BEFORE THE
STATE OF NEW YORK
BOARD ON ELECTRIC GENERATION
SITING AND THE ENVIRONMENT

In the Matter of

Cassadaga Wind LLC

Case 14-F-0490

May 12, 2017

Prepared Exhibits of:

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Cassadaga Wind LLC

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Case 14-F-0490
Application of Cassadaga Wind LLC for a Certificate of Environmental Compatibility and Public Need Pursuant to Article 10 to Construct a 126 MW Wind Energy Project.

Information Requested:

Subject: Turbines Sound Information

1. **Specify and document sound power levels (or sound pressure levels and distance of determination when sound power level information is not available) for sound, low frequency sound, and infrasound from the manufacturers for all turbine models that may potentially be selected for the Project. Include information in full-octave, fractional-octave and narrow bands, if available. Include a list identifying the models and manufacturers that will not be used for the project and those for which such information is not available, if any.**

2. **Specify whether Gamesa G114 2.625 MW is also the turbine model that has the highest sound power levels (including low-frequency and infrasound sound power levels) and provide graphical or tabular comparison for all turbine models that may potentially be selected for the Project.**

The Gamesa turbine has the highest A-weighted sound level. As for low frequency sound, it is not the highest of the turbine models presented in the Application and for which there is low frequency sound data from the manufacturer, but within 4 dB of the highest at 31.5 Hz.

We note that octave band sound levels are not guaranteed by the manufacturers. Therefore, a noise standard for specific low frequency octave bands is not being proposed. However, no matter what turbine model is selected for the project, mitigation will be provided such that the modeled sound levels will be below 65 dB at the 16 Hz and 31.5 Hz octave bands and 70 dB at the 63 Hz octave band.

Subject: Vibrations and Potential for Interference with Technological Activities

Section (k) (5) of Stipulation 19 requires a discussion of: "the potential for structural damage; and the potential for interference with technological, industrial or medical activities that are sensitive to vibration or infrasound."

The discussion in Exhibit 19, section (k) (5) of the Application is limited to air-borne induced vibrations related to sounds from the turbines on sensitive receptor buildings and infrasound impacts on CTBTO stations.

1. **Specify whether ground-borne transmitted vibrations from the operation of the Facility can reach a noise sensitive receptor and cause vibrations on the**

floors or on building envelope elements that could be perceived by its occupants. Specify whether ground-borne transmitted vibrations from the proposed Project could potentially exceed national or international standards (such as ANSI S2.71-1983 -Guide to the Evaluation of Human Exposure to Vibration in Buildings (R 2012) or ISO 2631-2-2003 -Evaluation of Human Exposure to Whole-body Vibration Part 2: Vibration in buildings (1 Hz to 80 Hz)) at sensitive receptors).

Research studying the amplitude of vibration due to wind farms, show magnitudes below the threshold of perception and health impacts, even at distances far less than typical receiver distances. For example, Botha 2013 found magnitudes of less than 0.01 mm/s or 0.00001 m/s at a distance of 92 m.[1] *For comparison, the ANSI S2.71 thresholds for perception are 0.0001 m/s or less for all frequencies. The ANSI thresholds are based upon the thresholds of perception for the most sensitive humans. Others have found that the ground waves due to wind farms decay according to* $1/(r^{1/2})$*, where r is the distance between the turbine and the receiver (Styles et al 2005).*[2] *Consequently, the magnitude at a distance of 450 m would be approximately 0.000005 m/s, this scales by the square-root of the number of turbines. If we assume that four turbines are at the distance of 450 meters, a conservative assumption, then the magnitude will be 0.00001 m/s, or a tenth of the threshold of perception for the most sensitive humans. To meet this threshold, 100 turbines would have to be located at a distance of 450 meters.*

2. **Specify whether ground-borne vibrations from operation of the facility could cause any interference with the closest seismological monitoring systems on both sides of the border between US and Canada. Provide a table with approximate GPS or GIS coordinates and distances from identified stations to the Project site.**

Note that no interference is neither realistic, nor necessary. For example, studies performed near the Eskdalemuir seismic array found that the environmental seismic noise was approximately 0.336 nm (nanometers). Based on this, it was found that wind power should not be allowed at distances below 10 km, but up to 1 GW of wind power could be allowed at a distance of 25 km and 1 TW at 50 km (Styles et al 2005). Eskdalemuir is renowned for a particularly low influence of anthropogenic noise.

Measurements near a wind arm in Germany found that at about a 2 km distance, the wave-field amplitude reduced to the level of other anthropogenic seismic noise and recommended a 6 km setback between a proposed wind farm and a gravitational wave detection device in Italy (Fiori et al 2009). [3]*The increased*

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[1] Botha, Paul. "Ground Vibration, Infrasound and Low Frequency Noise Measurements from a Modern Wind Turbine." *Acta Acustica United with Acustica.* 99(2013). pp. 537-544.
[2] Styles, Peter, et al. "Microseismic and Infrasound Monitoring of Low Frequency Noise and Vibrations from Wind Farms." *Keele University.* 18 July 2005.
[3] Fiori, Irene, et al. "A Study of the Seismic Disturbance Produced by the Wind Park Near the Gravitational Wave Detector GEO-600." *Third International Meeting on Wind Turbine Noise.* Aalborg, Denmark: 17-19 June 2009.

distance is determined by multiplying the distance of the turbines measured in Germany with the square root of the number of proposed turbines (nine). Based upon this, the setbacks between Cassadaga and the nearest seismologically sensitive facility should be 16 km (the square root of 59 is a bit less than eight).

A list of the ten closest seismological stations is shown in the table below. The closest station to the closest Cassadaga turbine, will be located in Erie, Pennsylvania, 62 kilometers away and well outside of recommended distances from studies.

Monitoring Location	Coordinates (UTM NAD83 Z17 N)		Distance to Closest Cassadaga Turbine (km)
	X (m)	Y (m)	
Erie, Pennsylvania	583576	4663261	62
Effingham, Ontario	637407	4772381	82
Standing Stone, Pennsylvania	763178	4503008	209
Binghamton, New York	914003	4684056	259
Sadowa, Ontario	647049	4959014	269
Mont Chateau, West Virginia	598996	4390436	294
Kingston, Ontario	859941	4906992	301
Ann Arbor, Michigan	280986	4686616	361
Alum Creek State Park, Ohio	331385	4455392	385
Williamsburg, Ontario	951215	4998951	430

Subject: Noise Design Goals and Degree of Compliance Indicated by Computer Model

Section (d) of Exhibit 19 (pp 16) in the Application states that "In October 2009, the World Health Organization for Europe updated the 2000 review of the scientific literature, and found a no-adverse effect noise level of 40 dB Lnight, outside, which is the A-weighted annual average nighttime sound level."

In addition, in the same section (pp 17) results show that "Under all circumstances and for all receptors, the modeling results show that WHO (1999) and WHO Europe (2009) guidelines are met." Also, section 1.4, pp 4 of the PNIA states "Annualized modeling showed that 40 dBA Lnight is not exceeded at any permanent non-participating home."

However in section (h) of Exhibit 19 in the Application (pages 26 and 27) WHO recommended Night Noise Guideline of 40 dB-outside (WHO 2009) is not listed. The guideline is also not listed in Appendix D of the PNIA, page 235.

As can be determined in Table 30 of the PNIA, 40 dBA L_{night} is met at non-participating permanent residences.

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1. Specify whether the 40 dB Lnight-outside Night Noise Guideline (NNG) from WHO (2009) corresponds to the "No Observed Effect Level" (NOEL) or to the "Lowest Observed Adverse Effect Level" (LOAEL).

According to the WHO's Night Noise Guidelines for Europe, 40 dBA L_{night} is the lowest observed effect level for night noise.

2. Specify whether one of the design goals for the project is to follow the Night Noise Guideline (NNG) of 40 dB-outside, recommended by WHO in 2009.

The design goal for the project is 45 dBA $L_{(8)}$.

Exhibit 19, page 25, "Audible Sound Design Goal" states:" Given the scientific evidence regarding sleep disturbance and other impacts that were reviewed by WHO, the Facility is being designed to not exceed 45 dBA LEQ(8), which is averaged over the entire night (11 pm to 7 am) outside at non-participating permanent residences and the Arkwright, Charlotte, and Cherry Creek noise standards of 50 dBA L_{10} during the day and night. This would not apply to areas that have transient uses such as seasonal homes, camps, driveways, trails, farm fields, and parking areas, which were evaluated to the sound level limits of the town (50 dBA L10). (…) The goal is both protective of human health and hearing loss, and prevents any quality-of-life concerns."

3. Specify the WHO 1999 guidelines and recommendations for sound levels for dwellings inside bedrooms (indoors) including noise descriptors and duration of evaluation.

The WHO 1999 recommended interior sound level to prevent against sleep disturbance is 30 dBA $L_{(8)}$ or 45 dBA L_{Fmax}.

4. Specify whether the 45 dBA Leq(8) hour nighttime recommendation is included in the 1999 or the 2009 WHO guidelines.

The 45 dBA $L_{(8)}$ nighttime recommendation is from the 1999 guidelines. (page 21 of the PNIA)

5. Specify:

a. assumptions for outdoor-to-indoor noise reductions in WHO-1999 and

The WHO 1999 guidelines assume sound level reduction provided by residential structures will be 15 dB. (Page 21 of the PNIA)

b. Whether typical residential construction in the project site are capable for providing equivalent noise reductions (including permanent residences, seasonal residences and camps, if any).

This cannot be known without testing of the individual structures, due to variabilities in window size, window type, structure orientation, and project layout.

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6. Specify whether the project will comply with WHO 1999 indoor guidelines and recommendations, as well.

It cannot be known whether or not the project will meet the WHO 2009 interior guidelines due to differences in residence orientation, construction, window construction, window size, and the extent that a resident opens a window.

7. Provide justification for setting different goals for seasonal homes and camps, if any.

Seasonal homes, ie hunting cabins, trailers, or similar structures without noted water/septic systems and/or not classified as residences in the County real estate records, have a higher sound design goal given the significantly shorter period of time during which the structure is occupied. The difference between the design goal for non-participating residences, 45 dBA $L_{(8)}$*, and seasonal homes, 48 dBA* $L_{(8)}$ *is 3 dBA and is lower than the sound standard in the local Town wind laws.*

8. Specify how the 45 dB(A) LAeq guideline from WHO-1999, relates with the nighttime guideline of 40 dB from WHO-2009.

The 45 dBA $L_{(8)}$ *guideline from 1999 is the average sound level over a single night. The 40 dBA* L_{night} *is the average sound level over all nights of a given year. Due to the intermittent nature of wind turbine operations and wind turbine sound emissions, the* L_{night} *will be lower than the* $L_{(8)}$*. Based on modeling for Cassadaga and other projects, we expect this to be a difference to be approximately 5 dB. See Table 30 of the PNIA for* $L_{(8)}$ *and* L_{night} *modeling results at all receptors.*

Pa**ge 39, exhibit 19 states: "However, it should be noted that the results of the CNR methodology (described in 3(i)(2) above) indicate that no reaction to turbine noise is expected from any non-participating receptor during average background sound level conditions."**

9. Specify if the CNR methodology was based on studies of community noise reaction to wind turbine noise.

The CNR was not based on response of communities to wind turbine noise.

Table 19-8., "Noise Standards and Degree of Compliance" in page 26 of Exhibit 19 in the Application lists several noise standards and the degree of Compliance with those standards from the project.

10. Specify when the NYSDEC Noise Guideline was developed and whether it was based on or was developed for wind turbine projects.

The NYSDEC guidelines were published in 2001 and were not specifically developed for wind turbine projects.

11. Specify

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a. whether the WHO guideline of 50 dBA for moderate annoyance was developed based upon studies of annoyance from wind turbine noise or transportation noise.

The Daytime WHO guideline of 50 dBA $L_{(16)}$ was based on annoyance for community noise (transportation, industrial, construction, etc.,) in general and not specifically wind turbine noise.

12. Specify if the EPA guideline of 55 dBA Ldn was based on the analysis of annoyance from wind turbine noise or consideration of Health effects. If based on consideration of health effects, list the health effects that were evaluated and year of evaluation.

The EPA guideline of 55 dBA L_{DN} was developed as "levels below which there is no reason to suspect that the general population will be at risk from any of the identified effects of noise." This was developed in 1974 and not specifically for wind turbine noise. Specific effects that were evaluated included: hearing loss, annoyance, speech interference, and activity interference.

Section 1.2 of the PNIA (pp 2) states:" We have established a design goal of 65 dB at the 16 Hz and 31.5 Hz octave bands and 70 dB at the 63 Hz octave band to avoid noise-induced vibrations". In addition, Table 5 of the PNIA (pp 31) reproduces the criteria from ANSI 12.9 Part 4 Annex D and sets 65 dB at 16, 31.5 and 63 Hz. as the sound level below which annoyance is minimal. The Application also states that "The Facility will fall below thresholds for clearly perceptible vibration and rattles, moderately perceptible, vibration and rattles, and annoyance from vibration and rattles at the worst-case non-participant. Therefore, the Facility is not expected to result in perceptible vibration or rattles or annoyance from vibration and rattles."

In section (h) of Exhibit 19 in the Application (pages 26 and 27) and in Appendix D of the PNIA, page 235, low frequency goals are not listed. Furthermore, no low frequency goals are included in the Wind Sound Monitoring and Compliance Protocol.

13. Provide a justification for selecting a design goal of 70 dB-outdoor at the 63 Hz octave band instead of 65 dB as recommended by ANSI S12.9 Part 4, Annex D for minimization of annoyance from low frequency noise.

The two ANSI standards have different criteria at 63 Hz. We do not know why this is the case. In any event, the project would meet 65 dBA at the 63 Hz octave band outside.

14. Specify goals for low frequency noise levels for the project at the full-octave bands of 16, 31.5 and 63 Hz to prevent perceptible airborne-induced-vibrations and minimize annoyance from low frequency noise.

The design goal is as stated in the question, at non-participating receivers. However, this is not a standard, since the wind turbine manufacturer sound power *guarantee typically applies to the A-weighted level, not the individual 1/1 or 1/3 octave bands.*

Note that given the spectral shape of wind turbine sound, if a project is modeled to meet 65 dB at 31.5 Hz, it will also meet 65 dB at 63 Hz.

Subject: Pre-construction Ambient

Noise Levels, Future Noise Levels and Modeled sound levels

Stipulation 19 (f) has nine different requirements to report pre-construction and future noise levels from the Facility. (See stipulations 19 (f) (1) to 19 (f) (9))

Section (f) of Exhibit 19 in the Application refers to tables 30 and 31 in Appendix C of the PNIA,

Columns 2 to 13 of Table 30 (pp 195 to 214) and 31 (pp 214 to 234) contain different noise level values.

1. **Column 1 in Tables 30 and 31 contain the names of the receptors: Specify whether the designation of receptors relates to the parcel ID numbers. If not, provide a cross-reference table with receptor labels and parcel ID numbers. Specify the meaning of letter designations (N, P, B, etc.), if any.**

   Letter designations indicate the applied sound scape. As an example "B" stands for Boutwell Hill, after the Boutwell Hill background sound level monitor.

   A Table comparing the parcel ID numbers to the receptor IDs is at the bottom.

2. **Columns 2 to 6 in Tables 30 and 31, report different ambient noise levels for the L90 and Leq noise descriptors:**
   a. **Specify the requirements of Stipulation 19 (f) that the information contained in each column fulfills (e.g. specify Exh. 19 (f) (7) for Column 5, if the listed information fulfills the requirement of Exh. 19 (f) (7)).**

PNIA Table 30 and 31 Column Number	Section Column Addresses
2	19 (f)(1)
3	19 (f)(2)
4	19 (f)(3)
5	19 (f)(7)
6	19 (f)(8)

   b. **Explain the derivation of these values and how they correlate with the information provided in Tables 19-2, 19-3 and 19-4 of Exhibit 19 (pp. 10**

to 11) in the Application and Table 1 in section 1.3 in the PNIA (pp. 3). Explain any differences.

Each receptor was assigned a soundscape, which is reflected in the letter following the receptor ID. For example, a receptor with the letter "B" is expected to have a soundscape similar to the Boutwell Hill background sound level monitoring location. These ("B") receptors are typically located in the higher elevation wooded areas in or around Boutwell Hill State Forest. The background sound level data from the Boutwell Hill monitor is applied to the "B" receptors for requirements of Exh 19(f) that use background sound levels. The values in Table 19-2 of the Application would be applied to 19(f)(3) or Column 4 and 19(f)(6) or Column 9. Table 19-3 would be applied to 19(f)(2) or Column 3 and 19(f)(5) or Column 8. Table 19-4 would be applied to 19(f)(1) or Column 2, 19(f)(4) or Column 7, 19(f)(7) or Column 5, 19(f)(8) or Column 6, and 19(f)(9) or Column 10.

3. Columns 7 to 9 in tables 30 and 31 report different worst-case noise levels.

a. Specify the specific requirement of Stipulation 19 (f) that the information contained in each column fulfills (e.g. Specify Exh. 19 (f) (4) for Column 7, if the listed information fulfills the requirement of Exh. 19 (f) (4)).

PNIA Table 30 and 31 Column Number	Section Column Addresses
7	19(f)(4)
8	19(f)(5)
9	19(f)(6)

b. Specify whether the information corresponds to the sum between the L90's and the L10's or to the L10 levels only.

These values are the sum (logarithmic) of background L90 sound level and the turbine-only L10 sound level.

4. Column 10 in tables 30 and 31 lists typical facility noise levels (dBA).

a. Identify the specific requirement of Stipulation 19 (f) that the information contained in the column fulfills (e.g. Specify Exh. 19 (f) (9) in Column 10, if the listed information fulfills the requirement of Exh. 19 (f) (9)).

Column 10 fulfills Exh. 19(f)(9).

5. Columns 11, 12 and 13 in tables 30 and 31 contain "modeled" values.

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a. **Identify the intent or the specific requirement of Stipulation 19 that the information contained in the columns fulfills (e.g. WHO 2009, WHO 1999, Local laws, etc.)**

PNIA Table 30 and 31 Column Number	Guideline Addressed	Time Interval
11	NYSDEC Background sound	1 year – logarithmic average
12	WHO Nighttime Noise Guidelines for Europe (2009)	All nights over a year – logarithmic average
13	WHO Guidelines for Community Noise (1999)	8-hour nighttime period – logarithmic average

b. **Specify time interval of evaluation. (E.g. 1-hour, 8-hour, 1 year). Also specify whether the value is a maximum value, or an arithmetic or logarithmic average. (e.g.: Max Leq 1-h in a year, Max Leq 8-h in a year, etc.)**

Columns 11 through 13 are all equivalent averages. The averaging times are shown in the table above.

c. **Specify whether the designation L(8) refers to an 8-hour period or to the L(8) statistical descriptor (5 minutes in an hour, approximately).**

The "8" refers to an 8-hour integration interval. This is the metric referenced in the WHO 1999 guidelines for the sound level averaged over the night.

6. For tables 30 and 31:

a. **Specify the range (maximum and minimum sound levels) as well as the typical (percentile 50) or average sound levels (arithmetic) of each column for all evaluated receptors, excluding the last two receptors (Boutwell Parking B and Worst Case Trail B).**

Table 1:Level Range for Table 30 of PNIA

Value	Daytime Ambient Noise Level (L90 dBA)	Summer Nighttime Ambient Noise Level (L90 dBA)	Winter Nighttime Ambient Noise Level (L90 dBA)	Daytime Ambient Average Noise Level (Leq dBA)	Nighttime Ambient Average Noise Level (Leq dBA)	Worst Case Daytime Future Noise Level (dBA)	Worst Case Summer Nighttime Future Noise Level (dBA)	Worst Case Winter Nighttime Future Noise Level (dBA)	Typical Facility Noise Levels (dBA)	Modeled Overall Leq (dBA)	Modeled Overall L_{night} (dBA)	Modeled Maximum $L_{(8)}$ (dBA)
Minimum	21	21	19	36	35	26	25	24	36	18	20	27
Maximum	30	29	32	49	42	44	44	44	49	40	40	45

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Median	26	26	24	40	38	36	35	35	41	31	32	38
Average	25	25	23	44	37	36	35	35	44	31	32	38

Table 2: Level Ranges for Table 31 of PNIA

Value	Daytime Ambient Noise Level (L90 dBA)	Summer Nighttime Ambient Noise Level (L90 dBA)	Winter Nighttime Ambient Noise Level (L90 dBA)	Daytime Ambient Average Noise Level (Leq dBA)	Nighttime Ambient Average Noise Level (Leq dBA)	Worst Case Daytime Future Noise Level (dBA)	Worst Case Summer Nighttime Future Noise Level (dBA)	Worst Case Winter Nighttime Future Noise Level (dBA)	Typical Facility Noise Levels (dBA)	Modeled Overall Leq (dBA)	Modeled Overall L_{night} (dBA)	Modeled Maximum $L_{(8)}$ (dBA)
Minimum	21	21	19	36	35	26	25	25	36	19	20	27
Maximum	30	29	32	49	42	44	44	44	49	40	41	46
Median	26	26	24	40	38	36	35	36	41	32	33	38
Average	25	25	23	44	37	36	35	36	44	31	32	38

Subject: Noise Levels from the Facility A weighted and Un-weighted

The following questions refer to Section (e) (1) of Exhibit 19 in the Application Tables 28, 29, 30 and 31 of Appendixes B and C of the PNIA.

1. Table 28

a. Specify whether the "Modeled Sound Pressure Levels" listed in Table 28 (Unmitigated and Mitigated) correspond to the maximum one-hour Leq noise level modeled for a year at each receptor. If not, specify noise descriptor (e.g. Leq) and time frame of evaluation (e.g. 1-hour, etc.).

These are maximum 1-hour L_{eq}s

b. Specify whether listed values in Table 28 are maximum or average values for a year (e.g. maximum, arithmetic average, logarithmic average). Specify whether any other hour in a year is expected to have a noise level greater than the ones listed in table 28 for each receptor.

These are maximum 1-hour L_{eq}s

c. Specify the range of values (maximum and minimum sound levels) for each column (Unmitigated and Mitigated), for all evaluated receptors in Table 28, excluding the last two (Boutwell Parking B and Worst Case Trail B).

Criteria	Sound Pressure Level (dBA)	
	Unmitigated	Mitigated
Minimum	29	27

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Maximum	48	48*

*This includes seasonal receptors. There are no non-seasonal receptors above 45 dBA.

