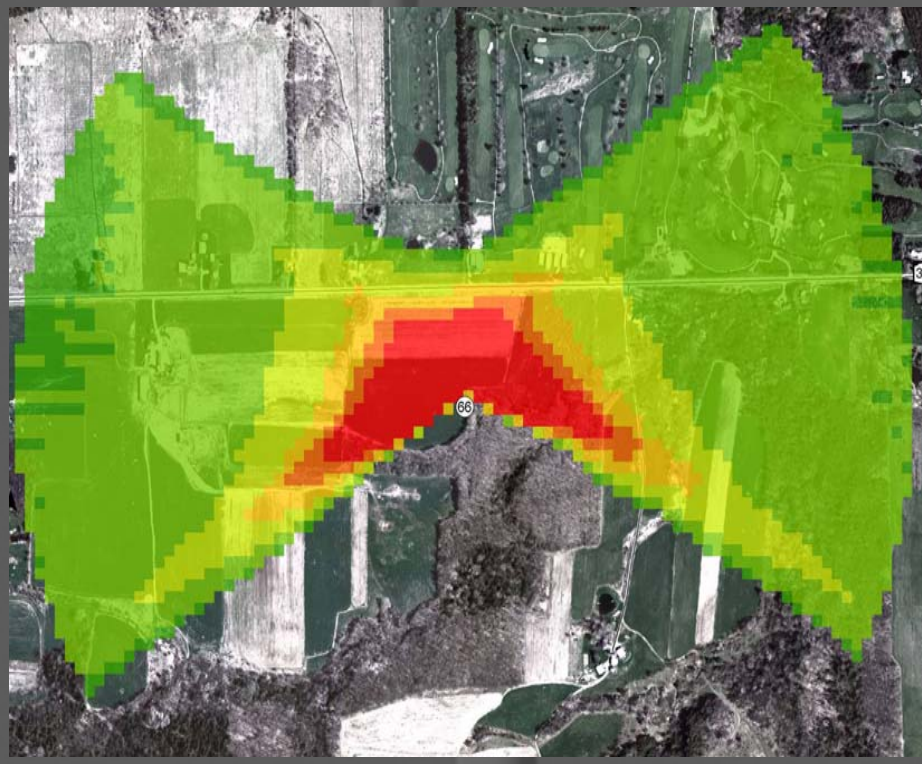
What Constitutes an Impact?

> Hours per year (worst-case or real-case value?)

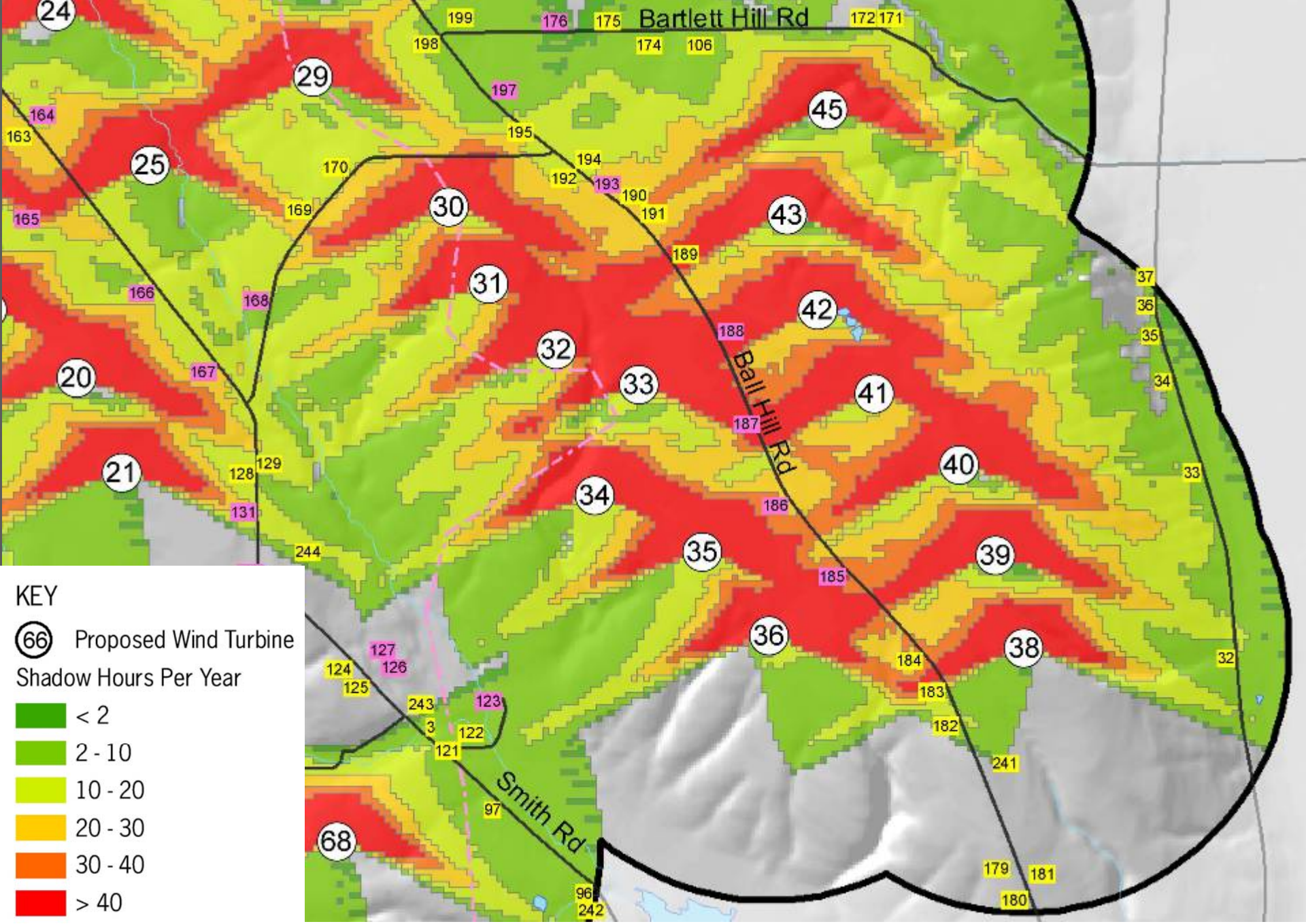
- 30 hours (1,800 min./ year cumulatively)
- “de facto” standard