2. Table 29

a. Specify whether the 1/1 Octave Band Results in Table 29 (Mitigated) correspond to the maximum one-hour Leq noise levels modeled for a year for each receptor. If not, specify noise descriptor and time frame of evaluation.

These are maximum 1-hour L_{eq}*s*

b. Specify whether listed values in Table 29 are maximum or average values for a year (e.g. maximum, arithmetic average, logarithmic average).

These are maximum 1-hour L_{eq}*s*

c. Specify whether any sound receptors are expected to receive turbine noise levels greater than those listed in Table 29 at full octave bands.

These are modeled maximum 1-hour L_{eq}*s, but octave band sound power levels are not guaranteed by the manufacturer.*

d. Specify the range of values (maximum and minimum sound levels for each column) for all evaluated receptors listed in Table 29 excluding the last two (Boutwell Parking B and Worst Case Trail B).

Table 3: Minimum and Maximum 1/1 Octave Band Sound Levels (includes seasonal receptors)

Value	1/1 Octave Band Sound Level (dBZ)								
	31.5 Hz	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz
Minimum	41	36	33	29	26	19	4	0	0
Maximum	60	55	49	48	47	43	36	19	0

3. Table 22:

a. Specify how "Modeled Worst Case Non-Participating Receptor Sound Levels" listed at Table 22 were determined.

These are the modeled maximum 1-hour L_{eq}*s from Table 29 for non-participating residences.*

Table 4: Receptor ID and Parcel ID Comparison

Receptor ID	Parcel ID	Parcel Owner Last Name

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Receptor ID	Parcel ID	Parcel Owner Last Name
Worst Case TrailB	201.00-1-9	People State Of New York
Boutwell ParkingB	219.00-1-8	State Of New York
4561B	236.00-1-32.2	Rattlesnake Enterprises, LLC
3179N	201.00-1-22	Lebaron
3738P	183.00-1-40	Gozdziak
2793N	219.00-1-44	Wall
2795N	219.00-1-44	Wall
1183B	236.00-2-31.2	Isula
3503P	200.00-2-18	Skinner
3391B	201.00-1-30.2	Chase
1299N	233.00-2-19	Riggle
2421B	219.00-1-18	Brinkworth
3505P	200.00-2-19	Skinner
3151N	201.00-1-23	Green Tree Servicing LLC
3305P	203.00-1-10	Rettig
2751P	220.00-1-12.3	Rowicki
3513P	200.00-2-18	Skinner
3518P	200.00-2-7	Penhollow
3524P	200.00-2-6	Penhollow
2755N	219.00-1-41	Scott
3473P	201.00-1-33	Morano
3443P	200.00-2-16	Conway
3519P	200.00-2-9	Goodwill
2874N	219.00-1-47	Peacock
2908N	219.00-1-46	Bromberg
3708P	202.00-1-35	Anderson
2911N	219.00-1-46	Bromberg
2032P	216.00-3-28	Pritchard
3521P	200.00-2-5	Christy
2923N	219.00-1-45.2	Hall-Gross
720P	254.00-1-6	Emke
1506B	235.00-1-7	Cleland
3501P	200.00-2-11	Sullivan
703P	254.00-1-7	Bailey
1736B	235.00-1-9	Sischo
2166P	218.00-1-32	Mettler
2920N	219.00-1-48	Morris
1749B	235.00-1-9	Sischo
3740P	183.00-1-39	Nutt
1604P	234.00-1-4	Boyland
2049P	216.00-3-27	Kifer
3084N	201.00-1-24	Lebaron

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Receptor ID	Parcel ID	Parcel Owner Last Name
3741P	183.00-1-39	Nutt
2048P	216.00-3-27	Kifer
1993P	235.00-1-2	Yusczyk
675P	254.00-1-9	Chudzinski
2021P	216.00-3-30	Mekus
652P	254.00-1-10	Marsh
1368B	235.00-1-6	Sorrento
3743P	183.00-1-38	Diakakis
3455P	200.00-2-12	Emory
1880P	217.00-1-34	Kauffman
3397P	200.00-2-15	Luce Cemetery
3067N	201.00-1-25	Pattyson
3095N	202.00-1-25	Mcdermott
2558P	220.00-1-10	Eklund
3250P	200.00-1-18.2	Holtz
1878P	217.00-1-34	Kauffman
2198P	218.00-1-33	Gierlinger
3112P	220.00-1-15	Dawley
2012P	217.00-1-36	Hagberg
2172B	218.00-2-27	Kelly
2189P	218.00-1-33	Gierlinger
2300W	218.00-1-38	Webber
626P	254.00-1-12	Chamberlin
791P	250.00-2-53	Smith
405B	253.00-1-19.3	Jakubczak
1952P	217.00-1-35	Jacques
3092N	202.00-1-25	Mcdermott
2698P	219.00-1-38	Wilcox
2707P	219.00-1-38	Wilcox
825P	254.00-1-4	Mast
1728P	217.00-1-28.2	
1965P	217.00-1-35	Jacques
2019P	216.00-3-31	Babcock
3204N	202.00-1-21	Waschensky
2736P	220.00-1-12.1	Rowicki
2775P	220.00-1-12.2	Dunlap
2164B	218.00-2-26	Mcmillan
2397B	219.00-1-17	Foringer
1866B	236.00-1-33	Rodgers
2055P	235.00-1-1	Camper
3110P	200.00-1-19	Heinrich
3107P	200.00-1-19	Heinrich
3856P	185.00-1-45	Nawrocki
2168P	218.00-1-38	Webber

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Receptor ID	Parcel ID	Parcel Owner Last Name
2174B	218.00-2-25.2	Walter & Sondra Blount Irrevocable Trust
864P	254.00-1-3	Westfield
2063P	235.00-1-1	Camper
3869B	183.00-1-29	Hart
2006P	218.00-1-30	Brown
1995P	218.00-1-30	Brown
2620P	219.00-1-35	Milks
3239N	202.00-1-19	Joy
391B	253.00-1-19.2.1	Richard
1800P	217.00-1-29	Higgs
2175B	218.00-2-25.2	Walter & Sondra Blount Irrevocable Trust
2132P	218.00-1-36	Thomas
2626P	219.00-1-35	Milks
2338B	219.00-1-16	Young
843P	254.00-1-4	Mast
969N	234.00-1-36	Emmott
1590N	233.00-2-16	Mcbratnie
2136P	217.00-2-20	Villella
1555N	233.00-2-17	Yannie
1565B	235.00-1-8	Pomietlasz
3373P	203.00-1-9	Baldwin
2009B	218.00-2-15	Gray
2096B	218.00-2-14	Bommer
3499N	201.00-1-32.2	Schroeder
913P	254.00-1-2	Hadley
859P	254.00-2-1	Hostetler
2540N	219.00-1-33	Smith
3406P	203.00-1-8	Zybert
2542N	219.00-1-33	Smith
3854P	185.00-1-46	Easterly
1884P	217.00-1-31	Higgs
2071P	217.00-1-38	Zuck
2086B	218.00-2-13	Barner
3734P	202.00-1-39	Jackson
3735P	202.00-1-39	Jackson
3784P	185.00-1-43	Crowell
1868P	217.00-1-30	Walker
2907N	218.00-1-3	Green
2877N	218.00-1-4	Snyder
3321N	202.00-1-12	Klipfel
2156P	217.00-2-23	Duliba
1939P	217.00-1-33	Lanphere

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Receptor ID	Parcel ID	Parcel Owner Last Name
2836N	218.00-1-47	Russo
2847N	218.00-1-2	Snyder
3514P	200.00-1-10	Ostroski
1947P	217.00-1-33	Lanphere
537P	254.00-1-13	Milspaw
2949P	200.00-1-21	Turnbull
309B	254.00-1-28	Winters
3350N	202.00-1-11	Jackson
1708N	233.00-2-15	Christ
322B	254.00-1-22	Gooch
2047P	217.00-1-39	Chamberlin
2903P	220.00-1-19	Zahm
3459P	203.00-1-6	Mitchell
1722N	233.00-2-14	Miller
2120B	218.00-2-11	Vogel
2898P	220.00-1-19	Zahm
3156P	203.00-1-21	Fisher
2131P	217.00-2-24	Rafferty
2545N	219.00-1-33	Smith
3150P	203.00-1-21	Fisher
900P	254.00-2-3	Hostetler
2100B	218.00-2-11	Vogel
995P	237.00-1-39.1	Jakob
300B	254.00-1-27	Brainard
381B	253.00-1-20	Nowak
531P	254.00-1-13	Milspaw
2905P	200.00-2-28	Forbes
2361N	219.00-1-32.1	Howard
2360N	219.00-1-32.1	Howard
1038P	237.00-1-39.1	Jakob
2784B	219.00-1-7	Mazur
2789B	219.00-1-7	Mazur
2754B	218.00-1-15	Johnson
2822P	217.00-2-5	Morley
1930N	236.00-1-28	Stevens
3517P	203.00-1-5	Ricchiazzi
940P	254.00-2-3	Hostetler
3523P	203.00-1-5	Ricchiazzi
3556P	202.00-1-48	Greenough
2815B	219.00-1-5	Civilette
2817B	219.00-1-4	Bentz
3561P	202.00-1-48	Greenough
2816B	219.00-1-5	Civilette
2203B	219.00-1-14.2	Brown

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Receptor ID	Parcel ID	Parcel Owner Last Name
2199B	219.00-1-14.2	Brown
2214B	219.00-1-14.2	Brown
3008W	200.00-1-20	Alaimo
874N	234.00-1-34	Robbins
3425N	202.00-1-8.1	Raetz
3605N	201.00-1-2.2	Lewis
1088P	237.00-1-35	Miller
3560P	203.00-1-4	Zicarelli
2040P	216.00-3-33	Lowczys
3606P	202.00-1-46	Christian
2725N	218.00-1-43	Nigro
1113P	237.00-1-32	Mosher
3603P	202.00-1-46	Christian
3733P	202.00-1-42.1	Mogiliski
1860B	236.00-1-3	Crumb
1117P	237.00-1-32	Mosher
1131P	237.00-1-31	Milks
2728N	218.00-1-43	Nigro
2770B	218.00-1-8	Wisniewski
1093P	237.00-1-33	Oakes
1069P	237.00-1-34	Blair
1836N	236.00-1-31.1	Bowman
377B	253.00-1-23	O connor
2264N	220.00-1-5	Zollinger
3648N	201.00-1-5	York
2263N	220.00-1-5	Zollinger
3846P	185.00-1-51.1	Nobles
2886B	218.00-2-6	Budniewski
3847P	185.00-1-51.1	Nobles
2038P	217.00-1-41	Morley
2064P	217.00-1-41	Morley
3619P	203.00-1-3	Wagner
3845P	185.00-1-51.1	Nobles
3655N	201.00-1-5	York
2894B	218.00-2-6	Budniewski
1141P	234.00-1-41	Lizauckas
3620P	203.00-1-3	Wagner
2112N	220.00-1-6	Libby
3135P	220.00-1-16	Kent
1793N	236.00-1-29	Bailey
1802N	236.00-1-29	Bailey
4395B	271.00-1-2	Adam
1821N	236.00-1-29	Bailey
4396B	271.00-1-2	Adam

Receptor ID	Parcel ID	Parcel Owner Last Name
3552N	202.00-1-6	Mansfield
4540P	183.00-1-44	Narraway
1349B	236.00-2-35	Peters
1161B	235.00-1-55	Hall
3132P	220.00-1-17	Giles
3555N	202.00-1-6	Mansfield
220B	254.00-1-21	Mosher
3682P	203.00-1-2	Mansibal LLC
1716B	236.00-2-7	Walters
1759N	236.00-1-30	Abbey
2215B	219.00-1-11	Green
2387N	220.00-1-4	Melinski
2945B	218.00-2-5.1	Troska
396P	254.00-1-19	Kurcz
406P	254.00-1-19	Kurcz
713B	253.01-1-8	Cartalano
1904N	216.00-3-35	Deering
1351B	236.00-2-35	Peters
2209B	219.00-1-11	Green
2202B	219.00-1-11	Green
2644N	217.00-2-19	Crandall
2948B	218.00-2-5.1	Troska
3689N	201.00-1-1	Zahn
698B	253.01-1-9	Shafer
2642N	217.00-2-19	Crandall
878P	254.00-2-7	Bolt
1550N	236.00-2-38	Burkholder
943P	254.00-2-9	Coleman
1671B	236.00-2-8	Lehsten
1780N	236.00-1-25	Brown
1791N	236.00-1-25	Brown
3843P	185.00-1-53	Easterly
1549N	236.00-2-38	Burkholder
1378P	237.00-1-19	Spier
1622N	236.00-1-21	Hill
1784N	236.00-1-24	Brown
667B	253.01-1-11	Mullen
1186B	236.00-2-25	Hall
1783N	237.00-1-2	Sweeting
1515B	236.00-1-19	Diaz-Bentham
1553N	236.00-1-20	Abbey
2161B	236.00-2-1	Smith
1370P	237.00-1-19	Spier
1624N	236.00-1-21	Hill

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Receptor ID	Parcel ID	Parcel Owner Last Name
1561N	236.00-1-20	Abbey
1304P	237.00-1-19	Spier
1585B	236.00-1-6	Goodwill
1525B	236.00-1-19	Diaz-Bentham
2150B	236.00-2-1	Smith
1374P	237.00-1-18	Frost
2073P	217.00-2-25	Deering
3737P	202.00-1-43	Jackson
1376P	237.00-1-18	Frost
1384P	237.00-1-18	Frost
680B	253.01-1-10	Swanson
2090P	217.00-2-25	Deering
2084P	217.00-2-25	Deering
3448P	200.00-1-39	Ellis
4537P	183.00-1-47	Parker
1221B	236.00-1-13	Logan
1787N	237.00-1-10	Lepp
2614N	217.00-2-6	Ross
881P	254.00-2-8	Hoffman
3720N	201.00-1-6	Zahn
3721N	201.00-1-6	Zahn
1077P	234.00-1-39	Wiles
371P	254.00-1-18	Raber
3631N	202.00-1-5	Mansfield
1373P	237.00-1-23	Cleveland
637B	253.01-1-14	Stewart
2631N	217.00-2-16	Bommer
4543B	183.00-1-31	Vercant
2087P	217.00-1-42	Jesionowski
1231B	236.00-1-12	Peacock
627B	253.01-1-14	Stewart
691B	253.01-1-37	Bly
2808P	217.00-2-1	Yale
4544B	183.00-1-33	Cordier
1205B	236.00-2-20	Wykstra
2658N	217.00-2-12	Ross
219P	254.00-1-20	Mosher
364P	254.00-1-18	Raber
3146P	203.00-2-19.4	Sheldon
568B	253.01-1-16	Fisher-Ellsworth
1245B	236.00-1-11	Hughes
1974P	217.04-1-4	Deering
1981N	216.00-3-37.2	DeGolier
2561N	217.00-2-43	Harmony

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Receptor ID	Parcel ID	Parcel Owner Last Name
2605N	217.00-2-7	Peacock
2608N	217.00-2-7	Peacock
3152P	203.00-2-19.4	Sheldon
1982N	216.00-3-37.2	DeGolier
208P	254.00-1-20	Mosher
1418B	236.00-2-36	Caskey
1434B	236.00-2-36	Caskey
598B	253.01-1-15	Miller
2568N	217.00-2-29	Higgs
1116B	235.00-1-55	Hall
2648P	217.00-2-4	Lerow
3276P	203.00-1-25.2	Lokietek
725N	251.01-1-7	Lanphere
1546B	236.00-2-9	Kinner
3765N	184.00-1-44.1	Gallant
3766N	184.00-1-44.1	Gallant
234P	254.00-1-20	Mosher
560B	253.01-1-16	Fisher-Ellsworth
2013P	217.04-1-5	Monfort
2123P	217.04-1-3.1	Vankoughnet
2135P	217.04-1-3.1	Vankoughnet
2582P	217.00-1-16	Postle
2653P	217.00-2-4	Lerow
3282P	203.00-1-25.2	Lokietek
2065N	216.00-3-38	Miller
2088N	216.00-3-38	Miller
3678N	202.00-1-3	Emley
1639B	235.00-1-20	Galucki Woods LLC
2447N	217.00-2-40	Higgs
2011C	217.04-1-7	Belote
2185N	216.00-3-40	Murray
2659N	218.00-1-42	Weise
3298P	203.00-1-26	Krenzer
1595B	235.00-1-20	Galucki Woods LLC
2478N	217.00-2-31	Singer
2480N	217.00-2-31	Singer
2153P	217.00-1-26.2	Sue A Oakes Revocable Trust
1532B	236.00-2-9	Kinner
3293P	203.00-2-18	Blair
3316P	203.00-1-27	Bukoskey
1099B	235.00-1-63	Gelenscer
2334P	217.00-1-48	Rosplock
2646N	217.00-2-12	Ross
2068C	217.04-1-22	Scott

Receptor ID	Parcel ID	Parcel Owner Last Name
2091C	217.04-1-22	Scott
647B	253.01-1-12	Hedden
3713N	202.00-1-2	Spellberg
1094B	235.00-1-64.2	Bardo
2067C	217.04-1-22	Scott
3541P	200.00-1-5	Greenstein
3544P	200.00-1-5	Greenstein
1655B	218.00-2-10	Korbas
2001A	234.00-1-6	Johnson
639B	253.01-1-12	Hedden
2020A	234.00-1-6	Johnson
2786P	217.00-2-2	Hattaway
3434P	200.00-1-42	Engasser
2102P	217.00-1-25	Oakes
2413P	217.00-1-51	Murphy
2414P	217.00-1-51	Murphy
3612P	200.00-1-2	Peterson
4547P	183.00-1-48	Spinler Farms
3128P	220.00-1-21	Mcginty
3131P	220.00-1-21	Mcginty
3162P	203.00-2-19.3	Sheldon
692N	251.01-1-4	Carlson
4389P	271.00-1-13	Sperazza
2231N	216.00-3-42	Dunlap
3458P	200.00-1-3	Dake
824P	234.00-1-30	Abbey
1241N	234.00-1-12.2	Benson
1244N	234.00-1-12.2	Benson
535P	250.00-2-9	Hopkins
1222N	234.00-2-34	Marsh
1218N	234.00-2-34	Marsh
3615P	200.00-1-6	Spinler
1160B	235.00-1-45	Wallin
1154B	235.00-1-45	Wallin
748N	251.01-1-11	Anzivine
726N	251.01-1-14	Gane
751N	251.01-1-11	Anzivine
2439P	216.00-3-17	Tarbrake
2366P	216.00-3-23	Reynolds
2456P	216.00-3-15	Teeter
2451P	216.00-3-25.2	Gonzalez
2458P	216.00-3-25.2	Gonzalez
901N	234.00-1-25	Murray
911N	234.00-1-24	Suber

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Receptor ID	Parcel ID	Parcel Owner Last Name
2285N	216.00-3-44	Oakes
4545P	183.00-1-9.1	Austin
3774B	184.00-1-39	Wykstra
587P	250.00-2-32	W & L Frost Family Trust I
706N	251.01-1-17	Sterling
2412P	216.00-3-22	Sheedy
1047N	235.00-1-62	Jordan
2420P	216.00-3-22	Sheedy
2502P	216.00-3-14	Brainard
4546P	183.00-1-9.1	Austin
775N	234.00-2-28	Rudy
928N	234.00-2-31	Mcclaran
2473P	216.00-3-19	Luh
2501P	216.00-3-9	Mcniff
884N	234.00-1-25	Murray
999N	235.00-1-58	Vincent
1120N	234.00-2-33	Harper
1124N	234.00-2-33	Harper
2508P	216.00-3-10.1	McNiff
986N	235.00-1-58	Vincent
581P	250.00-2-33	Runge
2322N	216.00-3-45	Watt
2527P	216.00-3-12	Mcniff
799N	234.00-1-29	Foster
363B	253.00-1-25	Hitchcock
584P	250.00-2-34	Anderson
671C	251.01-1-19	Williams
383B	253.00-1-25	Hitchcock
387B	253.00-1-25	Hitchcock
630C	251.01-1-33	Thomas
663C	251.01-1-19	Williams
1126N	234.00-1-14	Tarbell
4178B	253.00-1-25	Hitchcock
575P	250.00-2-34	Anderson
2461P	216.00-3-21	Crowell
610C	251.01-1-32	Larkin
2514W	216.00-3-20	King
611C	251.01-1-20	Thomas
1216N	233.00-1-37.1	Kelly
545C	251.01-1-35.1	Bailey
578C	251.01-1-21	Person
604N	251.01-1-34	Morley
1023N	234.00-1-19	Ceranowicz
1036N	234.00-1-19	Ceranowicz

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Receptor ID	Parcel ID	Parcel Owner Last Name
2296B	220.00-1-8	Fitzgerald
4557B	183.00-1-27.1	Sykes
1214N	233.00-1-37.1	Kelly
525C	251.01-1-30	Lloyd
902N	233.00-2-37	Higgs
870N	234.00-1-26	Lanphere
522C	251.01-1-30	Lloyd
526C	251.01-1-30	Lloyd
561P	250.00-2-35	Anderson
458A	251.03-1-10	W & L Frost Family Trust I
514C	251.01-1-29	McMurdy
1115N	233.00-2-39	Jaquith
851N	234.00-1-27	Rivera
1326N	233.00-1-8	Callen
1189N	233.00-2-41	Catanese
4556B	183.00-1-26	Paradiso
1048N	234.00-1-19	Ceranowicz
2374N	216.00-3-46	Mclaughlin
3700P	200.00-1-1	Christy
1084N	234.00-1-17	Olmstead
4555B	183.00-1-25	Stone
1061N	234.00-1-19	Ceranowicz
1052N	234.00-1-19	Ceranowicz
1056N	234.00-1-19	Ceranowicz
972N	234.00-1-22	Bohnsack
2378N	216.00-3-46	Mclaughlin
1055N	234.00-2-8	Sharp
1042N	234.00-2-11	Abbey
1049N	234.00-2-9.2	Merzweiler
588N	251.01-1-36	Okerlund
1013N	234.00-2-10	Abbey
1596N	233.00-2-10	J & S Signs of WNY, Inc.
998N	234.00-2-14	Scolton
1033N	235.00-1-48	Olmstead
1407N	233.00-2-6	Loucks
1475N	233.00-2-9	Gens
1433N	233.00-2-45	Pastor
2404B	218.00-1-24	Stec
2342B	218.00-2-23	Millcreek
2421B	219.00-1-21	Minnick
2462B	218.00-2-31	Sikorski
3238B	201.00-1-15	Rew
1465B	235.00-1-7	Cleland
1462B	235.00-1-7	Cleland

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Receptor ID	Parcel ID	Parcel Owner Last Name
2037B	236.00-1-39	Astry
3711P	200.00-2-3	Schmelzinger
2411B	219.00-1-18	Brinkworth
2500B	218.00-1-21	Cybart
3742P	183.00-1-39	Nutt
3535P	200.00-2-11	Sullivan
1461B	235.00-1-7	Cleland
3744P	183.00-1-38	Diakakis
2206P	218.00-1-33	Gierlinger
2208P	218.00-1-33	Gierlinger
2612B	218.00-1-16	Wisniewski
3248P	200.00-1-18.2	Holtz
3676W	202.00-1-39	Jackson
2703B	218.00-2-1	People State Of New York
2099P	235.00-1-4.2	Gierlinger
2093P	235.00-1-4.2	Gierlinger
3674W	202.00-1-39	Jackson
2201P	218.00-1-33	Gierlinger
3161N	202.00-1-23	Irish
2018B	218.00-2-17	Gibas
2735P	220.00-1-12.1	Rowicki
2731P	220.00-1-12.1	Rowicki
3149N	202.00-1-23	Irish
3206N	202.00-1-21	Waschensky
2719P	220.00-1-12.1	Rowicki
2975N	201.00-1-27	Forbes
3567P	200.00-1-10	Ostroski
1634B	235.00-1-15	Pasquarella
802P	254.00-1-4	Mast
1635B	235.00-1-15	Pasquarella
3484P	202.00-1-49	Bloom
2337B	219.00-1-16	Young
1617B	235.00-1-15	Pasquarella
1643B	235.00-1-15	Pasquarella
2618P	219.00-1-35	Milks
1738B	235.00-1-13	Rivers
3153P	203.00-1-20	Langless
3382P	203.00-1-9	Baldwin
3558P	202.00-1-48	Greenough
3728P	202.00-1-39	Jackson
1665B	235.00-1-15	Pasquarella
3526P	200.00-1-10	Ostroski
3530P	200.00-1-10	Ostroski
2844N	218.00-1-2	Snyder

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Receptor ID	Parcel ID	Parcel Owner Last Name
3183P	203.00-1-20	Langless
3331N	202.00-1-12	Klipfel
3359N	202.00-1-11	Jackson
1638B	235.00-1-15	Pasquarella
3087P	220.00-1-16	Kent
2832P	217.00-2-5	Morley
3343N	202.00-1-11	Jackson
2220W	217.00-1-37	Hagberg
2890P	220.00-1-19	Zahm
3490P	203.00-1-6	Mitchell
2824P	217.00-2-5	Morley
400B	253.00-1-20	Nowak
3522P	203.00-1-5	Ricchiazzi
2317N	219.00-1-32.2	Howard
2326N	219.00-1-32.1	Howard
3532P	203.00-1-5	Ricchiazzi
3011W	200.00-1-20	Alaimo
1845N	236.00-1-32.1	Bowman
1840N	236.00-1-32.1	Bowman
3492P	203.00-1-6	Mitchell
2266P	217.00-2-20	Villella
2467N	220.00-1-3.2	Guarino
1857N	236.00-1-32.1	Bowman
2379N	220.00-1-4	Melinski
3018W	200.00-1-20	Alaimo
1078P	237.00-1-34	Blair
2865P	200.00-1-22	Maclaren
1856B	236.00-1-3	Crumb
1841N	236.00-1-31.1	Bowman
3158P	203.00-1-21	Fisher
3379W	200.00-1-14	Waterman
1082P	237.00-1-33	Oakes
2525P	220.00-1-26	Rowicki
3247W	200.00-1-17	Hoisington
2957B	219.00-1-3	Krajewski
3157P	203.00-1-23	Bowen
3891P	203.00-1-23	Bowen
1127P	237.00-1-39.2	Shetler
716B	253.01-1-7	Miller
715B	253.01-1-7	Miller
1162B	235.00-1-55	Hall
4539P	183.00-1-10.2	Mendell
2142B	236.00-2-2.2	Mancinelli
2151B	236.00-2-2.2	Mancinelli

Name of Person(s)
Preparing Response: RSG, Ken Kaliski

Date: May 9, 2017

Receptor ID	Parcel ID	Parcel Owner Last Name
2217B	219.00-1-11	Green
1683N	236.00-1-22	Hill
2637N	217.00-2-19	Crandall
3785P	185.00-1-47	Newton
3736P	202.00-1-45	Christian
3844P	185.00-1-53	Easterly
2640N	217.00-2-19	Crandall
1761N	237.00-1-11.2.2	Abby
1822N	237.00-1-2	Sweeting
2371N	220.00-1-4	Melinski
191B	254.00-1-21	Mosher
3703P	203.00-1-1	Abdul
1656N	236.00-1-21	Hill
1657N	236.00-1-21	Hill
1658N	236.00-1-21	Hill
2819P	217.00-2-1	Yale
2046P	217.00-2-25	Deering
3712P	203.00-1-1	Abdul
1365P	237.00-1-18	Frost
3722N	201.00-1-6	Zahn
1136B	235.00-1-65	Greenawald
2162W	237.00-1-5	Besse
1278W	234.00-2-4	North
3636N	202.00-1-5	Mansfield
2635N	217.00-2-17	Deering
3643N	202.00-1-4.1	Mansfield
3866B	184.00-1-41.2.2	Gambino
1988P	217.00-1-27	Lanphere
2559N	217.00-2-30	Higgs
3739P	183.00-1-48	Spinler Farms
3159P	203.00-2-19.4	Sheldon
3867N	184.00-1-44.2	Moore
2308C	217.04-1-2	Nalbone
202P	254.00-1-20	Mosher
2671P	217.00-2-3	Carpenter
2675P	217.00-2-3	Carpenter
2141W	237.00-1-5	Besse
3771N	184.00-1-43	Lou Eibl Corral
3868N	184.00-1-44.2	Moore
1916P	217.04-1-6	Baughman
1937P	217.04-1-6	Baughman
2625P	217.00-1-15	Chaffee
2665P	217.00-2-3	Carpenter

Name of Person(s)
Preparing Response: RSG, Ken Kaliski Date: May 9, 2017

Receptor ID	Parcel ID	Parcel Owner Last Name
3865B	184.00-1-41.2.2	Gambino
2617P	217.00-1-15	Chaffee
3770N	184.00-1-43	Lou Eibl Corral
1753B	235.00-1-21	Mehok
2616P	217.00-1-15	Chaffee
1676B	235.00-1-17.3	Losel
1107B	235.00-1-64.2	Bardo
3407P	200.00-1-39	Ellis
1101B	235.00-1-64.2	Bardo
3772B	184.00-1-41.2.2	Gambino
1089B	235.00-1-63	Gelenscer
1940C	217.04-1-8	Haire
3717N	202.00-1-30	Sanderson
2347P	217.00-1-48	Rosplock
2353P	217.00-1-48	Rosplock
3571P	200.00-1-2	Peterson
2352P	217.00-1-48	Rosplock
3781W	185.00-1-40	Traber
3782W	185.00-1-40	Traber
1673W	233.00-2-12	J & S Signs of WNY, Inc
2349P	217.00-1-48	Rosplock
3604P	200.00-1-2	Peterson
1662B	218.00-2-10	Korbas
2053C	217.04-1-22	Scott
3780W	185.00-1-40	Traber
3858N	185.00-1-38	Mann
4390P	271.00-1-13	Sperazza
3353P	203.00-1-29	Mathewson
3778W	185.00-1-40	Traber
2402P	217.00-1-51	Murphy
2632N	217.00-2-13	Ross
451W	254.00-1-16	Lent
3460P	200.00-1-3	Dake
3124P	220.00-1-21	Mcginty
4560P	203.00-1-30	Hannon
3773B	184.00-1-29	Stahl
235P	254.00-1-16	Lent
4559P	203.00-1-30	Hannon
3776B	184.00-1-39	Wykstra
3777B	184.00-1-39	Wykstra
3564P	200.00-1-2	Peterson
621P	250.00-2-8	W & L Frost Family Trust I
3775B	184.00-1-39	Wykstra

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Receptor ID	Parcel ID	Parcel Owner Last Name
3783W	185.00-1-40	Traber
2422P	216.00-3-18	Ward
3779W	185.00-1-40	Traber
2533P	217.00-1-49.2.2	Imm
2529P	217.00-1-50	Christopher
1166B	235.00-1-44	Bolibrzuch
2539P	217.00-1-50	Christopher
571P	250.00-2-32	W & L Frost Family Trust I
582P	250.00-2-32	W & L Frost Family Trust I
1159N	234.00-1-13.2	Shreve
1138N	234.00-1-13.1	Shreve
1135N	234.00-1-13.1	Shreve
2528P	216.00-3-13	Feather
487P	250.00-2-10.2	Gennuso
642C	251.01-1-33	Thomas
601C	251.01-1-32	Larkin
592N	251.01-1-34	Morley
1237W	234.00-2-4	North
4558B	184.00-1-29	Stahl
1103N	234.00-1-16.1	Olmstead
3693P	200.00-1-1	Christy
1098N	234.00-1-18	Carlstrom
599N	251.01-1-36	Okerlund
1605N	233.00-2-10	J & S Signs of WNY, Inc.
1030N	234.00-2-9.1	Hitchcock
1037N	234.00-2-18	Green
1032N	234.00-2-18	Green
1018N	234.00-2-18	Green
1020N	234.00-2-18	Green
1582N	233.00-2-10	J & S Signs of WNY, Inc.
1411N	233.00-2-45	Pastor
1415N	233.00-2-45	Pastor

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2011

Assessing Sound Emissions from Proposed Wind Farms & Measuring the Performance of Completed Projects

NARUC

NARUC Grants & Research

October 2011

The National Association of Regulatory Utility Commissioners

A report for the Minnesota PUC
Funded by the U.S. Department of Energy

The report you are reading was created under the State Electricity Regulators Capacity Assistance and Training (SERCAT) program, a project of the National Association of Regulatory Utility Commissioners (NARUC) Grants & Research Department. This material is based upon work supported by the Department of Energy under Award Number DE-OE0000123.

The report was authored by David M. Hessler of Hessler Associates, Inc. Throughout the preparation process, the members of NARUC provided the author(s) with editorial comments and suggestions. However, the views and opinions expressed herein are strictly those of the author(s) and may not necessarily agree with positions of NARUC or those of the U.S. Department of Energy.

Special thanks to the Commissioners and staff at the Minnesota Public Utilities Commission for guiding this work, and to the Office of Electricity Delivery and Energy Reliability and the National Energy Technology Lab for their continued technical assistance to NARUC.

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BEST PRACTICES GUIDELINES FOR

ASSESSING SOUND EMISSIONS FROM PROPOSED WIND FARMS
and
MEASURING THE PERFORMANCE OF COMPLETED PROJECTS

October 13, 2011

Prepared for:

The Minnesota Public Utilities Commission

Under the auspices of the National Association of Regulatory Utility Commissioners (NARUC), Washington, DC.

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1.0 Introduction

The noise produced by wind turbines differs fundamentally from the noise emitted by other power generation facilities in terms of how it is created, how it propagates, how it is perceived by neighbors and how it needs to be measured. Essentially everything about it is unique and specialized techniques need to be employed in order to rationally assess potential impacts from proposed projects and to accurately measure the sound emissions from newly operational projects.

Existing ISO[1,2], and ANSI[3,4] standards that are perfectly appropriate for evaluating and measuring noise from conventional power generation and industrial facilities were not written with wind turbines in mind and contain certain provisions that make them unsuitable for application to wind turbines. For example, most test standards, quite sensibly, allow valid measurements only under low wind or calm conditions in order to preclude, or at least minimize, wind-induced directional effects, among other things. At a conventional power plant, which may operate around the clock, this requirement simply implies a wait for appropriate weather conditions. At a wind turbine project, however, there is nothing to measure during calm wind conditions, since the project is normally idle. Significant noise generation largely occurs during wind conditions that are generally above the permissible limit. At the present time, a lone standard, IEC 61400-11[5] exists for evaluating wind turbine sound levels, but only for the specific purpose of measuring the sound power level of a single unit. Sound power level is an arcane, intangible, derived quantity that is used as an input to analytical noise models and has little relevance to the sound level a wind farm is producing at someone's home. Consequently, this highly specialized test cannot be used or even adapted to serve as a way of determining whether a new multi-unit project is in compliance with a noise ordinance, for instance.

What all this suggests is that the standards and methodologies that exist for assessing and measuring noise from conventional industrial noise sources cannot be applied wholesale to wind turbine noise and completely different assessment and field measurement methodologies are required that are tailored to, and take into account, the unique circumstances and technical challenges surrounding their noise emissions. These guidelines seek to address this situation by describing suggested assessment and measurement techniques that have been developed over the past decade through field experience on roughly 70 wind projects, primarily in the Midwest and Eastern United States, nearly all of which were located in rural, yet moderately populated areas. Without question many mistakes were made in the early going into this uncharted field of study and many naïve assumptions about wind turbine noise were found to be incorrect. It is hoped that what was learned from this experience and what is summarized in these guidelines can help others circumvent this learning curve.

After a brief discussion on the nature of wind turbine noise, the following principal topics are discussed:

- Suggested design goals for new projects
- Evaluating potential noise impacts from proposed projects through noise modeling and field surveys of existing conditions
- Measuring the noise emissions from operational projects to determine compliance with design goals or regulatory limits

1.1 Executive Summary

Wind turbine noise differs fundamentally from the noise produced by other power generation and industrial sources in how it is produced, how it propagates and how it is perceived by neighbors. Because existing sound measurement standards were never written with wind turbines in mind they are largely unsuitable for use in wind turbine analyses, if only because measurements both prior to and after construction essentially must be performed in the windy conditions necessary for the project to operate – conditions that are prohibited by virtually all current test standards. Consequently, new and unique evaluation and measurement techniques must be used that are adapted to the special circumstances germane to wind turbines. These guidelines are intended to help remedy this situation by suggesting design goals for proposed project, outlining a methodology for evaluating potential impacts from new projects and describing how to accurately measure the noise emissions from operating projects.

Studies and field surveys of the reaction to operating wind projects both in Europe and the United States generally suggest that the threshold between what it is normally regarded as acceptable noise from a project and what is unacceptable to some is a project sound level that falls in a gray area ranging from about 35 to 45 dBA. Below that range the project is so quiet in absolute terms that almost no adverse reaction is usually observed and when the mean project sound level exceeds 45 dBA a certain number of complaints are almost inevitable. In view of this, it would be easy to avoid any negative impact by simply limiting the sound level from a proposed wind project to 35 dBA at all residences, but the reality is that such a stringent noise limit cannot normally be met even in sparsely populated areas and it would have the effect of preventing noise impacts by making it virtually impossible to permit and build most projects. In fairness then, any noise limit on a new project must try to strike a balance that reasonably protects the public from exposure to a legitimate noise nuisance while not completely standing in the way of economic development and project viability. It is important to realize that regulatory limits for other power generation and industrial facilities never seek or demand inaudibility but rather they endeavor to limit noise from the source to a reasonably acceptable level in terms of either an absolute limit or an allowable increase relative to the background level.

Based on the observed reaction to typical projects in United States, it would be advisable for any new project to attempt to maintain a mean sound level of 40 dBA or less outside all residences as an ideal design goal. Where this is not possible, and even that level is frequently difficult to achieve even in sparsely populated areas, a mean sound level of up to 45 dBA might be considered acceptable as long as the number of homes within the 40 to 45 dBA range is relatively small. Under no circumstances, however, should turbines be located in places where mean levels higher than 45 dBA are predicted by pre-construction modeling at residences. It is important to note that a project sound level of 40 dBA does not mean that the project would be inaudible or completely insignificant, only that its noise would generally be low enough that it would probably not be considered objectionable by the vast majority of neighbors.

Noise impact assessments for proposed projects can be absolute or relative in nature. In an absolute analysis the sound level contours from the project are plotted over a map of the turbine layout and the surrounding potentially sensitive receptors, normally permanent residences, and the sound levels are evaluated relative to the 40 and 45 dBA criteria discussed above. A relative assessment involves, as a first step, a field survey of the existing soundscape at the site followed by a noise modeling analysis. The potential impact of the project is evaluated in terms of the differential between the existing background sound level and the calculated project-only sound level, importantly, under identical wind conditions. As a general rule of thumb, an increase of up to 5 dBA above the pre-existing L_{A90} sound level is usually found to be acceptable whereas greater increases should be avoided. This design approach only holds for background levels of about 35 dBA or above. When lower background sound levels are found a design goal of 40 dBA or less at all residences should be sought.

Commercially available software packages based on ISO 9613-2 are suggested for noise modeling analyses. Recommended modeling procedures would consist of the following steps.

- Begin with a base map showing the turbine locations and all potentially sensitive receptors in and around the project area (residences, schools, churches, etc.)
- Build up the topography of the site in the noise model if the terrain features consist of hills and valleys with a total elevation difference of more than about 100 ft. – otherwise flat terrain can be assumed
- Locate point sources at the hub height of each turbine (typically 80 m)
- Use the maximum octave band sound power level spectrum, measured per IEC 61400-11, for the planned turbine model or the loudest model of those being considered
- Assume a ground absorption coefficient (A_g from ISO 9613-2) appropriate to the site area (a moderate value of 0.5 generally works well as an annual average for rural farmland)
- Assume ISO “standard day” temperature and relative humidity values of 10 deg. C/70% RH unless the prevailing conditions at the site are substantially and consistently different than that
- Plot the sound contours from the project assuming an omni-directional wind out to a level of 35 dBA
- Evaluate the potential impact of the project at residences relative to the suggested 40 and 45 dBA thresholds

A relative impact analysis is recommended whenever unusually high or low background levels are suspected at a site, the project is large or controversial, or when there is simply a desire to carry out a thorough analysis. The baseline field survey of existing environmental sound levels should:

- Use 6 to 14 measurement positions depending on the complexity of the site
- Select positions at residences (to the extent possible) that are representative of all the distinct settings that may be present within the site area, such as sheltered valleys, exposed hilltops, wooded areas, near major roadways, remote and secluded, etc.
- Monitor in continuous 10 minute intervals for a period of at least 14 days to capture a wide variety of wind and weather conditions
- Record a number of statistical parameters, giving precedence to the relatively conservative L_{A90} measure
- Use Type 1 or 2 integrating sound level meters fitted with oversize (7" diameter, or greater) windscreens
- Mount the microphones approximately 1 m above ground level, where feasible, to minimize self-induced wind noise
- Use one or more temporary weather stations at the most open and exposed measurement positions to record wind speed at microphone height and other parameters, such as rainfall.
- Apply a correction, if necessary, to the A-weighted sound levels for wind-induced, self-noise based on the microphone height anemometer readings
- Evaluate the L_{A90} results for consistency over the various measurement positions, segregating the results for different settings if there are clear and consistent differences
- Normalize the wind speed measured by the highest anemometers on all on-site met towers to a standard height of 10 m per Eqn. (7) of IEC 61400-11
- Correlate the design site-wide or individual setting background levels to the normalized wind speed to determine the mean value as a function of wind velocity
- Use the 6 m/s result as the critical design wind speed or determine the site-specific critical wind speed from a comparison between the turbine sound power and background levels
- Use the mean L_{A90} background level at the critical wind speed as a baseline for evaluating the modeled sound emissions of the project under those same conditions

The accurate measurement of noise from an operational project requires a determination of the concurrent background sound level present at the time each sample of operational noise is measured so that the wind and atmospheric conditions are consistent. Background levels measured at a different time and under inevitably different conditions are not suitable for use in correcting operational sound measurements.

The objective of an operational survey is to quantify the project-only sound level exclusive of background noise, which can easily be comparable to the project level at typical set back distances. Ignoring this background component will normally result in an overestimate of the project's actual sound levels.

A methodology is outlined in these guidelines for estimating the simultaneous background sound level by monitoring at a number of positions outside of the site area in locations and settings that are similar in nature to the on-site positions but remote from all turbine noise. In general, an operational survey to determine the sound emissions exclusively due to the project should:

- Use 6 to 10 on-site measurement positions depending on the complexity of the site and focused on the residences with maximum exposure to turbine noise (irrespective of their participation in the project)
- Set up 3 to 4 off-site background measurement positions at positions at least 1.5 miles from the project perimeter in diametrically opposed directions. These positions should be similar in setting and character to the on-site positions but removed from any exposure to project noise
- Monitor in continuous 10 minute intervals for a period of at least 14 days to capture a wide variety of wind and weather conditions
- Record a number of statistical parameters, giving precedence to the L_{A90} measure
- Use Type 1 or 2 integrating sound level meters fitted with oversize (7" diameter, or greater) windscreens
- Mount the microphones approximately 1 m above ground level, where feasible, to minimize self-induced wind noise
- Use one or more temporary weather stations at the most open and exposed measurement positions to record wind speed at microphone height and other parameters, such as rainfall.
- Apply a correction, if necessary, to the A-weighted sound levels for wind-induced, self-noise based on the microphone height anemometer readings
- Evaluate the off-site L_{A90} results for consistency over the various measurement positions, segregating the results for different settings if there are clear and consistent differences. Develop one or more design background levels to be used to correct the on-site levels.
- Subtract the appropriate design background level from the total measured level at each on-site receptor to derive the project-only sound level at each receptor position
- Normalize the wind speed measured by the highest anemometers on all on-site met towers to a standard height of 10 m per Eqn. (7) of IEC 61400-11
- Plot the derived project-only sound levels as a function of time or wind speed.
- Exclude all data points measured during calm conditions when the project was not operating
- Exclude all data points that appear to be associated with local contaminating noises; i.e. noise spikes, usually occurring at only one position, that are not accompanied by a simultaneous spike in wind speed
- Evaluate the final results with respect to the applicable design goal or ordinance limit. If the measured levels are lower than the design target at least 95% of the time the project can be considered in compliance.

2.0 Characteristics of Wind Turbine Noise

The magnitude and nature of wind turbine noise is entirely dependent on time-varying wind and atmospheric conditions, whereas a conventional fossil-fueled power station operates, often continuously and steadily, in a manner that is completely independent of the local environment. Consequently, a combustion turbine plant, for example, is most apt to be perceptible and a potential noise problem during calm and still weather conditions while a wind turbine project would, under most normal circumstances, not make any noise at all under those same conditions. During moderately windy conditions increased background noise would tend to diminish the perceptibility of the fossil fueled plant while the wind project would generally be at its loudest relative to the background level. At very high wind speeds background noise often becomes dominant to the extent it can obscure both sources.