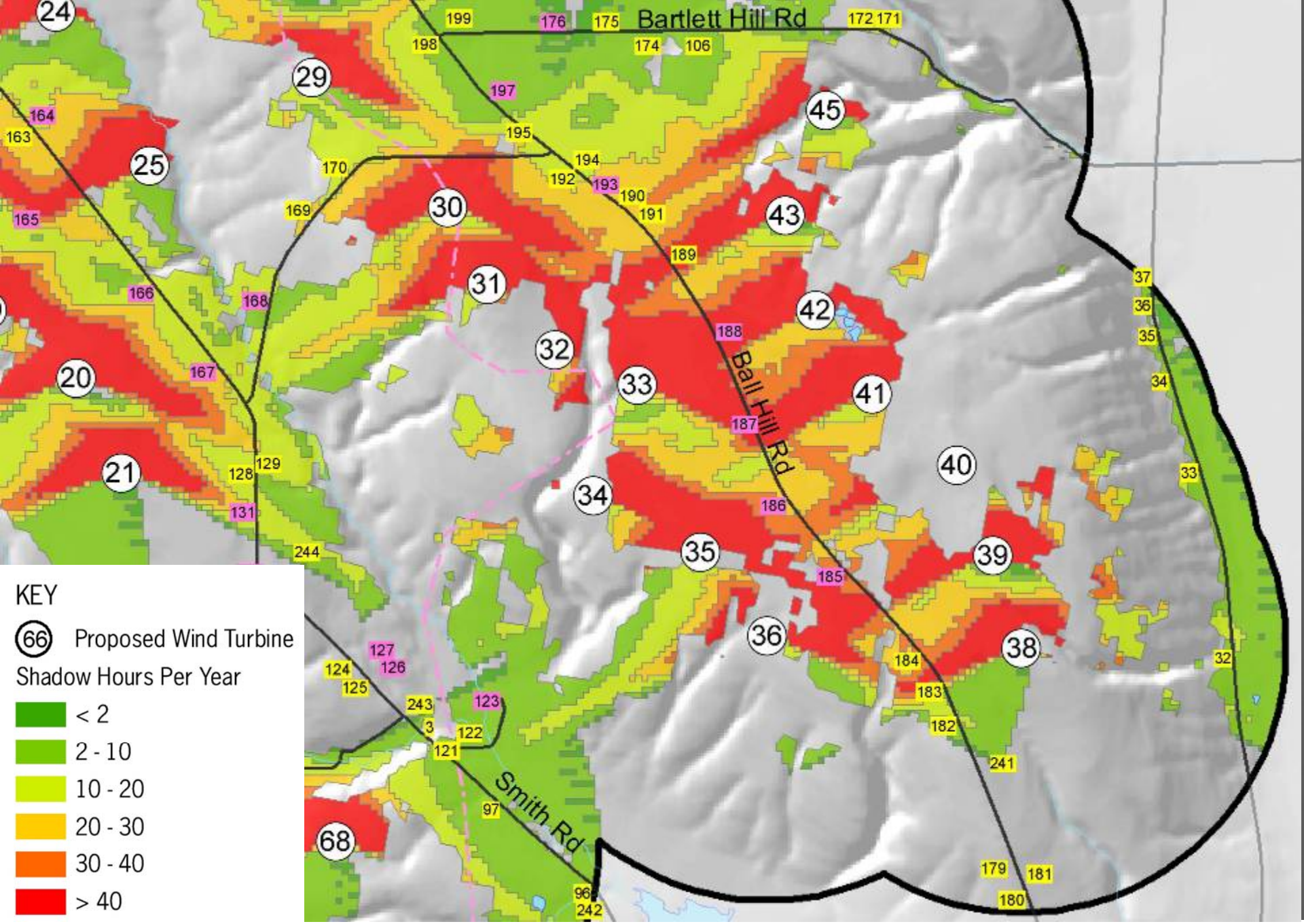
> Other Considerations:

- Real–case values
- Forest/structure screening
- Project participants vs. participants



Typical “Butterfly” Shadow Pattern


Bartlett Hill Rd
Ball Hill Rd
Smith Rd
KEY
66 Proposed Wind Turbine
Shadow Hours Per Year
< 2
2 - 10
10 - 20
20 - 30
30 - 40
> 40


Bartlett Hill Rd
Ball Hill Rd
Smith Rd
KEY
66 Proposed Wind Turbine
Shadow Hours Per Year
< 2
2 - 10
10 - 20
20 - 30
30 - 40
> 40

What does all this Really Mean to Residents?

> Days per year (maximum)

- Shadow rarely exceeds 30 consecutive days
- Impacted periods generally limited to spring and fall months

> Minutes per day (maximum)

- Generally less than 60 minutes per day

> Time of Day

- Near sunrise or sunset

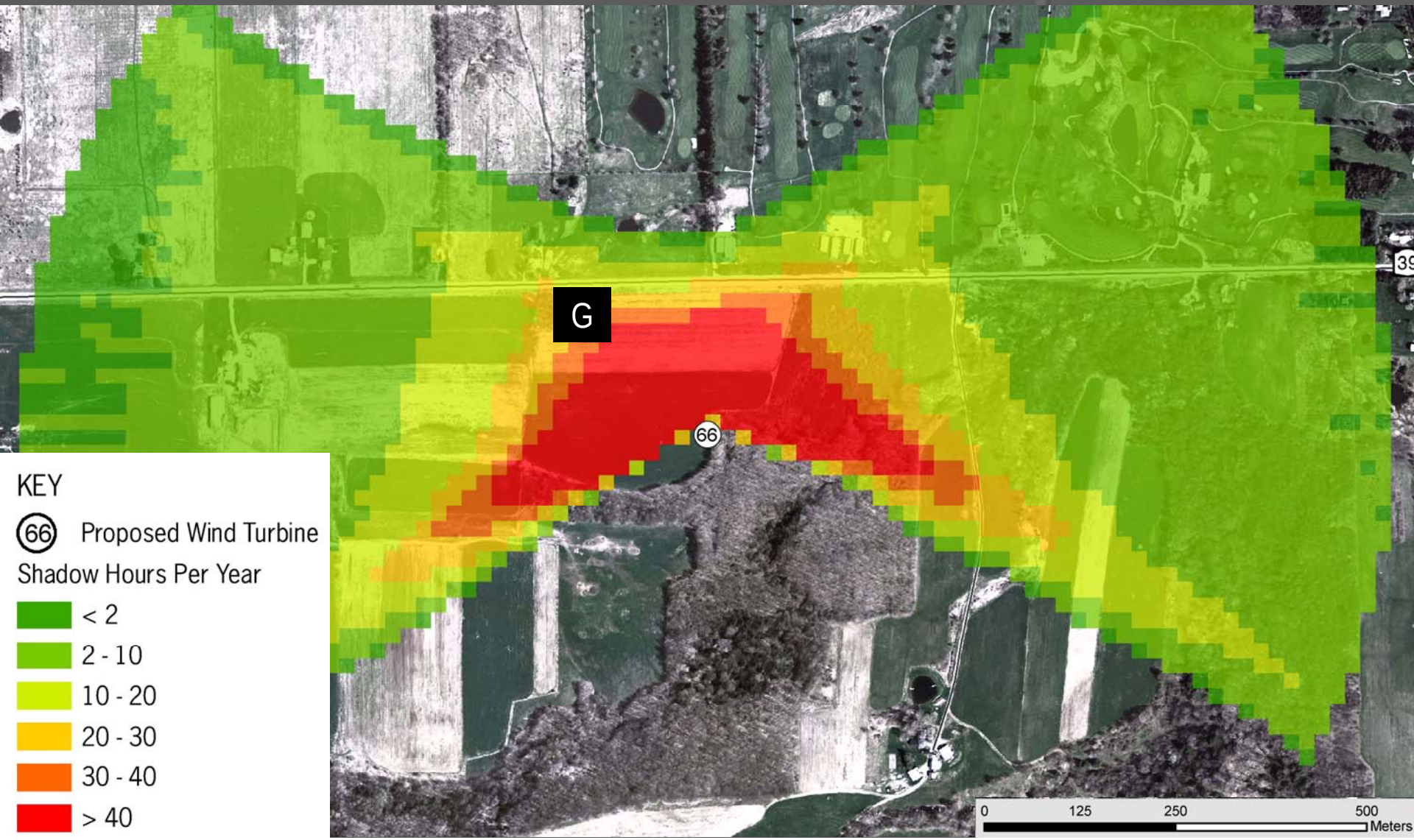
Receptor G - Example

Calculation Results

Shadow receptor

No.	Shadow, worst case: Shadow hours per year [h/year]	Shadow days per year [days/year]	Max shadow hours per day [h/day]	Shadow, expected values: Shadow hours per year [h/year]
A	53:52	73	0:57	15:16
B	0:00	0	0:00	0:00
C	0:00	0	0:00	0:00
D	24:51	50	0:38	7:06
E	0:00	0	0:00	0:00
F	0:00	0	0:00	0:00
G	33:30	58	0:45	9:21
H	73:38	104	0:58	20:21
I	52:13	64	1:00	15:55
J	0:00	0	0:00	0:00
K	11:34	37	0:24	3:13
L	7:28	28	0:20	2:07
M	13:39	46	0:24	3:54
N	15:00	61	0:21	4:36
O	5:51	24	0:19	1:45
P	27:21	97	0:21	8:51
Q	35:47	84	0:31	11:52
R	31:45	76	0:29	9:25
S	0:00	0	0:00	0:00
T	0:00	0	0:00	0:00
U	0:00	0	0:00	0:00
V	0:00	0	0:00	0:00
W	0:00	0	0:00	0:00
X	0:00	0	0:00	0:00
Y	0:00	0	0:00	0:00
Z	0:00	0	0:00	0:00

What does all this Really Mean to Residents?



What does all this Really Mean to Residents?

Assumptions for shadow calculations

Maximum distance for influence	2,000	m
Minimum sun height over horizon for influence	3	°
Day step for calculation	1	days
Time step for calculation	1	minutes

Sun shine probabilities (part of time from sun rise to sun set with sun shine)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.56	0.58	0.58	0.57	0.58	0.61	0.63	0.62	0.62	0.61	0.50	0.52