In addition to simply being dependent on prevailing wind and atmospheric conditions, wind turbine noise usually has a distinctive, identifiable character to it that makes it more readily perceptible than other industrial sources of comparable magnitude[6,7,8]. The fundamental noise generation mechanism, the turbulent interaction of airflow over the moving blades, is dependent on the characteristics of the air mass flowing into the rotor plane. For example, when the airflow is fairly constant and steady in velocity over the swept area noise is generally at a minimum. While such ideal, laminar flow conditions may exist much of the time, particularly during the day, they do not occur all of the time, and the reality is that the wind often blows in the form of intermittent gusts separated by short periods of relative calm rather than as a smooth continuous stream of constant velocity. In addition, the flow may contain turbulent eddies, may be unstable in direction and the mean velocity may vary considerably over the vertical diameter of the rotor, which is typically in the 77 to 112 m (250 to 370 ft.) range on the utility scale turbines now in common use. These uneven and unstable airflow conditions generally cause more noise to be generated - and it is generated sporadically as each gust sweeps past and as the wind varies amorphously in speed or direction over the rotor plane. Such unstable conditions can lead to sound levels that change very noticeably in the short-term not only in general volume but also in character.

Qualitatively, under average circumstances rotor noise, as perceived at a common set back distance of around 400 m (1200 ft.), might be described as a churning, mildly periodic sound due to blade swish, particularly when there are several units at comparable distances from the point of observation. The normally non-synchronized and incoherent sounds from multiple units tend to blur the sound and minimize the perception of swish, although it is most commonly weak during “normal” circumstances even if only one unit is present. Another common description is that the noise is reminiscent of a plane flying over at fairly high altitude. This apt comparison is probably partly due to the basic similarity in frequency content of the two sounds but also to the phenomenon where the sound can fade in and out randomly. In the case of an actual plane it is the intervening non-homogeneous atmosphere that alternately enhances or hinders sound propagation from the distant source producing this effect while, in the case of the wind turbine, it is more likely to be short-term variations in noise generation at the source itself, or a combination of both source and path effects.

A pure path effect that occasionally occurs is the enhanced propagation of turbine noise due to thermal layering, known as a stable atmosphere, where the air is warmer above the surface than at the surface causing sound rays to diffract downward and making a distant sound louder than it would otherwise be. At night, this phenomenon, most likely in combination with the wind speed gradient, is most likely to lead to an increase in periodic noise (generally referred to as amplitude modulation, or AM)[9,10]. The exact mechanism behind this noise, particularly when it becomes unusually pronounced, is not entirely understood, but, in simple terms, it is thought to be caused when the wind speed at the top of the rotor is significantly higher than the wind speed at the bottom; i.e. when the vertical wind speed gradient is more slanted and less vertical, as is usually the case at night. Having said that, however, this phenomenon is not always present or particularly pronounced at all sites, but *when of sufficient magnitude*, the fairly pronounced swishing or thumping sound that can result on certain evenings can and does give rise to quite legitimate complaints. In fact, this is probably the primary cause of serious complaints about wind project noise. In general, the occurrence of this phenomenon in its pronounced or enhanced form is rather rare making detailed measurements difficult[11] but a major effort[(ibid)] is currently underway in the United Kingdom seeking to quantify and further understand this noise.

2.1 Low Frequency Noise and C-weighted Sound Levels

When the swishing, thumping or beating noise alluded to above does occurs it is usually at a rate of about once per second, or 1 Hz, which is the blade passing frequency of a typical three-bladed rotor turning at 20 rpm. Although the "frequency" of its occurrence at 1 Hz obviously falls at the very low end of the frequency spectrum, this noise is not "low frequency" or infrasonic noise, per se. It is simply a periodic noise where the actual frequency spectrum may contain some slightly elevated levels in the lower frequencies but where the most prominent noise is roughly centered around 500 Hz near the middle of the audible frequency spectrum. In general, the widespread belief that wind turbines produce elevated or even harmful levels of low frequency and infrasonic sound is utterly untrue as proven repeatedly and independently by numerous investigators[12,13,14,15,16] and probably arose from a confusion between this periodic amplitude modulation noise and actual low frequency noise. Problematic levels of low frequency noise (i.e. those resulting in perceptible vibrations and complaints) are most commonly associated with simple cycle gas turbines, which produce tremendous energy in the 20 to 50 Hz region of the spectrum – vastly more than could ever be produced by a wind turbine.

The mistaken belief that wind turbines produce high levels of low frequency noise can also be attributed, perhaps even more definitively, to wind-induced microphone error where wind blowing through virtually any windscreen will cause the low end, and only the low end, of the frequency spectrum to substantially increase due to self-generated distortion. The magnitude and frequency response of this error has been theoretically/mathematically quantified by van den Berg[10] and empirically by Hessler[17] by subjecting a variety of commonly used windscreens to known air speeds in a massively silenced wind tunnel – thereby directly measuring the frequency response to air flow alone (the specific results of this study and its applications are discussed further in Section 5.1). The results of this wind tunnel experiment were used to evaluate measurements of actual wind turbine noise at a site in Southern Minnesota by Hessler in 2008[18]. Figure 2.1.1 below shows, as an example, the frequency spectra measured under fairly windy conditions in a rural soybean field 1000 ft. from an isolated unit and, at the same time, in an identical soybean field 3 miles away from any turbines.

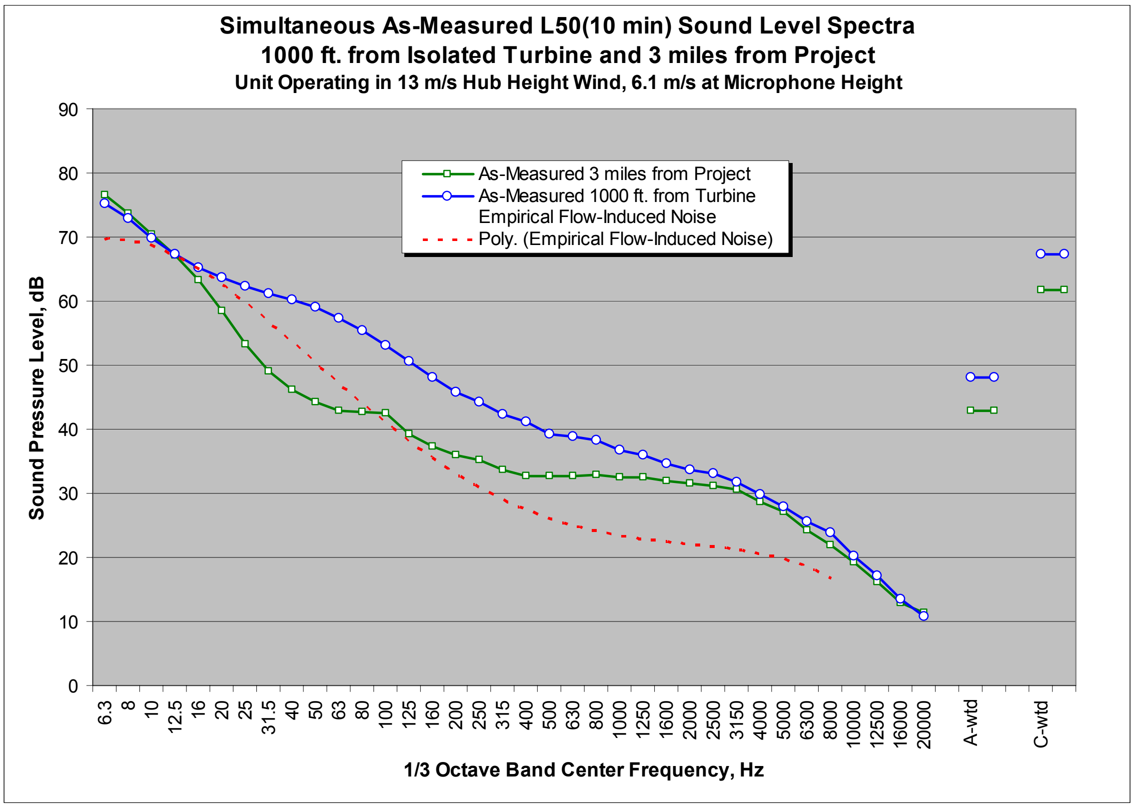

Figure 2.1.1

The two measurements show the same values in the lowest frequency bands. Since there is clearly no source of low frequency noise present in the background measurement, the low frequency levels - in both measurements – simply represent self-generated distortion and are not the actual sound emissions of anything. This can be confirmed from the wind tunnel study where the measured frequency spectrum for this particular windscreen (7" diameter) subjected to a 6.1 m/s wind is also plotted in Figure 2.1.1[a].

What all this shows is that virtually any measurement taken under moderately windy conditions will be severely affected by false-signal noise in the lower frequencies, even

[a] It should be noted that the wind tunnel results quantify the minimum amount of false-signal noise measured under more or less laminar flow conditions in the absence of possible further distortion from turbulence and atmospheric conditions.

when a large windscreen is used as in the example above. The measurement will appear to show high levels of low frequency noise - whether a wind turbine is present or not.

Figure 2.1.1 also illustrates another important point concerning C-weighted sound levels; namely, that the C-weighted levels at 1000 ft. and 3 miles are somewhat similar at 67 and 62 dBC, respectively. The significance of this is that C-weighted sound levels, as opposed to the much more common A-weighted metric, are normally used for the specific purpose of quantifying, investigating or placing a limit on noise sources that are rich in low frequency noise. The reason for this is that C-weighting does not mathematically suppress the low frequencies the way A-weighting does making it highly sensitive to and usually dominated by the low frequency content of a sound. Figure 2.1.2 shows this graphically for the example measurement at 1000 ft. from a wind turbine.

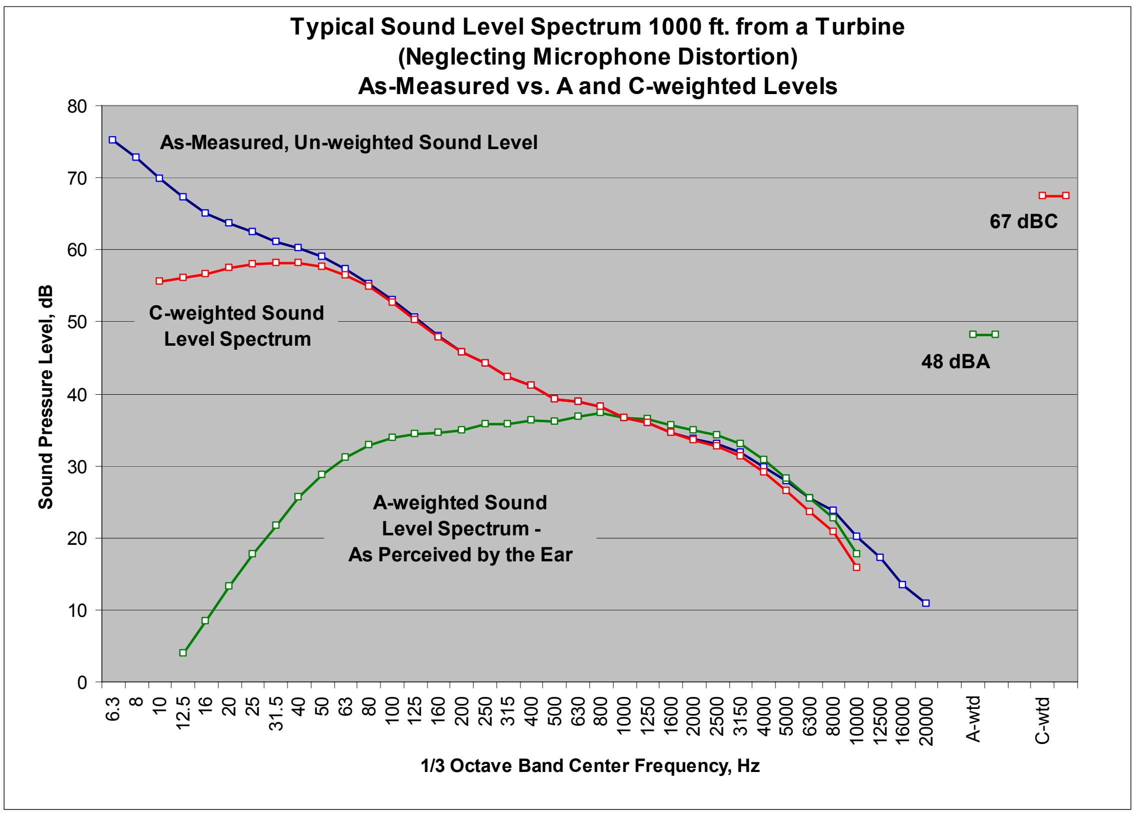

Figure 2.1.2

The as-measured sound level, warts and all, without any weighting applied is the blue trace. C-weighting reduces the low end of the frequency spectrum by a moderate amount whereas A-weighting reduces it substantially. There is no tangible or physiological rationale behind C-weighting but A-weighting serves the very useful purpose of adjusting the frequency spectrum of the sound so that it matches the way it is subjectively perceived by the human ear, which is relatively insensitive to low frequency sounds. Figure 2.1.2 shows that what is actually heard at 1000 ft. from this turbine is mid-frequency sound from roughly 100 to 2500 Hz – and even if the artificially elevated low frequency levels were actually attributable to the turbine nothing would still be audible in the low frequencies (recall that this measurement is unadjusted for low frequency false-signal noise).

The ultimate point of this discussion is that C-weighted sound levels cannot be measured in any kind of meaningful way in the windy conditions associated with turbine operation, since they essentially quantify the level of low frequency microphone distortion rather than any actual noise.

As another example, the plot below shows the C-weighted sound levels measured over a two week period at a residence surrounded by several wind turbines and simultaneously by a monitor located miles away from the project area in a similar setting (rural Midwestern farm country).

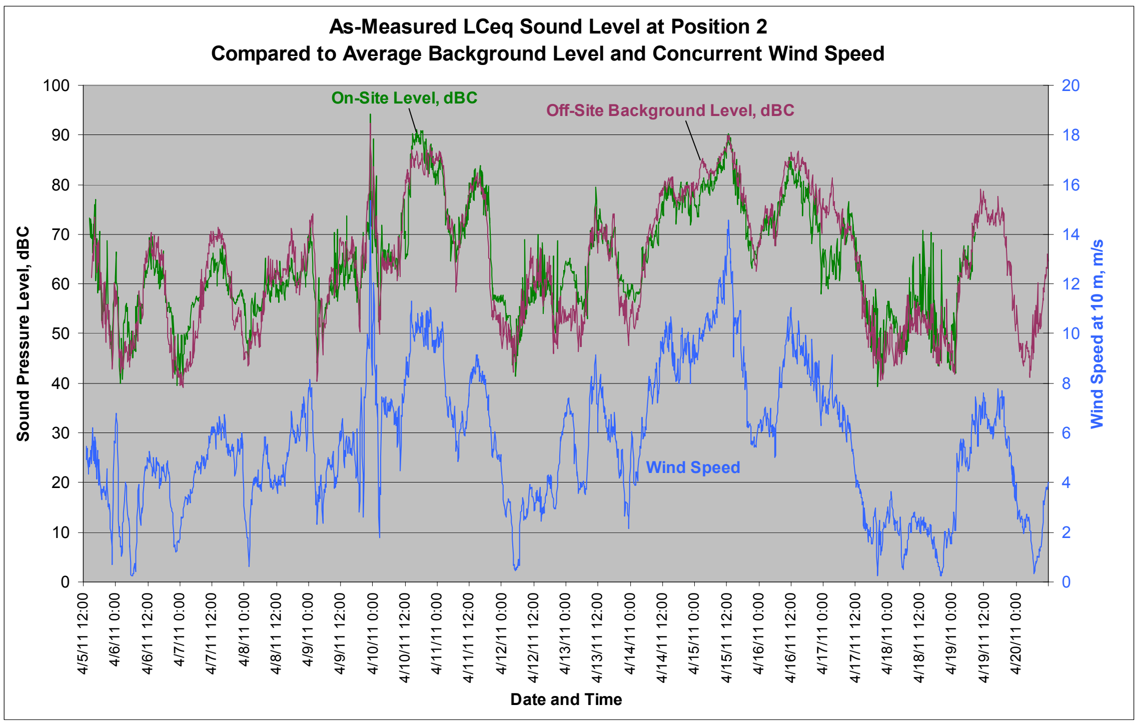

Figure 2.1.3

In essence, the levels are largely the same at both places and are more a measurement of the prevailing wind speed and its effect on the microphone rather than any real source of low frequency noise.

Consequently, despite their occasional appearance in local ordinances as an intended way of limiting the low frequency noise emissions from wind projects, by either an absolute limit or a dBA-dBC differential, C-weighted sound levels have no practical place in the measurement of wind turbine sound.

3.0 Recommended Design Goals

It would be a trivial solution to set an extremely low sound level of, say, 30 dBA as a permissible sound level for a new wind project at potentially sensitive receptors or to impose massive set back distances to any residences. While such restrictions would probably ensure that there was no adverse impact whatsoever from the project, the effective inaudibility of project noise would be due more to the fact it was never built than to its low sound emissions. Realizing virtual inaudibility or maintaining set backs of several thousand feet from all residences is generally an impracticality at all but the most remote sites. In fairness then, any noise limit on a new project must try to strike a balance that reasonably protects the public from exposure to a legitimate noise nuisance while not completely standing in the way of economic development and project viability. It is important to realize that regulatory limits for other power generation and industrial facilities never seek or demand inaudibility but rather they endeavor to limit noise from the source to a reasonably acceptable level either in terms of an absolute limit (commonly 45 dBA at night) or a relative increase over the pre-existing environmental sound level (typically 5 dBA[19]).

Research, principally by Pedersen[20,21] and Persson-Waye[22], on what the reaction is to wind turbine sound levels and what levels might be considered acceptable has been on-going for some time now in Europe. These studies analyze the responses to blind questionnaires distributed to residents living near wind farms in Sweden and The Netherlands in an effort to correlate the level of annoyance with noise and other factors with the calculated project sound level at each residence. In general, the results suggest among many other important findings that a project sound level in the 40 to 45 dBA range can lead to relatively high annoyance rates of around 20 to 25%[(ibid)]; however, it important to understand that these numbers refer to the percentage of those with exposure to such sound levels and not the entire population in the vicinity of the projects. Viewed within the context of the total survey population the rate of adverse reaction comes down to a handful of individuals or very roughly about 4 to 6% when residences are exposed to project sound levels in the 40 to 45 dBA range.

A somewhat similar rate of complaints/annoyance expressed as a percentage of the total population living within 2000 ft. of a turbine was found by Hessler[23] during compliance sound testing at a number of typical, newly operational wind projects in the United States. In each survey the total number of residents where complaints or even mild concerns about noise had been called in was obtained from project operations and the actual sound levels at all of these locations were measured over 2 to 3 week periods. The fundamental results are summarized in the following table.

Table 3.0.1 *Number of Observed Complaints Relative to the Total Number of Households in Close Proximity to Turbines [Hessler, 23]*

Project	Total Households in the Site Area (Approx.)	Number of Complaints as a Function of Project Sound Level (dBA) (a)			Total Number of Complaints	Percentage Relative to Total Households
		< 40	40 - 44	45 or Higher		
Site A	107	0	2	1	3	3%
Site B	147	0	3	3	6	4%
Site C	151	0	3	0	3	2%
Site D	268	0	2	4	6	2%
Site E	91	1	1	4	6	7%
					Overall Average:	4%
(a) Sound levels expressed as long-term, mean values						

Although the purpose of these surveys was to confirm compliance with regulatory noise and not specifically to evaluate community reaction, the findings, taken together with the European research mentioned above, suggest that the vast majority of residents living within or close to a wind farm have no substantial objections to project noise, particularly if the mean sound level is below 40 dBA. It is important to add that all of the sites investigated in these studies were just as prone as any other site to all the adverse character issues mentioned above, such as amplitude modulation, stable atmospheric conditions, highly variable sound levels and higher nighttime noise levels. While the possibility of annoyance, if not serious disturbance, can almost never be completely ruled out, it appears that the total number of complaints would be fairly small as long as the mean project level does not exceed 40 dBA. Above that point, specifically in the 40 to 45 dBA range, complaints can be expected with some certainty but, as indicated in Table 3.0.1, still at a fairly low rate of about 2% relative to the total population in close proximity to the project.

Consequently, it would be advisable for any new project to attempt to maintain a mean sound level of 40 dBA or less outside all residences as an ideal design goal. Where this is not possible, and it frequently is difficult to achieve even in sparsely populated areas, sound levels of up to 45 dBA might be considered acceptable as long as the number of homes within the 40 to 45 dBA range is relatively small. Under no circumstances, however, should turbines be located in places where mean levels higher than 45 dBA are predicted by pre-construction modeling at residences. A project sound level of 40 dBA does not mean that the project would be inaudible or completely insignificant, only that its noise would generally be low enough that it would probably not be considered objectionable by the vast majority of neighbors based on the actual reaction to other projects.

It is important to note that the sound levels in Table 3.0.1 and the suggested sound level targets discussed above are mean, long-term values and not instantaneous maxima. Wind turbine sound levels naturally vary above and below their mean or average value due to wind and atmospheric conditions and can significantly exceed the mean value at times. Extensive field experience measuring operational projects indicates that sound levels commonly fluctuate by roughly +/- 5 dBA about the mean trend line and that short-lived (10 to 20 minute) spikes on the order of 15 to 20 dBA above the mean are occasionally observed when atmospheric conditions strongly favor the generation and propagation of noise. Because no project can be designed so that all such spikes would remain below the 40 or 45 dBA targets at all times, these values are expressed as long-term mean levels, or the central trend through data collected over a period of several weeks.

4.0 Noise Impact Assessments

4.1 Noise Modeling

The principal mechanism for evaluating the potential impact of a proposed wind project is to analytically model its noise emissions. A sound level contour map showing the expected sound emissions from the project relative to all the residences in the area is essentially a graphic illustration of the potential impact. It follows from the preceding discussion of ideal design goals that predicted levels below 40 dBA at residences can be associated with a relatively low adverse impact, while higher levels, particularly those higher then 45 dBA, suggest a relatively high probability of serious complaints.

Because there are few options to reduce noise from a project once it becomes operational, any necessary noise abatement must essentially be designed into the project while it is still in the planning stage. Computer modeling allows the potential noise impact to be visualized but, importantly, also allows mitigation options to be explored, since the effects of relocating or removing individual turbines or using alternate turbine models can be easily evaluated. Such optimization studies are best performed early in the development process while there is still some flexibility to move things around. This process can be repeated iteratively as the design develops and lease and easement agreements evolve to help keep community noise levels as low as possible within the context, of course, of many other constraints.