Operational time

N	NNE	ENE	E	ESE	SSE	S	SSW	WSW	W	WNW	NNW	Sum
685	637	351	337	250	275	625	1,303	1,211	546	782	656	7,659

	January	February	March		April	May	June	July	August	September		October		November	December
1	07:11	06:57	06:20		07:05 (1)	05:42	05:13	05:14	05:38	06:10		06:41	07:31 (1)	06:16	06:51
	16:25	16:59	17:34	23	07:28 (1)	19:42	20:11	20:23	20:04	19:19		18:28	45 08:16 (1)	16:40	16:15
2	07:12	06:56	06:19		07:02 (1)	05:41	05:13	05:14	05:39	06:11		06:42	07:31 (1)	06:17	06:52
	16:25	17:01	17:35	28	07:30 (1)	19:43	20:12	20:23	20:03	19:17		18:26	44 08:15 (1)	16:39	16:15
3	07:12	06:55	06:17		07:01 (1)	05:40	05:12	05:15	05:40	06:12		06:43	07:31 (1)	06:18	06:53
	16:26	17:02	17:37	31	07:32 (1)	19:44	20:13	20:22	20:02	19:16		18:24	44 08:15 (1)	16:38	16:15
4	07:12	06:54	06:16		06:59 (1)	06:38	05:12	05:15	05:41	06:13		06:44	07:31 (1)	06:19	06:54
	16:27	17:03	17:36	34	07:33 (1)	19:45	20:13	20:22	20:01	19:14		18:23	43 08:14 (1)	16:37	16:15
5	07:12	06:53	06:14		06:58 (1)	05:37	05:11	05:16	05:42	06:14		06:45	07:31 (1)	06:20	06:55
	16:28	17:05	17:39	36	07:34 (1)	19:46	20:14	20:22	20:00	19:12		18:21	42 08:13 (1)	16:35	16:15
6	07:12	06:52	06:13		06:56 (1)	06:21	05:36	05:11	05:16	05:43	06:15		06:46	07:31 (1)	06:22	06:56
	16:29	17:06	17:40	39	07:35 (1)	19:15	19:47	20:15	20:22	19:57	19:11		18:19	41 08:12 (1)	16:34	16:14
7	07:11	06:51	06:11		06:55 (1)	06:19	05:35	05:11	05:17	05:44	06:16		06:47	07:32 (1)	06:23	06:57
	16:30	17:07	17:41	40	07:35 (1)	19:16	19:48	20:15	20:22	19:56	19:09		18:18	39 08:11 (1)	16:33	16:14
8	07:11	06:50	07:09		07:54 (1)	06:17	05:34	05:11	05:18	05:45	06:17		06:48	07:32 (1)	06:24	06:58
	16:31	17:08	18:42	42	08:36 (1)	19:17	19:49	20:16	20:21	19:55	19:07		18:16	38 08:10 (1)	16:32	16:14
9	07:11	06:49	07:08		07:53 (1)	06:16	05:32	05:10	05:18	05:46	06:18		06:49	07:33 (1)	06:25	06:59
	16:32	17:10	18:44	43	08:36 (1)	19:18	19:50	20:17	20:21	19:53	19:06		18:14	35 08:08 (1)	16:31	16:14
10	07:11	06:47	07:06		07:52 (1)	06:14	05:31	05:10	05:19	05:47	06:19		06:50	07:34 (1)	06:27	07:00
	16:33	17:11	18:45	44	08:36 (1)	19:19	19:51	20:17	20:21	19:52	19:04		18:13	32 08:06 (1)	16:30	16:14
11	07:11	06:46	07:04		07:52 (1)	06:12	05:30	05:10	05:20	05:48	06:20		06:51	07:35 (1)	06:28	07:01
	16:34	17:12	18:46	45	08:37 (1)	19:20	19:52	20:18	20:20	19:51	19:02		18:11	29 08:04 (1)	16:29	16:14
12	07:10	06:45	07:03		07:51 (1)	06:11	05:29	05:10	05:21	05:49	06:21		06:52	07:36 (1)	06:29	07:01
	16:35	17:13	18:47	45	08:36 (1)	19:21	19:53	20:18	20:20	19:49	19:00		18:09	25 08:03 (1)	16:28	16:14
13	07:10	06:44	07:01		07:51 (1)	06:09	05:28	05:10	05:21	05:50	06:22		06:54	07:40 (1)	06:30	07:02
	16:36	17:15	18:48	45	08:36 (1)	19:22	19:54	20:19	20:19	19:48	18:59		18:08	20 08:00 (1)	16:27	16:15
14	07:10	06:42	06:59		07:51 (1)	06:07	05:27	05:10	05:22	05:51	06:23		06:55	07:43 (1)	06:31	07:03
	16:38	17:16	18:49	45	08:36 (1)	19:23	19:55	20:19	20:19	19:47	18:57		18:06	13 07:56 (1)	16:26	16:15
15	07:09	06:41	06:58		07:51 (1)	06:06	05:26	05:10	05:23	05:52	06:24		06:56		06:33	07:04
	16:39	17:17	18:50	44	08:35 (1)	19:24	19:56	20:20	20:18	19:45	18:55		18:05		16:25	16:15
16	07:09	06:40	06:56		07:50 (1)	06:04	05:25	05:10	05:24	05:53	06:25		07:52 (1) 06:57		06:34	07:04
	16:40	17:18	18:52	44	08:34 (1)	19:25	19:57	20:20	20:18	19:44	18:53	10	08:02 (1) 18:03		16:24	16:15
17	07:08	06:39	06:54		07:50 (1)	06:03	05:24	05:10	05:24	05:54	06:26		07:48 (1) 06:58		06:35	07:05
	16:41	17:20	18:53	43	08:33 (1)	19:27	19:58	20:21	20:17	19:42	18:52	18	08:06 (1) 18:01		16:23	16:16
18	07:08	06:37	06:53		07:51 (1)	06:01	05:23	05:10	05:25	05:55	06:27		07:45 (1) 06:59		06:36	07:06
	16:42	17:21	18:54	42	08:33 (1)	19:28	19:59	20:21	20:16	19:41	18:50	23	08:08 (1) 18:00		16:23	16:16
19	07:07	06:35	06:51		07:51 (1)	06:00	05:22	05:10	05:26	05:56	06:28		07:42 (1) 07:00		06:37	07:06
	16:43	17:22	18:55	41	08:32 (1)	19:29	20:00	20:21	20:16	19:39	18:48	28	08:10 (1) 17:58		16:22	16:16