4.1.1 *Acceptable Sound Propagation Standards*

Wind turbine noise is actually rather simple to model because the project consists of more or less ideal point sources located high in the air. Consequently, the dominant sound propagation factor is simply spherical wave spreading with distance, which is an axiomatic law of physics that is built into every modeling software package. All other effects, such as ground or air absorption, are minor subtleties by comparison so great sophistication in modeling software is not required. In fact, all that is really necessary is to calculate sound propagation from the project using ISO 9613-2 *Acoustics – Attenuation of sound during propagation outdoors. Part 2: General method of calculation* (1996)[24], which is, by far, the prevailing and most widely accepted worldwide standard for such calculations and the basis for essentially every commercial noise modeling program.

Like the other test standards alluded to in the introduction, ISO 9613-2 was not written with wind turbines in mind and its applicability to elevated sources (usually 80 m) and long propagation distances is occasionally questioned. Table 5 in the standard gives the estimated accuracy of the method for noise sources up to 30 m high and for propagation distances up to 1000 m. This 30 m height figure is sometimes interpreted to mean that the standard cannot be used for 80 m high sources, but it is just that no specific accuracy estimate is given for such cases, not that the standard is inappropriate. As mentioned earlier, the principal sound propagation loss in wind turbine modeling is simple geometric spreading of the sound wave, which is a phenomenon that has no dependence on the specific point of origin or its height above ground level.

Source height is a factor, however, in the relatively minor ground absorption loss (i.e. the tendency of the ground surface to variously absorb or reflect sound waves) but measurements of actual wind turbine sound levels vs. predictions show reasonably good agreement indicating that the calculation of the ground absorption loss and, indeed, the entire methodology, is perfectly valid for wind turbines.

Having said that, it should be noted that ISO 9613-2 does not consider atmospheric conditions, such as the wind and temperature gradients, stability, turbulence, etc., and was always intended to portray very long-term or average propagation conditions under slightly conservative downwind conditions. Consequently, the model results using this standard need to be interpreted as the expected sound level under “average” conditions, meaning that the actual sound level will be close to the prediction much of the time but higher *and* lower levels will occur with about equal regularity due to fluctuating atmospheric conditions, which affect both the generation and propagation of wind turbine noise. The plot below shows a typical comparison between the measured project-only sound levels over a two week period compared to predictions at various wind speeds. The model predictions tend to agree with the central trend line. The scatter evident in this chart is normal and inevitable and reflects the natural variability of wind turbine sound levels as observed at a distant point.

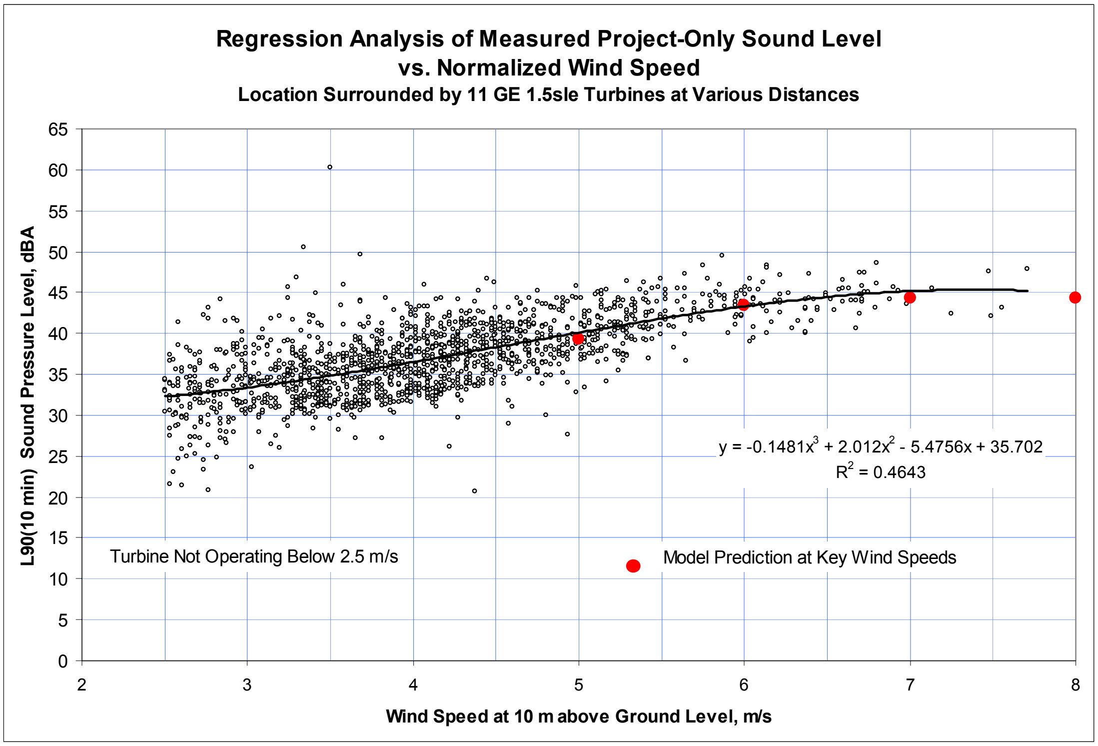

Figure 4.0.1

It should be pointed out that there is an alternative prediction methodology to ISO 9613-2 that takes atmospheric conditions into account: NORD2000[25], which is a proprietary software package that has been in development in Denmark for quite some time. However, it is rather complicated and is not in wide use partially because it has not been integrated or fully integrated into the most commonly used modeling programs. This sound emissions model is based on the fundamental mathematics of wave propagation rather than the empirical studies that form the basis for most of the propagation losses in ISO 9613-2, but despite its sophistication it does not seem to yield substantially better results than ISO 9613-2[26]. As exemplified by Figure 4.0.1, there is no reason why the more common and simpler ISO 9613-2 methodology should not be used.

4.1.2 *Modeling Software*

In theory, then, any program based on ISO 9613-2 can ostensibly be used to model wind turbines but there is more to it than the calculation of sound propagation losses. What emerges as the key differentiation between programs is basically how well and easily the site plan can be imported into the program and the quality and nature of the program's output.

Typical wind projects consist of dozens of units either spread out over many square miles in flat or rolling country or strung out along ridgelines. At the first type of site the turbines are frequently mixed in with potentially sensitive receptors (typically permanent residences) that can easily number into the hundreds. With ridgeline projects the nearest receptors are usually all around the base of the mountain or promontory on which the turbines are proposed and the effective project area (i.e. the region where residences exist within possible earshot of the project) can be vast. Consequently, it is best, if not essential, to use a modeling program that allows for the reasonably easy importation and scaling of a site map that shows not only the turbine locations but also all of the surrounding potentially sensitive receptors. Such a map is normally in shapefile (.shp) format with a layer for the turbines, a layer for structures (unfortunately not often differentiated into houses, barns, garages, commercial buildings, etc.) and layers for other features such as roads or topography. While nominally possible, it is not normally desirable to use only numerical tables of turbine coordinates to create the model for the principal reasons that a separate base map needs to be found and imported and different coordinate systems can become confused. In addition, publically available maps (used as a base map for the model) almost never show, or at least accurately show, all the residences in the vicinity of the project.

In addition to the turbines and houses the topography of the site often needs to be considered in the model – not only because of the line sight between the turbines and houses may be partially blocked or obstructed, but more generally because the source-receptor distance at sites with fairly dramatic terrain is affected and usually lengthened when modeled in three-dimensions. Consequently, a program that has the ability to import terrain contours and then mathematically consider their effect on sound propagation is essential for any project in a hilly or mountainous setting. This factor can only be safely ignored for sites with fairly flat or gently rolling topography.

In terms of output the most important element is the ability of the program to map sound contours in high resolution over the input base map. The potential impact from any wind project is normally graphically evaluated from contour plots. It is the number of houses within a certain threshold or sound level that usually determines whether the project is likely to result in complaints or not or whether it will comply with regulatory noise limits.

In terms of specific programs, Cadna/A® developed by Datakustik GmbH (Munich, Germany), appears to be used most often by engineers and consultants and is fully capable of importing shapefiles, modeling complex terrain and producing detailed contour maps.

The second most common noise prediction program is the sound emissions component of the WindPRO® software package (EMD International A/S, Denmark), which is a generalized siting tool for wind farms. The noise prediction module is only one aspect of the much larger program.

SoundPLAN® (Braustein & Berndt GmbH, Backnang, Germany), is evidently similar in capability to Cadna/A® but, for reasons that are unclear, is not often used for wind turbine analyses despite its apparent capability to integrate the NORD2000 algorithm as an optional calculation methodology.

One other program, WindFarm® (ReSoft Ltd, U.K.), is another general project design package of which the noise component is only a small part.

Any one of these programs would be generally acceptable for modeling the noise from a new project.

4.1.3 *Model Inputs*

In contrast to models of acoustically complex fossil fueled power plants that consist of dozens of major sources, the sound levels of which often need to be estimated, the input to a wind turbine project model is a single sound power level spectrum that is known with considerable accuracy. Turbine sound power levels are tested in accordance with IEC 61400-11[5], in which highly specialized and meticulous techniques are used to derive the sound power level of a wind turbine over a range of wind speeds from 6 to 10 m/s (as measured at 10 m above ground)[b]. The best input to use for any model is the maximum octave band sound power level frequency spectrum taken directly from a field test report.

Although such reports are sometimes made available by manufacturers, it is more common for the acoustical performance to be reported second-hand (based on either an IEC 61400-11 test or analytical calculations) in a technical specification document published by the manufacturer. The reported sound levels may or may not contain an explicit design margin and/or may be stated as warranted sound levels. While input sound levels that have been artificially inflated would tend to needlessly overstate the potential impact of a project, there often isn't any alternative to using whatever performance the manufacturer decides to publish. Whatever the source of the data is, it should be clearly stated in the impact assessment report.

4.1.4 *Modeling Methodology*

Recommended procedures for modeling wind turbine project noise are as follows:

- Begin with a base map showing the turbine locations and all potentially sensitive receptors in and around the project area (residences, schools, churches, etc.)
- Build up the topography of the site in the noise model if the terrain features consist of hills and valleys with a total elevation difference of more than about 100 ft. – otherwise flat terrain can be assumed
- Locate point sources at the hub height of each turbine (typically 80 m)
- Use the maximum octave band sound power level spectrum for the planned turbine model or the loudest model of those being considered
- Assume a ground absorption coefficient (A_g from ISO 9613-2) appropriate to the site area (a moderate value of 0.5 generally works well as an annual average for rural farmland, although higher values specifically for farm fields during summer conditions may be appropriate. A value of 0 (100% reflective ground) is likely to produce highly conservative results)

[b] In its current edition (2.1). A revision to this standard has been in development for some time that would expand this wind speed range and add a number of other refinements (and complexities) to the test procedure. It is unclear whether this new edition will ever actually be adopted.

- Assume ISO "standard day" temperature and relative humidity values of 10 deg. C/70% RH unless the prevailing conditions at the site are substantially and consistently different than that
- Plot the sound contours from the project assuming an omni-directional wind out to a level of 35 dBA (shading the area between each 5 dBA gradation with a different color often greatly improves legibility)

The assumption of an omni-directional wind means that the sound power level of the turbine, which is measured in the IEC 61400-11 procedure downwind of the unit, is modeled as radiating with equal strength in all directions; i.e. the sound level in every direction is the downwind sound level. Although this may seem be depict an unrealistic situation and over-predict upwind sound levels, the fact of the matter is that this approach generally results in predictions that are consistent with measurements irrespective of the where the receptor point is located. Although somewhat counterintuitive, the reason for this is that wind turbine noise under most normal circumstances is not particularly directional and generally radiates uniformly in all directions. As an example, the plot below shows the sound levels measured in three directions 1000 ft. from a typical unit in a rural project in Southern Minnesota. Although there are periods when the levels differ, implying some directionality, the majority of the time all three sound levels are generally about same irrespective of the wind direction. Moreover, the sound level at the downwind position is almost never elevated relative to other directions as one might expect.

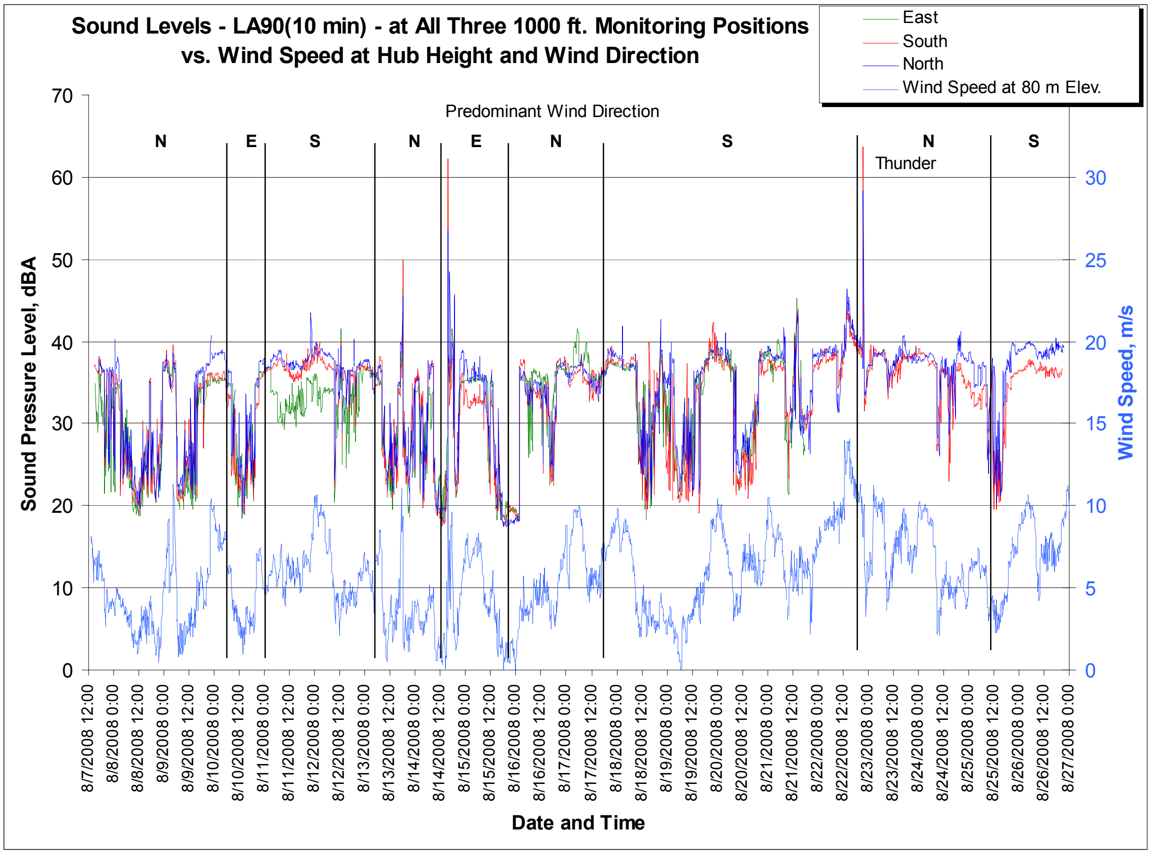

Figure 4.1.4.1 *Sound levels at 1000 ft. from a Typical Unit in Three Directions*

4.1.5 *Interpretation of Model Results*

An example plot for a hypothetical project, prepared using Cadna/A® and the procedures outlined in Section 4.1.4, is shown in Figure 4.1.5.1. In this instance, the units are located on a fairly prominent ridgeline and the topography has been recreated in the model.

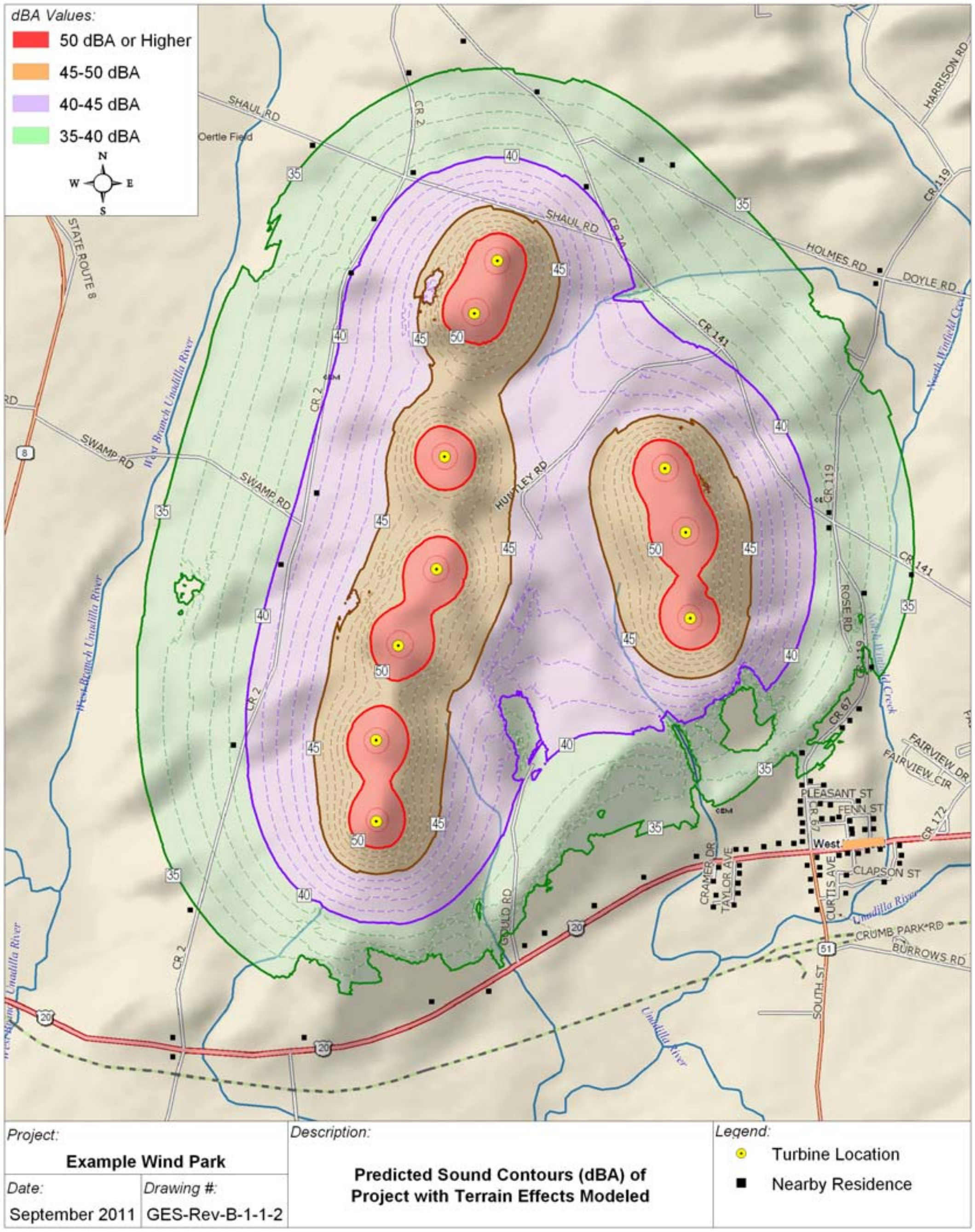

Figure 4.1.5.1 *Noise Model Plot – Example A*

Based on the plot, the potential noise impact from this project can be characterized as being fairly mild in the sense that nearly all of the residences in the vicinity of the project are expected to see a mean sound level of 40 dBA or, in most cases, less. The few houses that are nominally above 40 dBA are only marginally above that threshold and none are close to the 45 dBA absolute upper limit. The green region between 40 and 35 dBA generally represents the area where in all likelihood project noise would still be readily audible some of the time, if not much of the time, but at a fairly low magnitude. The audibility of and reaction to sound levels in this range would be somewhat dependent on the level of natural background sound in the area, since environmental sound levels in rural areas are commonly in the mid to high 30's dBA during the moderate wind conditions necessary for the project to operate – or, in other words, the background sound level could be roughly equivalent to the project sound level limiting its perceptibility. Below 35 dBA project noise generally becomes so low that it is only rarely considered objectionable even in extremely low noise environments. Complete inaudibility does not occur for quite some distance from most projects in quiet areas because of the distinctive, periodic nature of wind turbine noise. The actual distance to the point of inaudibility varies amorphously with atmospheric conditions and is generally much further at night than during the day. Consequently, the exact reaction to any project can never be predicted with certainty because project noise is often audible to some extent, at least intermittently, far from the project. However, the studies of response to wind turbine noise discussed in Section 3.0 suggest that the threshold between a mild or acceptable impact and a fairly significant adverse reaction is a gray area centered at 40 dBA.

An additional sound contour plot is shown in Figure 4.1.5.2 representing another hypothetical but typical project, this time in essentially flat Midwestern farm country.