What does all this Really Mean to Residents?

Feb. 1
No Impact

March 1
23 minutes
7:05 to 7:28 am

Apr. 1
No Impact

	Feb.	Mar.			Apr.
Date	Rise/Set	Rise/Set	Minutes	Start/Stop	Rise/Set
1	06:57	06:20		07:05	06:29
	16:59	17:34	23	07:28	19:09
2	06:56	06:19		07:02	06:27
	17:01	17:35	28	07:30	19:10
3	06:55	06:17		07:01	06:26
	17:02	17:37	31	07:32	19:11
4	06:54	06:16		06:59	06:24
	17:03	17:38	34	07:33	19:12
5	06:53	06:14		06:58	06:22
	17:05	17:39	36	07:34	19:13

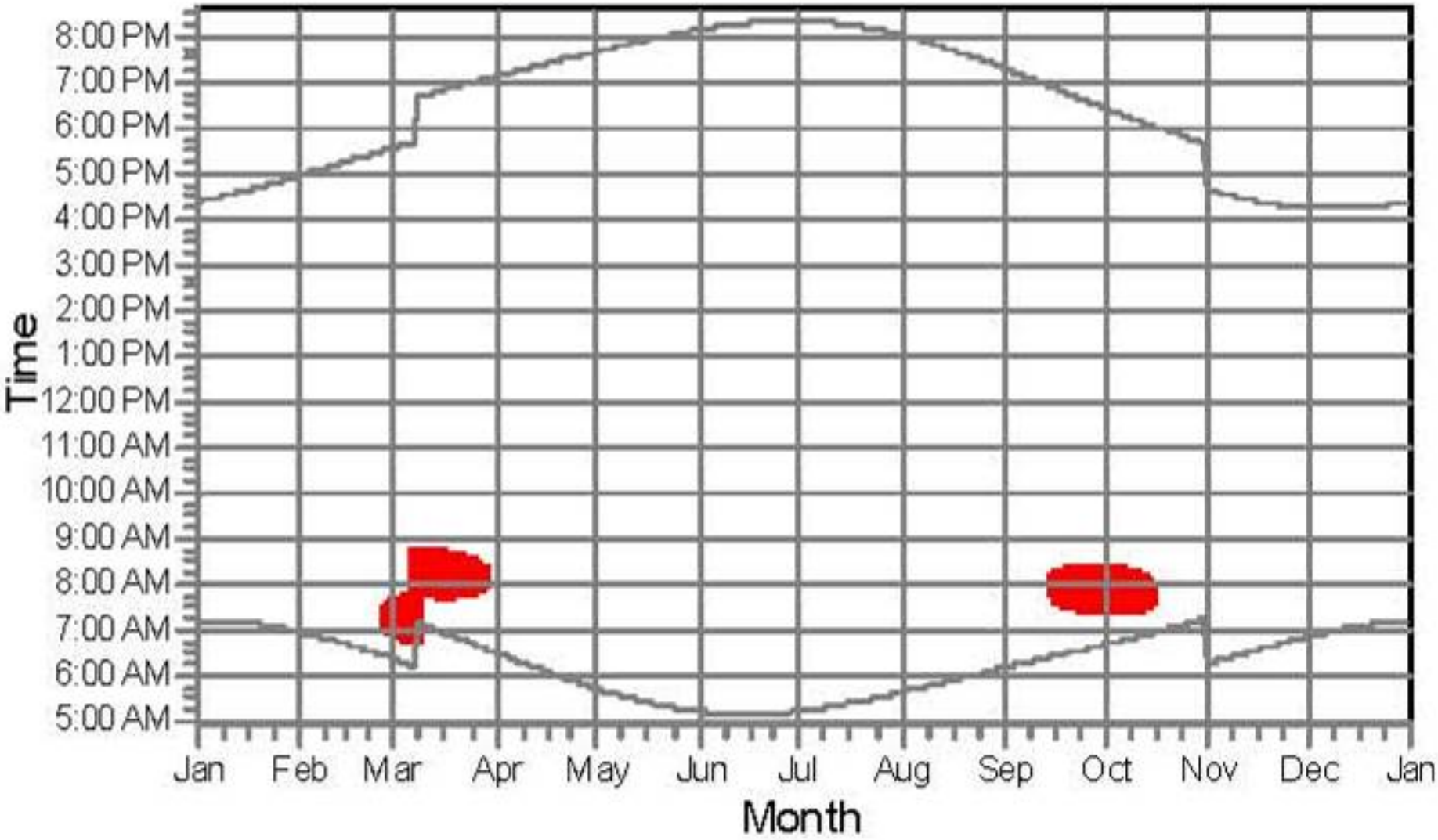
Sept. 1
No Impact

Oct. 1
45 minutes
7:31 to 8:16 pm

Nov. 1
No Impact

	Sept.	Oct.			Nov.
Date	Rise/Set	Rise/Set	Minutes	Start/Stop	Rise/Set
1	06:10	06:41		07:31	06:16
	19:19	18:28	45	08:16	16:40
2	06:11	06:42		07:31	06:17
	19:17	18:26	44	08:15	16:39
3	06:12	6:43		07:31	06:18
	19:16	18:24	43	08:15	16:38
4	06:13	6:44		07:31	06:19
	19:14	18:23	42	08:14	16:37
5	06:14	6:45		07:31	06:20
	19:12	18;24	41	08:13	1635

What does all this Really Mean to Residents?



What does all this Really Mean to Residents?

Play Video

Wind_Turbine_Time-Lapse-Shadow-Study.m1v

Why do People Care?

> Backyard vs. Not in My Backyard

- Conflicting land ethic
  - Working landscape/scenic landscape
  - Clean renewable energy/ "Industrialized landscape"
- Resident's attachment to place
  - Rural landscape is considered "special" by someone

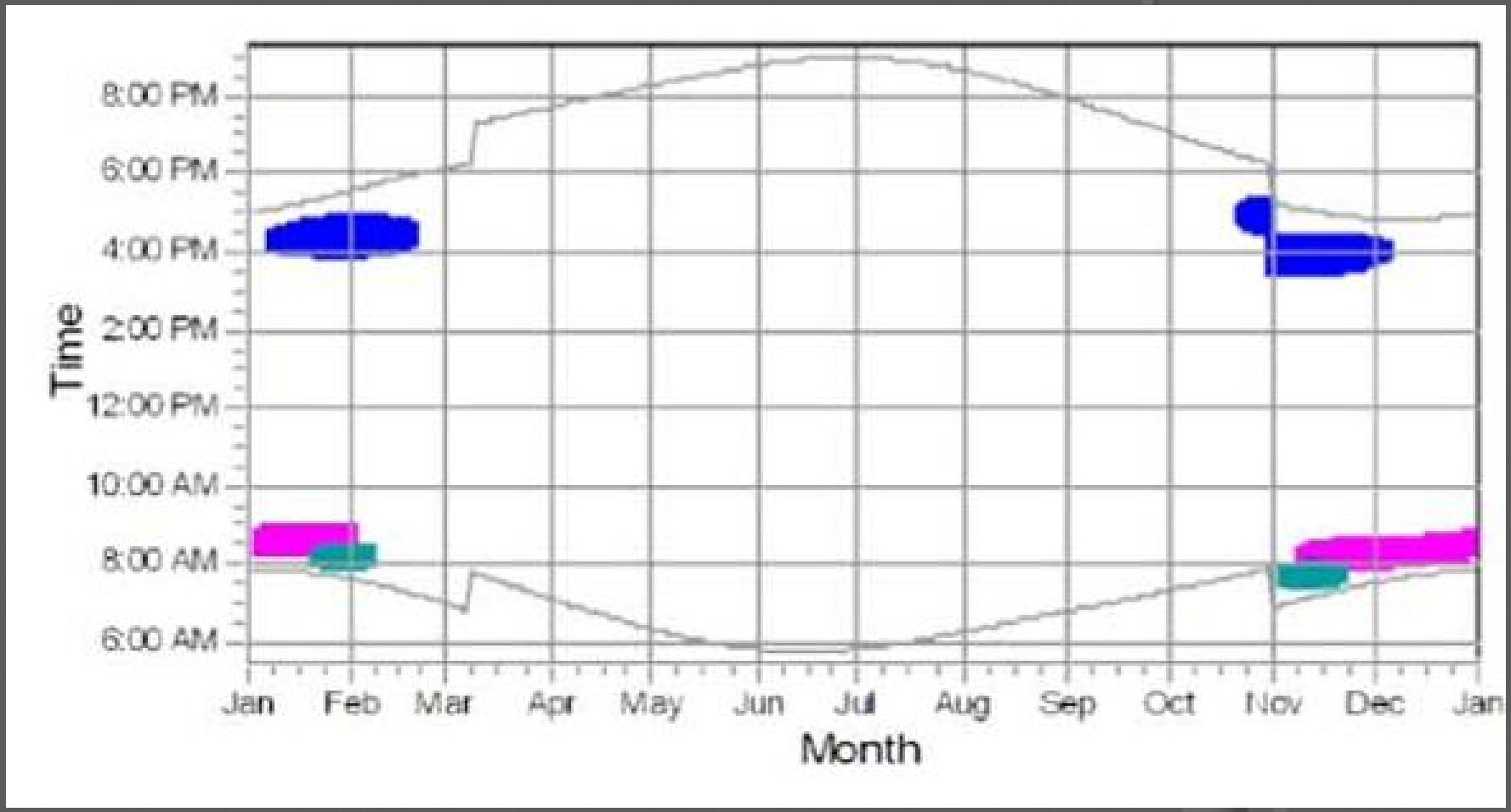
"I support renewable energy, but this is not the right place"