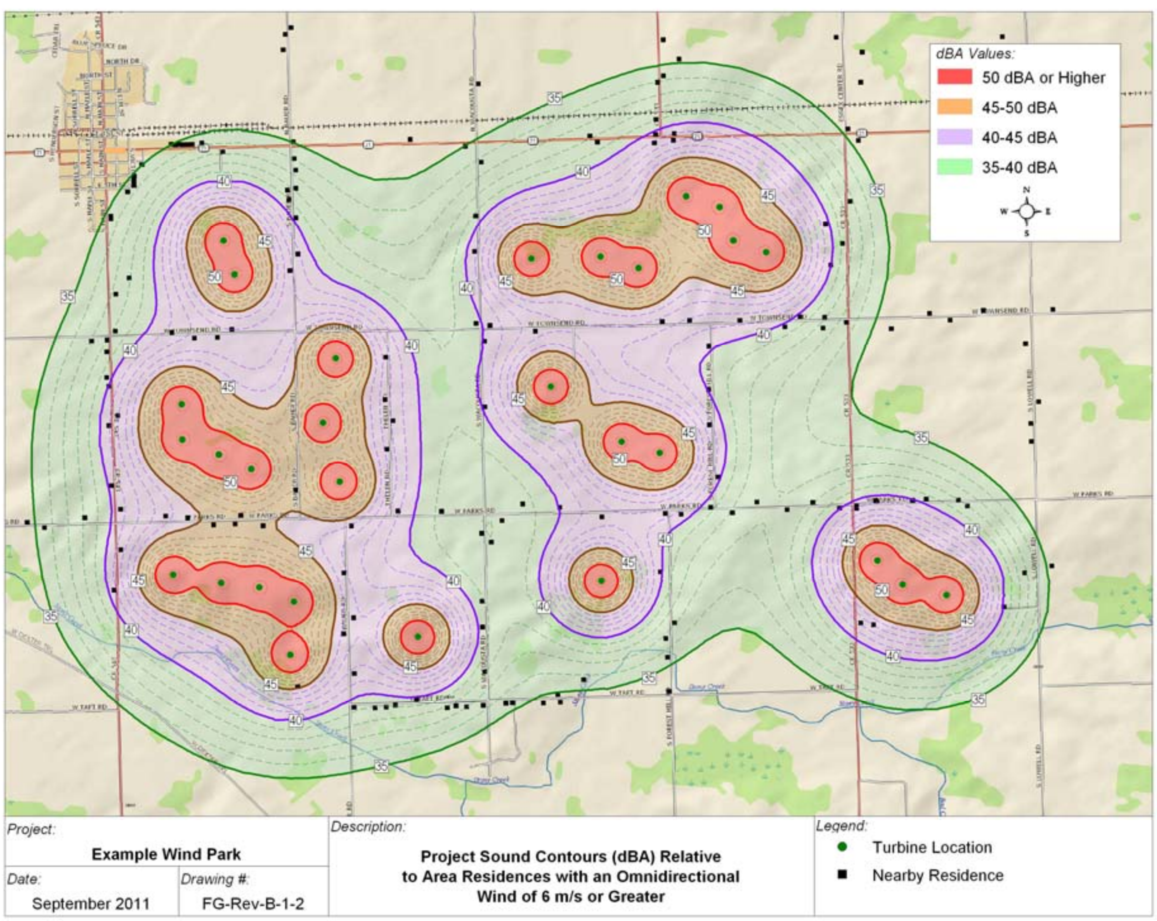

Figure 4.1.5.2 *Noise Model Plot – Example B*

In contrast to Example A, there are many homes inside of the 40 dBA sound contour in this scenario and even a few above 45 dBA, which is a common occurrence. One would have to conclude that at least a few complaints about noise would arise from this project if it were to proceed to completion in this configuration. The population density is such at this site that an optimization study should be undertaken to evaluate the feasibility of removing and relocating turbines outside of the present site area so that sound levels are substantially reduced at the homes with predicted levels of above 45 dBA and so that the number of residences above 40 dBA is dramatically diminished.

4.2 Pre-Construction Background Sound Surveys

Noise impacts can be evaluated in both absolute and relative terms. In the discussion immediately above the reaction to the example projects was estimated directly from the predicted project sound levels, neglecting background noise or essentially assuming a rural setting with generally quiet background sound levels. However, not all sites are the same and it is often prudent to perform a survey of existing conditions to establish just what the baseline sound levels are at residences in the proposed project area. In general, the audibility of, and potential impact from, any project is a function of how much, if at all, its noise exceeds the prevailing background level. A comparison between the predicted/modeled sound level from a proposed project and the actual background sound level measured in the project area under comparable wind and weather conditions gives a site-specific indication of the potential relative impact from the project.

Such a survey is not essential in all cases but is recommended when:

- Unusually high background levels are suspected (e.g. due to the proximity of a major highway, urban areas or existing industrial facilities)
- Unusually low background levels are suspected
- The project is unusually large or controversial
- There is simply a desire to carry out a complete and thorough assessment

4.3 Recommended Field Survey Methodology

The objective of a pre-construction survey is to establish what levels of environmental sound are currently being experienced at typical residences within the general project area in order to form a baseline against which the predicted sound emissions from the project can be compared. There is no need, nor would it be practical, to measure at every house. The idea is to get a set of samples that can be considered representative of the overall site area. In rural areas away from significant sources of man-made noise, it is common to find that the sound levels at all positions are generally similar indicating that background sound levels are for all intents and purposes uniform throughout the site area.

Contrary to popular belief, such a survey is *not* useful for the purpose of establishing the pre-existing environmental sound level as a baseline against which to compare the measured sound emissions from the completed project. The background sound level varies dramatically with time, typically over a dynamic range of 30 dBA or more, depending not only on the wind speed but many other factors, such as the prevailing atmospheric conditions, the time of day, season of the year, etc., so the level measured one or two years earlier cannot be taken to accurately represent the background level present during an operational compliance test. In fact, the only valid background level is the background level occurring, literally, at the same time that the operational sound level is measured. A methodology for overcoming this seeming impossibility is discussed later in Section 5.1.

4.3.1 *Measurement Positions*

Specific monitoring positions should ideally be located at or near typical residences in the site area. It is the sound level where people actually are most of the time and especially at night that is of primary importance (rather than at property lines, for instance). Permission to set up equipment on private property is usually freely granted upon request.

If a site is largely flat and homogenous in nature (e.g. rural farmland away from any major highways, urban areas or industry) monitor positions should be selected at points that are more or less evenly distributed over the project area. In such simple cases, 6 to 8 monitoring positions are usually more than sufficient even if the project area is fairly large.

For more complex sites, where the topography is significant or where man-made noise sources already exist, more monitoring positions will generally be required with the objective of capturing sound levels at residences in each kind of setting. A "setting" is defined as an area where the prevailing environmental sound level is suspected of differing significantly from other parts of the project area. For example, houses in the bottom of ravines or valleys may experience different ambient sound levels than nearby houses on exposed hilltops. Monitors should be located at positions representative of both of these settings. Another type of unique setting might be at homes that are located directly on a major road or highway or in an urban area versus others in the project area that are in remote areas. In some cases, a wind farm already exists adjacent to the area where a new project is proposed. Measurements should be made at homes that have maximum exposure to the sound emissions from the operating turbines for comparison to measurements at residences that are remote from the existing project. The total number of monitoring positions is generally limited by equipment availability and logistical concerns but no more than about 12 to 14 positions are normally required, even for the most complex sites.

4.3.2 *Survey Duration and Scheduling*

Short duration spot samples are insufficient to capture environmental sound levels over the variety of wind and atmospheric conditions that are relevant to project operation. For example, a brief sample on a calm, quiet night is meaningless in the sense that it does not represent the background sound level that will exist on a continuous basis or during the moderately windy conditions necessary for the project to generate noise. In fact, background sound levels in the rural areas where wind projects are most commonly sited are remarkable for their variability and substantial dependency on wind speed. It is the background sound level that occurs when it is moderately windy that is actually of interest for comparison to project sound emissions. In the very typical example below, the background sound level measured at four positions widely distributed over a proposed wind project site in the Midwest can be seen to parallel the concurrent wind speed and, moreover, to vary dramatically from 17 dBA during calm conditions to 54 dBA during windy conditions.

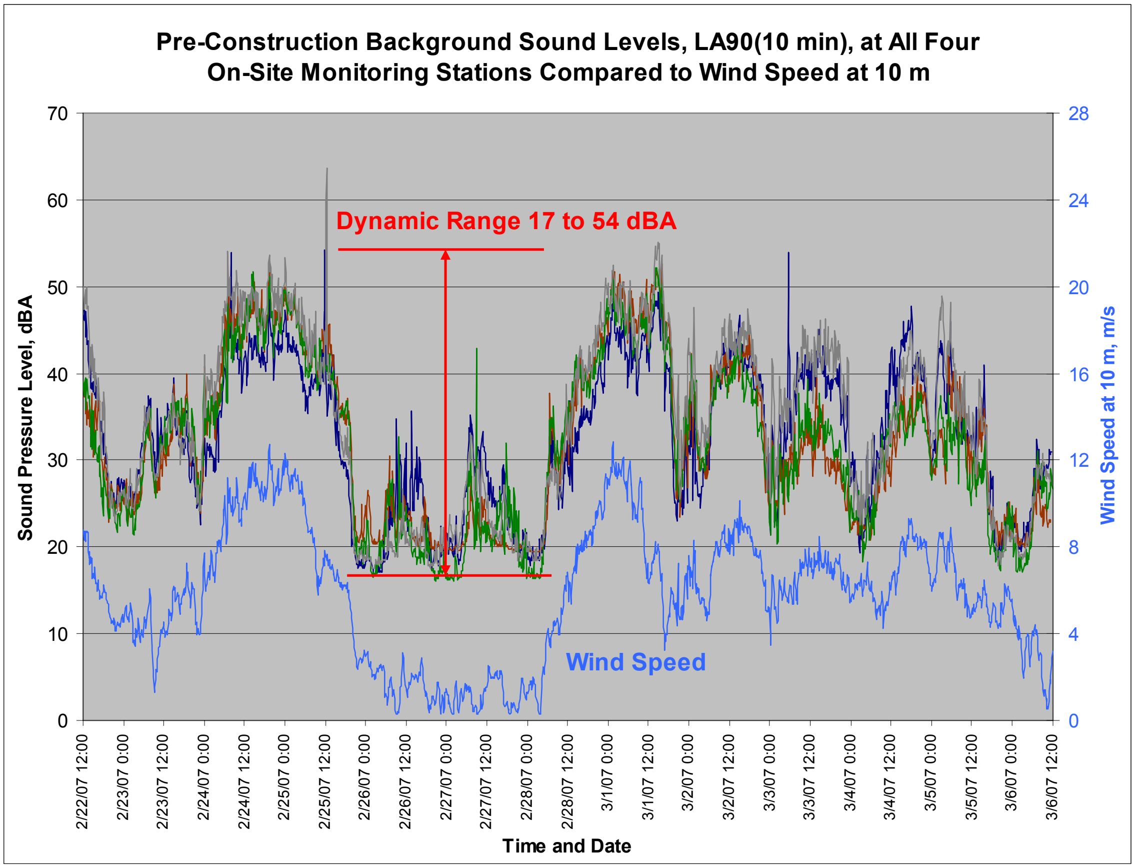

Figure 4.3.2.1

Consequently, a long-term, continuous monitoring approach is needed in which multiple instruments are set up at key locations and programmed to run day and night for a period of about two weeks or more. In essence, it is necessary to cast a wide net in order to capture sound levels during a variety of wind and atmospheric conditions and provide sufficient data so that the relationship between background noise and wind speed can be quantitatively evaluated.

Field experience suggests that an adequate range of wind speeds, from 0 to 10 m/s at 10 m above ground level, will usually be observed over any given 14 day period at most wind energy project sites, except perhaps during the low wind season at sites that might have very pronounced seasonal wind characteristics. Probably the principal reason for this observation is that this length of time is large relative to the time normally taken for weather patterns, wind directions and general atmospheric conditions to change, which essentially ensures that the data are statistically independent, as discussed in great detail in ANSI S12.9-1992/Part 2[27]. Data independence implies that the test results can be taken to represent the longer-term acoustic situation for that area, at least for the general time of year of the test. However, if a review of the weather conditions that occurred during the survey period shows that the winds were unusually calm or if an insufficient number of data points were collected at the higher wind speeds, the survey may need to be extended for another two weeks. Low wind conditions are most commonly captured and the vast majority of the measurements will be for conditions below or just above the cut-in wind speed. High winds normally occur intermittently over a few hours or a few days separated by sometimes lengthy periods of relatively calm conditions. It may sound counterintuitive, but it is not critical to capture extremely high wind conditions, say higher than about 12 m/s at 10 m, since most complaints and issues with wind turbine noise occur during moderate or even light wind conditions, while background noise tends to predominate under very windy conditions.

As a practical matter, the instruments for such a survey are set up, started and left to run unattended for the nominal two-week test period following which they can be retrieved and downloaded. Of course, one could stay on site through the test making additional intermittent manned measurements and observations but the very high cost of such an effort would be difficult to justify, particularly since it would not necessarily guarantee a better or more definitive result than could be derived from the monitor data alone.

In terms of scheduling, it is highly preferable to conduct this type of survey during cool season, or wintertime, conditions to eliminate or at least minimize possible contaminating noise from summertime insects, frogs and birds. In addition, it is best for deciduous trees to be leafless at sites where they are present in quantity to avoid elevated sound levels that might not be representative of the minimum annual level. Human activity, such as from farm machinery or lawn care, is also normally lower during the winter. While summertime surveys can be successful they should, as a general rule, be avoided wherever possible because nocturnal insect noise, for instance, can easily contaminate the data and make it impossible to quantify the relationship between sound levels and wind speed.

In addition to seasonal concerns, it is desirable, when practical, to attempt to schedule the survey set up to just precede a predicted period of moderate or high winds. This not only ensures that the survey period will capture these winds but also creates an opportunity for manned observations and measurements to be made for a day or two to augment to the longer term monitoring survey.

4.3.3 *Instrumentation and Test Set-up*

As with any field sound survey, what equipment is used and how it is deployed must adhere to certain minimum technical standards. These requirements are generally described in numerous standards, such as ANSI S12.9-1992/Part 2[27]; however, the focus of this section is not to repeat and belabor those details but rather to point up what adaptations need to be made for the specific application of performing general site-wide surveys for wind turbine projects. As mentioned earlier, no standard exists that can be directly used for this purpose, if only because they limit data collection to low wind conditions.

In terms of instrumentation, most environmental sound measurement standards recommend the use of Type 1 precision equipment per IEC 61672-1[28] or ANSI S1.43-1997[29] while also allowing for the use of Type 2 equipment. There is certainly no reason on technical grounds to oppose this recommendation but, from a practical perspective, it is often necessary to use Type 2 equipment for surveys of this type because of the large number of instruments needed. The normally negligible difference in technical performance between these two instrument classes is totally inconsequential within the inherently and unavoidably imprecise nature of this type of survey. It is much more important that the equipment is durable, reliable and specifically designed for extended use in the outdoors. Delicate and expensive Type 1 precision grade equipment can be unreliable in such applications or even unable to be programmed as a data logger.

Although high cost and extreme precision are not essential, the functional capabilities to statistically integrate sound levels over a user defined time period and automatically store the results are necessary. Because the on-site wind and weather monitoring towers, or met towers, normally integrate and store measurements in 10 minute increments it is convenient, if not necessary, to measure and store sound data in synchronization with the wind data collected by these towers for later correlation. It is evidently universal practice for met towers to store data 6 times an hour in 10 minute intervals that begin at the top of the hour; as in 9:00, 9:10, 9:20, etc. Consequently, sound data logging should be started using a trigger function to begin at the top of an hour and not randomly by the manual push of the start button. The timers on all instruments should be exactly synchronized to local time. Of course, all of the instruments must be field calibrated at the beginning of the survey and checked again for drift at the end of the survey.

Because this long-term survey approach involves unattended monitoring, the instrument and the microphone must be capable of withstanding damage, interference or outright destruction from rain and snow, which, among other things, means that the ground plate technique specified in IEC 61400-11 – where the microphone is laid flat in the center of a board on the ground and covered with one or more hemispherical windscreens – is not a viable option, despite its otherwise highly desirable advantage of minimizing wind-induced pseudo noise. Consequently, the microphone must be mounted above ground level and protected from wind-induced distortion by a spherical weather-treated windscreen, which normally entails a higher density foam that is hydrophobically treated to shed water (windscreens and wind-induced noise are discussed in detail later). As a general rule, a slightly lower than normal microphone height of about 1 m above ground level is preferred for this application on the premise that wind speed diminishes exponentially with decreasing elevation theoretically going to zero at the surface, or boundary layer. To illustrate this, the nominal wind speed profile, or shear gradient, per Eqn. (7) in IEC 61400-11 is illustrated below in Figure 4.3.3.1 for a common turbine operating condition where the wind speed is 6 m/s at the standard elevation of 10 m above ground level.

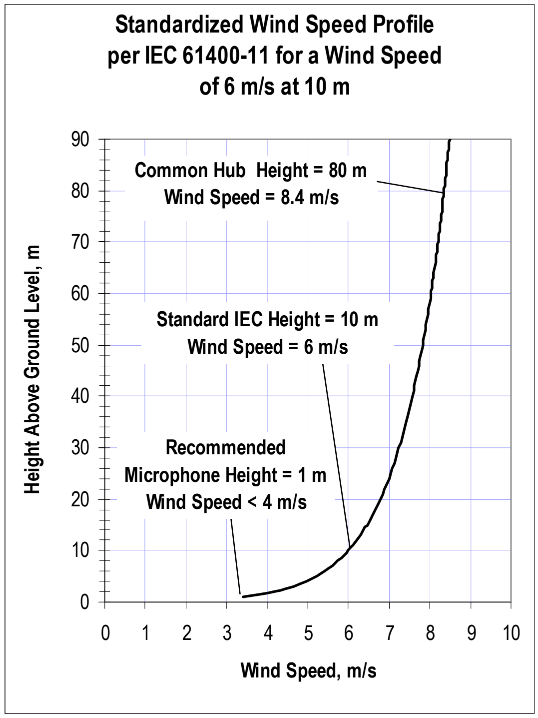

Figure 4.3.3.1

For these moderate wind conditions, the wind speed at a 1 m microphone height would be less than about 3 or 4 m/s, which as shall be seen later, means that distortion from wind blowing through the windscreen is of little or no consequence with respect to the A-weighted sound level so long as an extra large windscreen is used (typically 7” in diameter, as a minimum).

In addition to arranging for the microphone to be about 1 m off the ground so that it is not adversely affected by precipitation, it is also necessary to keep the instrument itself dry and secure in a waterproof case, which is best mounted above the ground on a fencepost, utility pole or other support.

While the microphone can be remotely connected to the instrument with a cable and independently supported, another option is to use a self-contained system where the microphone is attached to the instrument case with a rigid boom to hold the microphone away from the box and the entire assembly is mounted 1 m above ground level with a strap as shown, for example, in Figure 4.3.3.2. While there is nothing wrong with supporting the microphone separately on a tripod there is a tendency, unique to wind turbine survey work, for tripods to blow over, even after being weighted down and/or firmly staked to the ground. The use of temporary metal fence posts to support either the microphone alone or the entire system is a more reliable option and is sometimes the only option in places where there are no existing supports, such as in open fields.

Figure 4.3.3.2 *Typical Integrating Sound Monitor with 7" Weather-treated Windscreen*

In addition to sound level meters it is also advisable to set up at least one temporary weather station at the most exposed measurement position in order to measure the wind speed at microphone height and other parameters such wind direction and rainfall. All weather data should also be logged in 10 minute increments for later correlation to the sound data.

4.3.4 *Measurement Quantities*

For a background survey of this type the principal quantity of interest is the L_{A90} statistical measure, which is the A-weighted sound level exceeded 90% of the measurement interval (10 minutes in this case). What this means is that the sound level is higher than the L_{A90} value most of the time and, conversely, that the L_{A90} level represents the near-minimum sound level for each interval. It essentially captures the momentary, quiet lulls between sporadic noise events, like cars passing by, and, as such, is a conservative measure of the environmental sound level.

The average A-weighted sound level, or L_{Aeq}, which is the fundamental metric for highway noise surveys and the calculation of the Day-Night Average Level, L_{dn}, is unsuitable for wind turbine background surveys in rural areas because this level is extremely sensitive to contaminating noise events, such as from occasional traffic, planes flying over or dogs barking – things that cannot be relied on to be consistently present and available to potentially mask project noise on a permanent basis. The L_{A90} measure, on the other hand, automatically excludes these events for the most part and essentially defines the true "background" noise floor.

4.4 Analysis and Interpretation of Results

4.4.1 *Data Analysis and Wind Speed Correlation*

At the completion of the survey the L_{A90} sound levels measured at all positions should be plotted together to evaluate their consistency and to determine if the levels in different settings should be segregated. For example, if the sound levels at sheltered valley locations are consistently lower than measurements on higher ground then the data should be analyzed separately to develop typical background levels for each setting. Somewhat surprisingly, the need for this kind of separate treatment is rare and the much more common result is for the sound levels at all of the positions to be generally similar in magnitude at any given time with each generally following the same temporal trends and intertwining with each other. As a typical example, the as-measured L_{A90} levels at 7 positions spread over a fairly large site in Southern Minnesota are shown below.

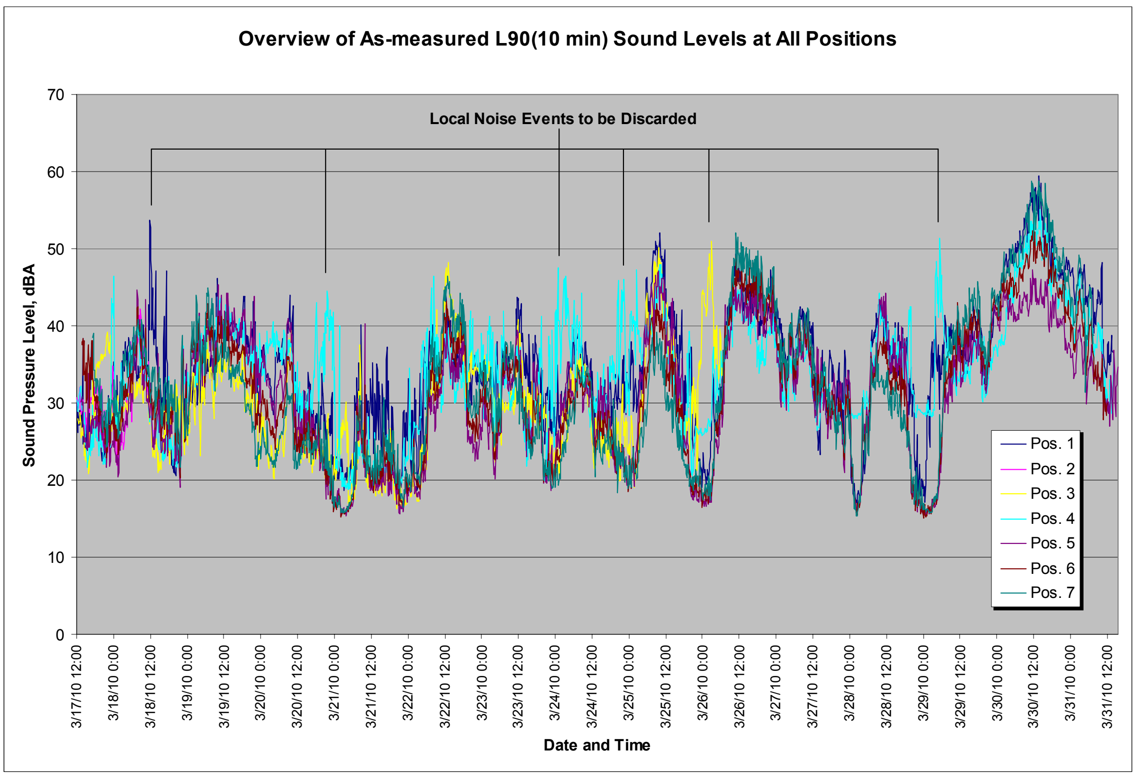

Figure 4.4.1.1

All positions follow each other and there is no one position that is consistently higher or lower than the others. Since these positions are miles apart from each other one would not expect exact agreement yet the levels are remarkably similar indicating that the environmental sound level over the entire site are is more or less uniform (sometimes termed a "macro-ambient"). If obvious contaminating events - those occurring at only one position - are discarded (as noted in the figure) the arithmetic average of the remaining data points can reasonably be considered the typical sound level over the site area. However, the question becomes: what is the sound level? The level varies substantially with time from almost complete silence (17 dBA) to nearly 60 dBA. The background level is obviously not a single number. The reason for this variation becomes clear if the average site-wide sound level is compared to the concurrent wind speed (Figure 4.4.1.2).