Why do People Care?

> Opinion often divided by:

- Project participation
  - "You get the money – I get the view/ shadow"
- Economic status
  - Family farms vs. family estates

What Can be Done to Minimize Flicker?

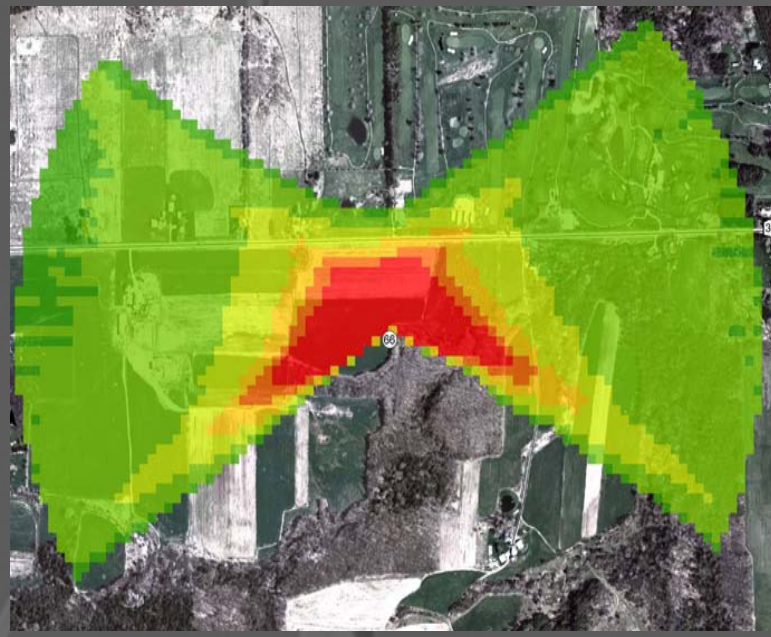


What Can be Done to Minimize Flicker?

> Establish Project Guidelines

- Define acceptable impact
  - Worst-case or real-case?
  - Differentiate between AM and PM impact?
  - Differentiate between project participants and non-project participants?

- Setbacks are for safety not shadow!
  - Residential setbacks need not be uniform to mitigate shadow flicker



What Can be Done to Minimize Flicker?

> Evaluate Alternatives

- Use computer modeling to identify optimum project layout
  - Minimize the number of residences that exceed project guidelines
- Micro-Siting
  - Adjust turbine location to diminish shadow duration in sensitive locations

What Can be Done to Minimize Flicker?

> Operational Guidelines

- Use analysis data to program brief shutdown periods into turbine controls
  - No blade rotation – no shadow impact

> Good Neighbor Policy

- Outdoor plantings
  - Pros and cons, but a good gesture
- Shade the shadow
  - Window blinds, shades or curtains

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