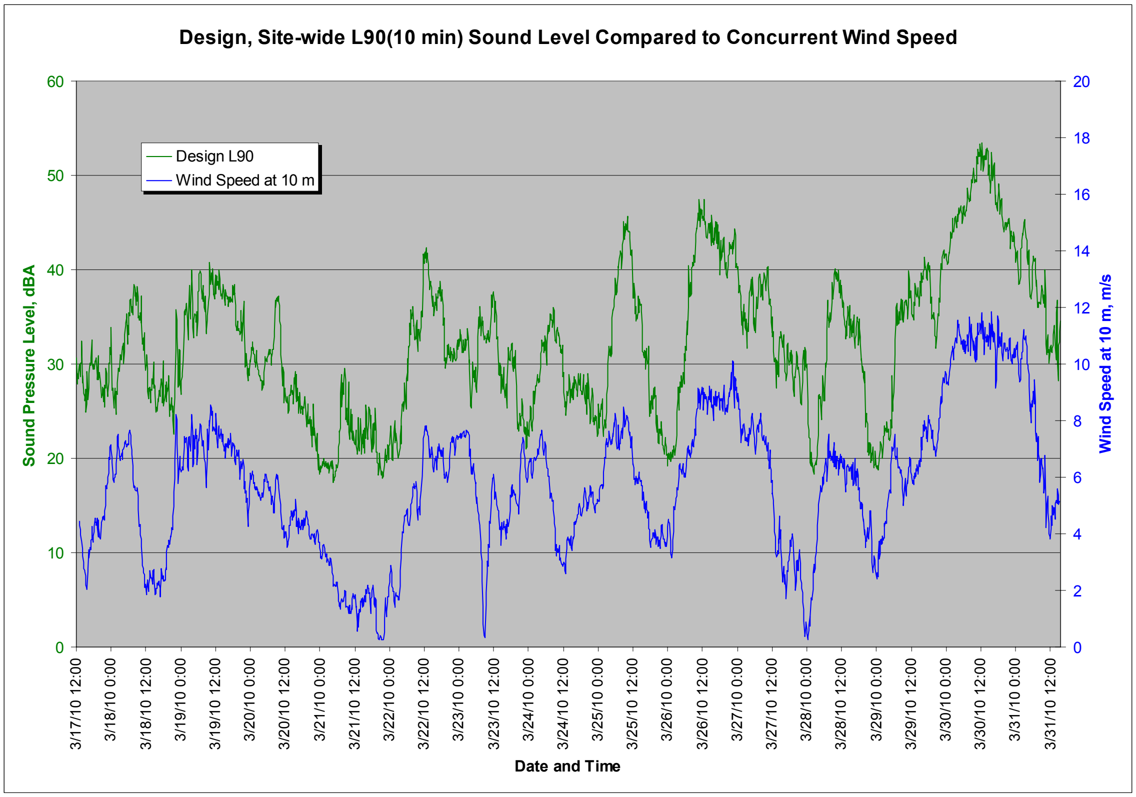

Figure 4.4.1.2

Clearly, the sound level in this area is driven by wind-induced sounds; in this case, mostly grass or crops rustling. Consequently, the sound level is almost entirely a function of the wind speed occurring at any given moment. This relationship can be quantified by re-plotting the sound levels in Figure 4.4.1.2 as a function of wind speed (normalized to a standard height of 10 m per Eqn (7) in IEC 61400-11).

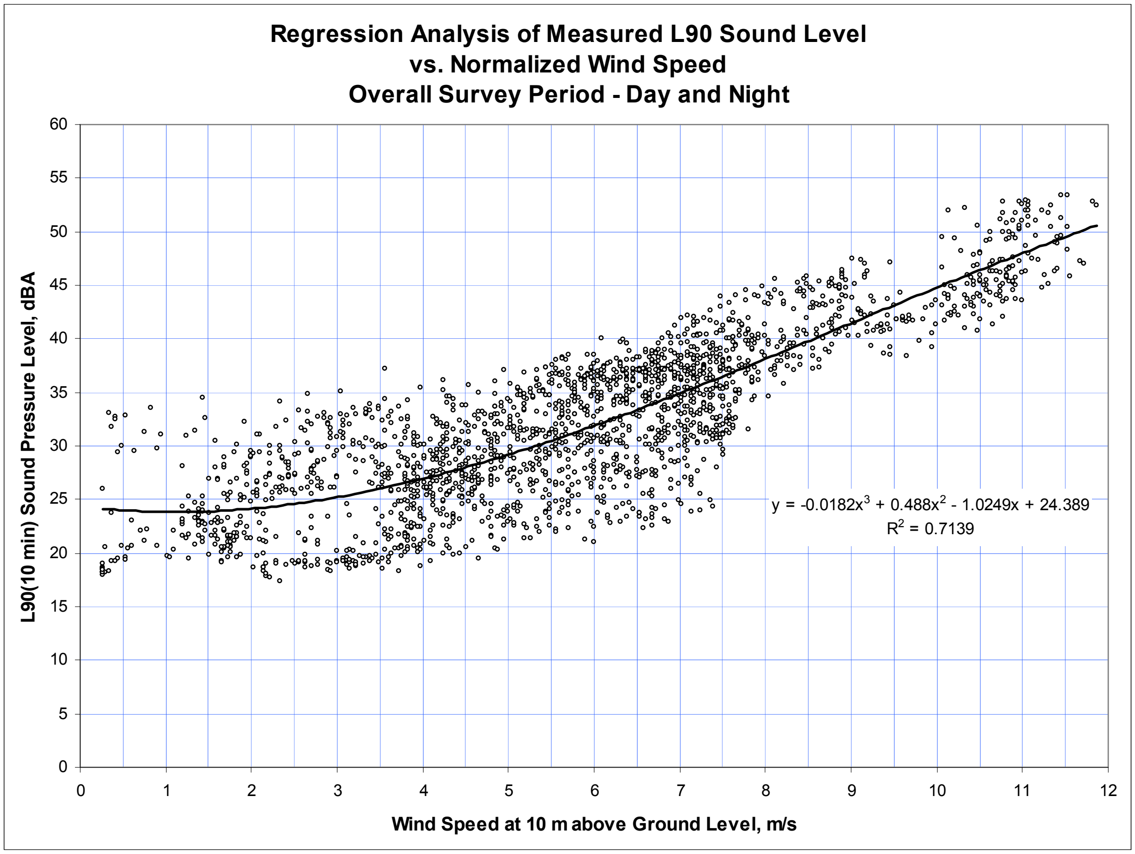

Figure 4.4.1.3

The central trendline through the data gives the mean L_{A90} sound level for any particular wind speed – at least in terms of the overall survey period.

It is important to point out in this context that, although the wind speed correlated to the sound data is the normalized value at the IEC standard elevation of 10 m, the measurement is actually taken at the top of the met tower, usually 60 m (197 ft) above ground level. Thus, the wind speed associated with turbine operation (not far below hub height) is directly correlated to the sound level measured near ground level; where the wind speed may well have been negligible. In other words, Figure 4.4.1.3 is *not* showing the relationship between the sound level and wind speed at the measurement position, as is quite often supposed.

4.4.2 *Daytime vs. Nighttime Levels*

Since nighttime conditions are of the most relevance with respect to potential disturbance from project noise, the data should be broken down into daytime (7 a.m. to 10 p.m.) and nighttime (10 p.m. to 7 a.m.) levels to see if it is significantly quieter at night - something that is not always particularly apparent in the level vs. time data (Figure 4.4.1.1). In this instance, the nighttime levels (Figure 4.4.1.4) are substantially quieter than during the day (Figure 4.4.1.5), particularly, in the vicinity of 6 m/s, which is usually the point where wind turbines first start to generate significant noise but the background level is typically still rather low thereby maximizing the potential audibility of project noise. In these examples, the mean background level for 6 m/s wind conditions during the day is 34 dBA while the nighttime level is about 28 dBA. Both of these levels are extremely quiet, but 28 dBA is so low that any potential masking from background noise can essentially be neglected as insignificant.

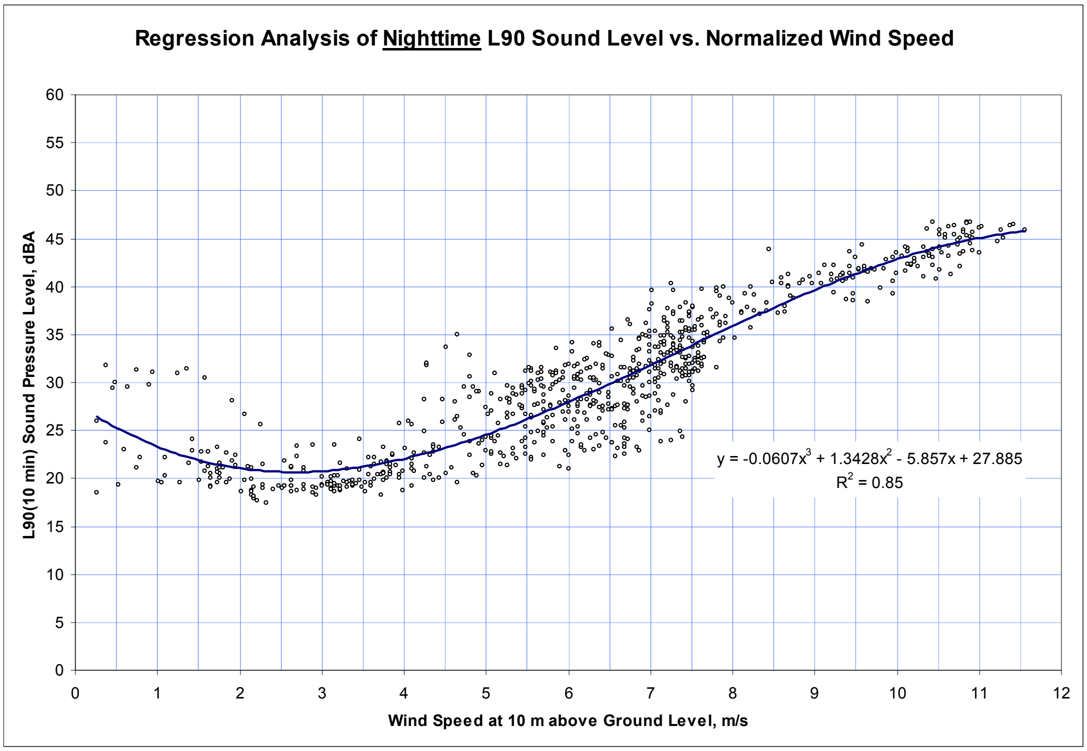

Figure 4.4.1.4

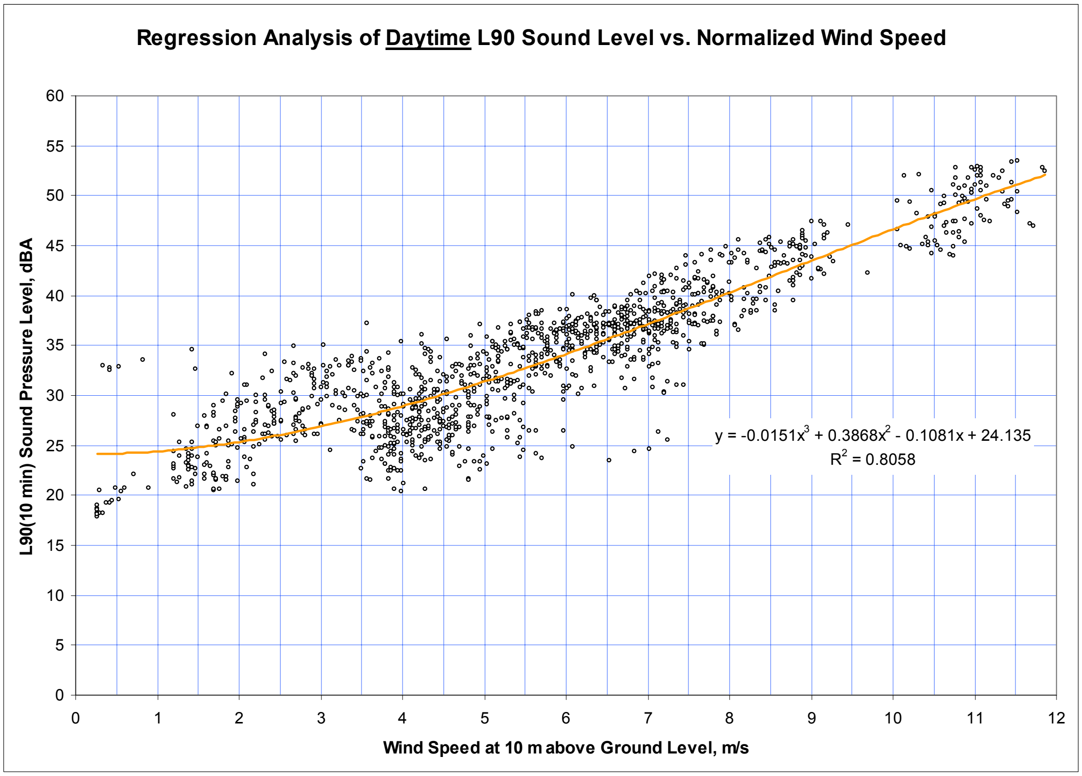

Figure 4.4.1.5

4.4.3 *Assessing the Potential Impact*

The sound levels measured in this survey, especially at night, indicate this site is an extremely quiet rural environment where any masking from wind-induced background noise can effectively be disregarded during moderate wind conditions (4 to 7 m/s). Under high wind conditions, say around 10 m/s, background noise is in the mid-40's dBA irrespective of time of day and therefore will act to partially obscure project noise, but during low wind conditions when the project is operating at low load an adverse impact can be expected unless the mean project sound level is kept to a relatively low level at residences. In this instance, it would be advisable to strictly design the project so that all residences are predicted to have average sound levels no higher than 40 dBA.

In general, background survey results may be used to establish a very rough impact threshold of 5 dBA over the ambient when the nighttime L_{A90} is about 35 dBA or more under what is usually the critical wind speed of 6 m/s. For example, if the measured level is 40 dBA then little adverse reaction might be expected from project levels up to 45 dBA (predicted with the project operating during comparable 6 m/s wind conditions). This 5 dBA increase metric does not hold for very low background levels (<35 dBA) because the background sound level and the project level both become so low as to be insignificant in absolute terms. If the background were 10 dBA, for instance, there would be no need to design a project to not exceed 15 dBA – both levels represent almost complete silence and are inconsequential. For low background situations like the example discussed above the outcome of the survey would be to set a firm upper limit of 40 dBA at residences. In terms of a potential noise impact, a low background level combined with predicted project levels of more than 40 dBA at numerous residences would be an undesirable situation likely to lead to complaints.

Although 6 m/s may be assumed in most cases to be the critical wind speed - i.e. the point where turbine noise is likely to be loudest relative to the amount of background noise available to potentially obscure it – the site-specific critical wind speed may also be calculated by comparing the sound power levels of the particular turbine model planned for the project with the L_{A90} background levels actually measured at the site. The critical condition corresponds to the point where the simple differential between these two values is maximum, as illustrated in the following example.

Table 4.4.3.1 *Comparison of Turbine Sound Power Levels to Measured Background Levels to Determine Critical Wind Speed*

Wind Speed at 10 m, m/s	Measured Overall L_{90}, dBA	Turbine Sound Power Level, dBA re 1 pW[c]	Differential
4	27	95	68
5	29	99	69
6	**32**	**102**	**70**
7	35	104	69
8	38	104	66
9	41	104	63
10	45	104	59
11	48	104	56

In this case (based arbitrarily on the data in Figure 4.4.1.3) the maximum differential of 70 occurs at 6 m/s – meaning that the sound emissions from the turbine are the highest at this particular point relative to the background level indicating that project noise would theoretically be most audible under these conditions. Ironically, the maximum audibility point does not usually correspond to the wind speed when the turbine first reaches its maximum noise emission point (in this example 7 m/s and a sound power level of 104 dBA re 1 pW).

As a side note, this analysis illustrates one of the reasons why it is beneficial to normalize the met tower wind speed data to 10 m; namely, because wind turbine sound power levels are expressed as a function of wind speed at 10 m above grade (and not at hub height). Consequently, the background sound levels and the turbine sound levels are all compared on an equal footing.

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[c] The fundamental unit of sound power is Watts and sound power levels are expressed with reference to 1 picoWatt, or 10^{-12} W. By convention this reference is explicitly stated to help distinguish power levels from pressure levels, which are measured in terms of Pascals.

5.0 Measuring Wind Turbine Sound Emissions

5.1 Project-wide Compliance Testing

5.1.1 *Historical Approaches*

In general, it has been difficult, historically, to devise or settle on a completely satisfactory methodology for testing newly completed wind projects for the purpose of determining whether or not they are in compliance with permit or regulatory conditions. One of the principal stumbling blocks has generally been accounting in some meaningful way for background noise, since the total measured sound level at the typically substantial distances to residences and, therefore, the point of measurement, commonly contains a very prominent background component that cannot be disregarded without causing the result to be erroneously high. It is, of course, the project-only sound level and not the total sound level that is limited by regulations. Consequently, it is the project-only sound level that is sought in such surveys.

Existing guidelines and standards that mention the topic of compliance testing at all do not lay out or detail test procedures that are entirely satisfactory in this and other respects. For example, the often beleaguered[30] ETSU-R-97 report *The Assessment and Rating of Noise from Wind Farms*[31] published by the Department of Trade and Industry in the U.K. addresses the issue of background noise in one sentence, quoted below, by suggesting simply that one might want to measure operational turbine noise at night.

> To minimize the effects of extraneous noise sources it may be necessary to perform these measurements during night-time periods when other human and animal activity noise sources are likely to be at a minimum.

This approach, which involves measuring only for a relatively short period of time (20 to 30 $L_{A90,\ 10\ min}$ samples), is connected with the idea of taking measurements only at, or close to, a specific critical wind speed identified from "monitoring", carried out in an unspecified manner, and correlated to logged observations by complainants as to when the "noise is most intrusive" (ibid). In short, the idea is for the test engineer to be physically at the location and ready to take measurements when the wind conditions that result in maximum noise are occurring - so long as those conditions are happening at night on a night when the background sound level is negligible (i.e. roughly 10 dBA or more lower in magnitude than the turbine sound level). As might be imagined, the unfortunate reality is that the probability of all these things coming together at the same time is miniscule. In particular, it is typically difficult, for a number of reasons, for a test engineer to schedule a site visit to coincide with a particular wind speed or direction.

In general, the notion of being on hand to observe and measure wind turbine noise when it is at its loudest may sound reasonable on paper but it is seldom practical to actually do it.

Another approach to the issue of background noise that has been used, for example in the New Zealand Standard NZS 6808:1998 *Acoustics – The assessment and measurement of* *sound from wind turbine generators*[32], is to measure the background level at one time, say, prior to construction or start-up, and the operational noise from the project at another time - and then subtract the two to derive the project-only sound level. While this is often thought of or suggested as a reasonable approach, the problem is that both the background and wind turbine sound levels are extremely dependent on circumstances that vary significantly with time in both the short and long-term. The two sounds are highly specific not only to the prevailing wind speed at a particular time but also to factors such as the stability of the wind (whether it's gusty or constant in nature, for instance), wind direction, shear gradient, thermal gradient, time of day and time of year. Moreover, the background level is also exclusively influenced by foliage (bare trees vs. leafed out trees, for example), insects, frogs, distant or nearby traffic, farm equipment and a myriad of other human activities that occur sporadically and unpredictably. Consequently, a background sound level measured days, months or years before can't be used with a tremendous amount of confidence to correct a later measurement of operational noise, even if both have been normalized to similar wind speed conditions, because so many other unquantifiable factors may have had a hand in shaping the final results. What is needed, of course, is the background sound level that would have existed at that particular time and at that place if the project had not been operating.

This latter objective can sometimes be essentially realized by using the technique of temporarily shutting down, or parking, the nearest turbines to a measurement position, if not the entire project. While this technique has its applications, which will be discussed later, it is not usually a practical method that can be used for a general site-wide compliance test. Widespread or complete shutdowns would be required repeatedly over a variety of wind speed conditions and times of day to get even a minimally complete set of usable background levels.

Thus, there are certain impracticalities associated with the few existing guidelines, standards or common practices that deal with the testing of operational noise from wind turbine projects.

5.1.2 *Test Methodology*

The suggested methodology outlined below, which has been developed over time through field experience on a variety of wind projects, does not purport to completely solve the problems of background noise and capturing the periods of maximum noise, among other things, but it has been found to work very well in numerous field applications.

5.1.3 *Survey Duration and Scheduling*

In order to overcome the problem of being on hand to take short-duration measurements when conditions might favor noise generation at the source and/or sound propagation from the turbines to typical receptor points, a long-term, continuous monitoring approach is needed in which multiple instruments are set up at key locations and programmed to run day and night for a period of about two weeks or more. In essence, it is necessary to capture sound levels during a variety of wind and atmospheric conditions; something that is extremely difficult to achieve by taking intermittent manned samples, which amount to static snapshots of a dynamic situation.

Field experience suggests that an adequate range of wind speeds, from 0 to 10 m/s at 10 m above ground level, will usually be observed over any given 14 day period at most wind energy project sites, except perhaps during the low wind season at sites that might have very pronounced seasonal wind characteristics.

As a practical matter, the instruments for such a survey are set up, started and left to run unattended for the nominal two-week test period following which they can be retrieved and downloaded.

In terms of scheduling, it is highly preferable to conduct this type of survey during cool season, or wintertime, conditions to eliminate or at least minimize possible contaminating noise from summertime insects, frogs and birds. In addition, it is best for deciduous trees to be leafless at sites where they are present in quantity to decrease this source of wind-driven background noise and maximize the signal to noise ratio. Human activity, such as from farm machinery or lawn care, is also normally lower during the winter. While summertime surveys have been successful they should, as a general rule, be avoided wherever possible because nocturnal insect noise, for instance, can easily render the project sound level indeterminate at some or all of the measurement positions. If measurements are required during the summer, and they often are for reasons of project scheduling, high frequency contamination can be analytically factored out by taking the measurements in octave or 1/3 octave bands and correcting the spectra, as will be discussed later in greater detail.

In addition to seasonal concerns, it is desirable; when practical, to attempt to schedule the survey set up to just precede a predicted period of moderate or high winds. This not only ensures that the survey period will capture these winds but also creates an opportunity for manned observations and measurements to be made for a day or two to augment to the longer term monitoring survey. There is generally nothing to observe or measure at a wind turbine site when the winds are calm, so if one can be on site with the proper equipment just before a windy period useful short-term measurements can probably be made that can later be viewed within the context of the long-term monitor results for that time period.

As an alternative or supplemental approach, another opportunity for these supplemental manned observations can sometimes be arranged by coordinating the instrument retrieval visit with a predicted windy period. The specific end date for the survey is usually flexible, although instrument battery life is normally the limiting factor. The principal danger in carrying out manned measurements just before the end of a survey, however, is that all of the long-term monitors may not still be recording due to power supply issues or any number of other lamentable and sometimes comical things, such as tampering, weather damage or the removal of the windscreen by livestock.

5.1.4 *Test Positions*

The test positions should be selected to capture data at a number of potentially sensitive receptors (usually non-participating and participating residences within or near the site area) or other relevant points of interest, where maximum project sound levels might be expected either from modeling or a simple inspection of the site plan. In just about every case, it is not practical or even possible to establish a monitoring station at every house in the vicinity of a project so it is necessary to carefully select a limited but adequate number of sites that are representative of the worst-case exposures at potentially sensitive receptors in all relevant settings. Examples of specific settings would be: homes in sheltered valleys below ridge top turbines; homes on high, open ground with exposure to the wind and nearby project turbines; homes in generally flat open country with turbines in multiple directions; homes in wooded area; homes on the outer edge of a project area, etc. Because every site is unique the number of monitoring stations required to adequately evaluate project noise will vary but the general concepts are to reasonably account for different settings, to cover a number of points were maximum project sound levels are likely to occur at residences and to cover the entire project area with a generally even but somewhat random distribution. Adding one or two deliberately random positions can help increase the statistical independence of the data and avoid inadvertent bias. For sparsely populated sites in open and uniform farm country only about 4 or 5 on-site monitors might be needed while at more densely populated sites with more complex topography the number of monitoring stations would only be limited by the quantity of equipment reasonably available to the test engineer either from in-house stock or outside rental. Realistically, it is seldom possible to gather enough equipment for more than about 10 to 14 on-site monitoring points, but that is normally enough. A typical survey at a fairly large project site with numerous residences intermixed with the turbines might call for about 10 positions at receptors within the project area.

As mentioned above, the general objective is to capture sound levels throughout the site area at key receptors in all distinct settings within the project area. In addition, it is commonly necessary and desirable to establish a measurement position at all homes where complaints or concerns about noise have been expressed to the operations staff. In these instances, it is sometimes possible to enlist the help of residents by having them try to keep a date and time log of when the noise becomes particularly noticeable or unusually loud or when other non-project sounds are present; for example, from lawn moving, farm activity, etc. When this is actually done the comments can provide some valuable insights that help explain and identify peaks in the recorded sound levels.

It is often assumed that project noise is of no concern to project participants who were, and presumably still are, favorably disposed to the project and are receiving lease royalties for units on their land; however, experience at a number of sites suggests that this is not always the case largely due to the confluence of two factors: (1) these residences are typically the closest ones to turbines (sometimes only a few hundred feet away) and (2) the actual sound levels from these nearby units can turn out to be substantially louder than they expected them to be or they were led to believe. Consequently, monitoring at the homes of project participants in response to complaints is fairly common – even though participants are often, but not always, technically exempt from ordinance or permit noise limits.

It is usually best to start the site selection process a week or two in advance of the actual survey by circling proposed measurement areas on a site map or sound contour plot and submitting this to operations personnel at the site for their input on who, within or near each designated area, might be willing to host a sound monitor at their house and where else, outside of these proposed areas, it might be also be desirable to measure (at complaint locations, for instance). The objective of this preparatory review is to obtain approval and permission from homeowners to set up equipment on their property prior to arrival. Although it is desirable to inspect the proposed locations and make a judgment as to their suitability in person, attempts to arrange for permission on the day of the survey are often unsuccessful due to the simple fact that people are not at home and cannot be reached. Calling ahead usually settles the issue before the equipment is shipped to the site. Setting up the equipment in the rear yard of a house where permission has been obtained generally ensures that the equipment will still be there upon returning at the end of the survey, that the equipment won't be interfered with and that it can be minimally attended to, if necessary (replacing the windscreen after the family dog has run off with it, for example). Positions that are not at anyone's house, such as on utility poles along the public right-of-way, are sometimes necessary to collect data at strategic locations without a suitable host, but they do not have any of these advantages and, in fact, the risk of theft or tampering is uncomfortably high.

In terms of the specific placement of the monitor at each position, it should be located in an area representative of but away from the house, or any other building with large reflective surfaces, and that is not prone to frequent activity or contaminating local noises, such as from air conditioning units, milking machines at dairy farms or flowing streams or rivers.

As a final note on placement, it is best to avoid using fences or posts to mount the monitor or microphone in areas where livestock or other domestic animals may be able to get at the equipment during the survey. Microphone windscreens are evidently of keen interest to cows, horses and dogs, among others.

5.1.5 *Background Noise*

On the important issue of background noise, an approach that has worked well in a number of field applications is to set up a number of monitoring stations outside of the project area in settings similar to those at the on-site monitor positions. Of course, considerable judgment is involved in selecting these positions but in an ideal situation of, say, an isolated project in open farm country that is largely uniform in character both within and beyond the project area one would want monitors at least 1.5 to 2 miles from the perimeter of the project (nearest turbines) in the four cardinal directions. The locations should be far enough away that project noise is negligible and yet close enough that they are reasonably representative of the site area. At the end of the survey the off-site positions can then be evaluated for consistency. If the levels are generally similar, and, somewhat surprisingly, this is usually the result, the average can be taken as a time history record of the background sound level that probably would have existed within the site area and then used to correct the on-site measurements taken, importantly, at the same time under identical environmental conditions.

Figure 5.1.5.1 below is an example from a site in the Eastern United States where the landscape is rural and generally homogenous in nature within the project area and for some distance beyond it in terms of topography (rolling hills), vegetation (a mix of farm fields and wooded areas) and population density (farms and residences scattered more or less uniformly over the site area). The 80 or so 1.5 MW turbines are spread throughout a roughly 20 sq. mi. project area on numerous parcels of private land and thoroughly intermixed with the residences in the area. Proxy background measurement positions were set up about 1.5 miles beyond the perimeter of the turbine array to the northwest, east and south of the project (a neighboring wind project to the west prevented measurements in that direction) at locations that were similar in character to the various settings near on-site residences: one was on an open and exposed hilltop, another was at the edge of a field with nearby trees and a third was essentially in a forested area. The expectation was that there might be a consistent difference between these different positions – with the sheltered forest location being quieter than the windy hilltop, for instance – in which case background corrections for a particular setting would be applied to on-site measurements at positions with comparable settings. However, as can be seen from the figure, the levels at all three locations, each many miles from the others, were largely the same at any given time and, perhaps more significantly, no one position is consistently higher or lower than the others. Consequently, the arithmetic average of all three, with the site area physically lying between them, can be taken as a reasonably reliable estimate of the on-site background level at any particular time that accounts for the specific wind speed, direction, time of day and atmospheric conditions prevailing during that 10 minute period.

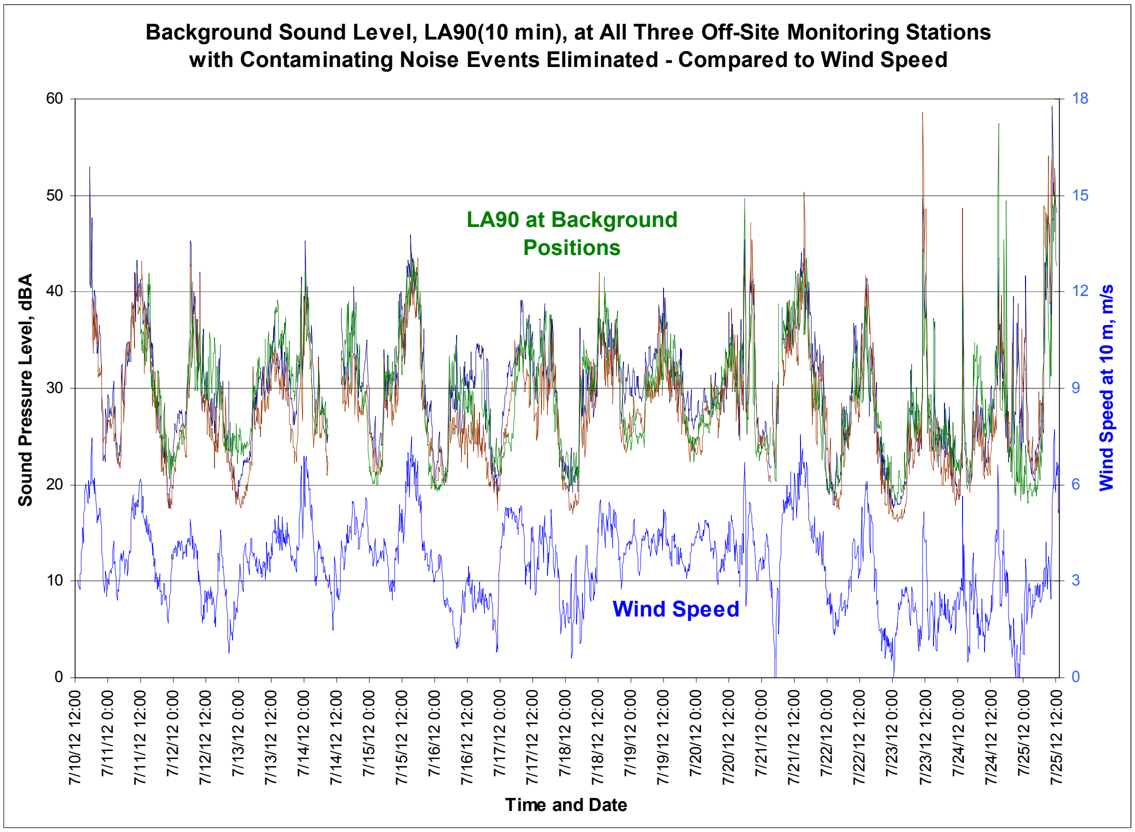

Figure 5.1.5.1 *Measured Background Sound Levels at Three Off-Site Proxy Positions*

The data in Figure 5.1.5.1 have been edited to remove noise spikes that were observed only at one position and not at any others, indicating a contaminating local noise event that is not representative of the area as a whole. Spikes were also deleted (from both the on-site and background data) if there were no concurrent spike in wind speed, even if they may have occurred at multiple locations, on the premise that the noise was not associated with the turbines and may have been due to thunder, rain, a helicopter flyover or some other area-wide noise event.

The results shown in the example above are not unique to that site and a similar consistency between the off-site proxy location sound levels has been observed at a number of other projects in rural areas even though the background monitors are deliberately set up in diverse settings. Fortunately, for the purpose of estimating simultaneous background sound levels, most wind projects are located in rural areas but, of course, not all of them are and other situations exist. In urban settings or near major highways the background sound is no less important, in fact more so, but its dependence on wind and atmospheric conditions is greatly diminished, if not relegated into complete insignificance. In such cases, the proxy background technique is still theoretically viable although the selection of background positions that are representative of receptors potentially affected by project noise becomes highly specific to the circumstances at each receptor. In the case of a highway, for instance, one might try to find a background position that is the same distance from the roadway as the actual point of interest and similar in all other ways but far enough from any turbines that they are undetectable. In this kind of a complicated situation where the background level is more dependent on man made noise than natural, wind-induced sounds it may be necessary to perform a pre-construction survey at the key receptors near turbines and at a number of candidate background positions to evaluate the validity of the proxy locations before the project turbines become operational.

5.1.6 *Sound Test Equipment and Set up*

As with any field sound survey, what equipment is used and how it is deployed must adhere to certain minimum technical standards. Most environmental sound measurement standards recommend the use of Type 1 precision equipment per IEC 61672-1[28] or ANSI S1.43-1997[29] while also allowing for the use of Type 2 equipment. There is certainly no reason on technical grounds to oppose this recommendation but, from a practical perspective, it is often necessary to use Type 2 equipment for surveys of this type because of the large number of instruments needed. The utterly intangible difference in technical performance between these two instrument classes is totally inconsequential within the inherently and unavoidably imprecise nature of this type of survey. It is much more important that the equipment is durable, reliable and specifically designed for extended use in the outdoors.

Although high cost and extreme precision are not essential, the functional capabilities to statistically integrate sound levels over a user defined time period and automatically store the results are necessary. Because the on-site wind and weather monitoring towers, or met towers, normally integrate and store measurements in 10 minute increments it is convenient, if not necessary, to measure and store sound data in synchronization with the wind data collected by these towers for later correlation. It is evidently universal practice for met towers to store data 6 times an hour in 10 minute intervals that begin at the top of the hour; as in 9:00, 9:10, 9:20, etc. Consequently, sound data logging should be started using a trigger function to begin at the top of an hour and not randomly by the manual push of the start button. The timers on all instruments should be exactly synchronized to local time or to the project's SCADA control system clock, if it is different from the actual time, which it often is.

Of course, all of the instruments must be field calibrated at the beginning of the survey and checked again for drift at the end of the survey.

Because this long-term survey approach involves unattended monitoring, the instrument and the microphone must be capable of withstanding damage, interference or outright destruction from rain and snow, which, among other things, means that the ground plate technique specified in IEC 61400-11 – where the microphone is laid flat in the center of a board on the ground and covered with one or more hemispherical windscreens – is not a viable option despite its otherwise highly desirable advantage of minimizing wind-induced pseudo noise. Consequently, the microphone must be mounted above ground level and protected from wind-induced distortion by a spherical weather-treated windscreen, which normally entails a higher density foam that is hydrophobically treated to shed water (windscreens and wind-induced noise are discussed in detail later). As a general rule, a slightly lower than normal microphone height of about 1 m above ground level is preferred for this application on the premise that wind speed diminishes exponentially with decreasing elevation theoretically going to zero at the surface, or boundary layer.

For these moderate wind conditions, which are often when turbine noise tends to be most prominent relative to the background level, the wind speed at a 1 m microphone height would be less than about 3 or 4 m/s, which as shall be seen later, means that distortion from wind blowing through the windscreen is of little or no consequence with respect to the A-weighted sound level.

In addition to arranging for the microphone to be about 1 m off the ground so that it is not adversely affected by precipitation, it is also necessary to keep the instrument itself dry and secure in a waterproof case, which is best mounted above the ground on a fencepost, utility pole or other support.

While the microphone can be remotely connected to the instrument with a cable and independently supported, another practical option is to use a self-contained system where the microphone is attached to the instrument case with a rigid boom to hold the microphone away from the box and the entire assembly is mounted 1 m above ground level with a strap. While there is nothing wrong with supporting the microphone separately on a tripod there is a tendency, unique to wind turbine survey work, for tripods to blow over, even after being weighted down and/or firmly staked to the ground. The use of temporary metal fence posts to support either the microphone alone or the entire system is a more reliable option and is sometimes the only option in places where there are no existing supports, such as in open fields.

5.1.7 *Weather Stations and Wind Speed Monitoring*

In addition to the sound monitors it is also advisable to establish at least one temporary weather station at the sound monitoring position with the most exposure to wind. The primary reason for this station is to measure the maximum wind speed at microphone height (about 1 m) for use in correcting the measured sound data for wind-induced distortion as described in a later section. Wind speed at 1 m, direction and rainfall are the primary parameters to be recorded by this station, or others set up in other settings as appropriate, such as at a sound monitoring position sheltered from the wind by the local terrain (to demonstrate, for instance, that wind-induced distortion is negligible at such locations). This data should be integrated and stored in 10 minute blocks in synchronization with the sound monitors.

This temporary anemometer at 1 m above ground is solely there to evaluate microphone wind exposure and it is the on-site met tower anemometers, usually at 50 to 80 m above ground level, that should be used to correlate the measured sound levels at ground level to the wind speed essentially experienced by the turbine rotors. Turbine nacelle anemometers scattered throughout the site may also be used to determine wind speed, but this is somewhat less desirable because a free field correction usually needs to be applied to this data to account for the energy extracted from the wind by the rotor just upstream of the wind speed sensor.

It is customary to normalize mast top or nacelle wind speeds to a standard elevation of 10 m above grade per IEC 61400-11. It is this result that is compared to the measured sound levels.

5.1.8 *Measurement Quantities and Parameters*

The objective of a compliance survey is to extract the project-only sound level from the total soundscape and compare that result to the permissible limit. As such, the principal challenge is identifying and eliminating contaminating noises that are unrelated to the project over many days and thousands of measurements. If it were practical to take a manned sample for 20 minutes, removing spurious noises by pausing the instrument or discarding contaminated subsamples, and declare the result as the performance of the project it would be a trivial matter; however, over a relatively long time period of unattended monitoring it is necessary to use the L_{A90} statistical measure to generally perform this function in an automated manner, since it captures the consistently present sound level during relatively quiet periods between common interfering and identifiable noise events like cars passing by or planes flying over. A 10 minute sampling duration has been found to work very well since it allows direct correlation with met mast wind speed data and is generally short enough that fairly rapid changes in project noise are captured.

The use of the average, or $L_{Aeq,\ 10\ min}$, sound level or a finer time resolution of, say, 1 minute come to mind as alternatives to the L_{A90}, but these approaches have their own serious drawbacks. If the L_{Aeq} is used to measure at on-site positions with the idea of better quantifying turbine sound levels, then the L_{Aeq} measured at the proxy background positions must also be used as an apples-to-apples correction factor. But the L_{Aeq} is often completely unusable for this application. As an example, multiple statistical measures were recorded at the off-site background measurement positions previously mentioned in connection with Figure 5.1.5.1, including the L_{Aeq}. Figure 5.1.8.1 below shows the average L_{A90} and L_{Aeq} levels measured at all three locations compared to wind speed.

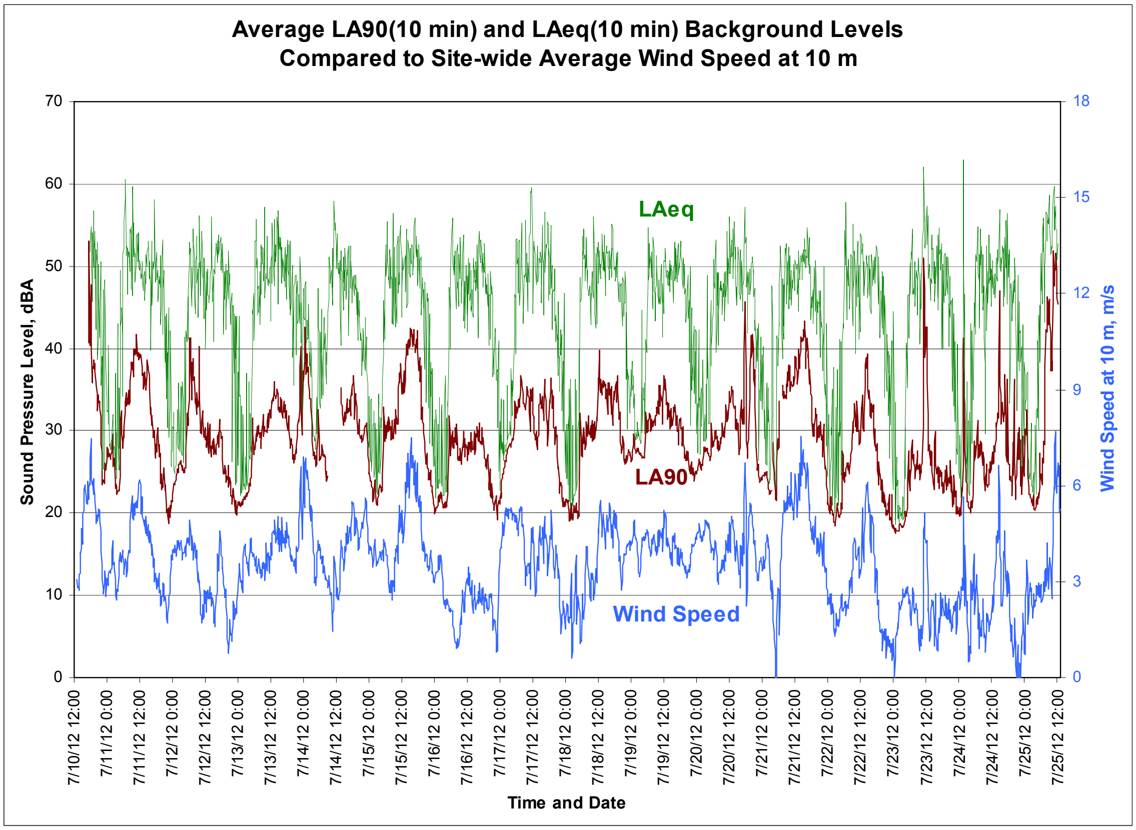

Figure 5.1.8.1

What is immediately obvious from this plot is that the $L_{Aeq,\ 10\ min}$ level is clearly driven by daily human activity; primarily intermittent vehicular noise on nearby sparsely traveled roads (noise that is filtered out by the L_{A90}). The L_{Aeq} levels rise to about 53 dBA every morning, stay there all day irrespective of the wind conditions and then gradually fall off in the evening hours bottoming out briefly somewhere around 23 dBA every night. The L_{A90} level, on the other hand, is clearly more attuned to the natural environmental sound level, which in rural areas like this one is normally a function of wind speed. The unsuitability of the $L_{Aeq,\ 10\ min}$ as a measure that might quantify project noise can be seen in Figure 5.1.8.2 where the average background L_{Aeq} level from Figure 5.1.8.1 is compared to the L_{Aeq} level measured at a typical, randomly selected on-site receptor.

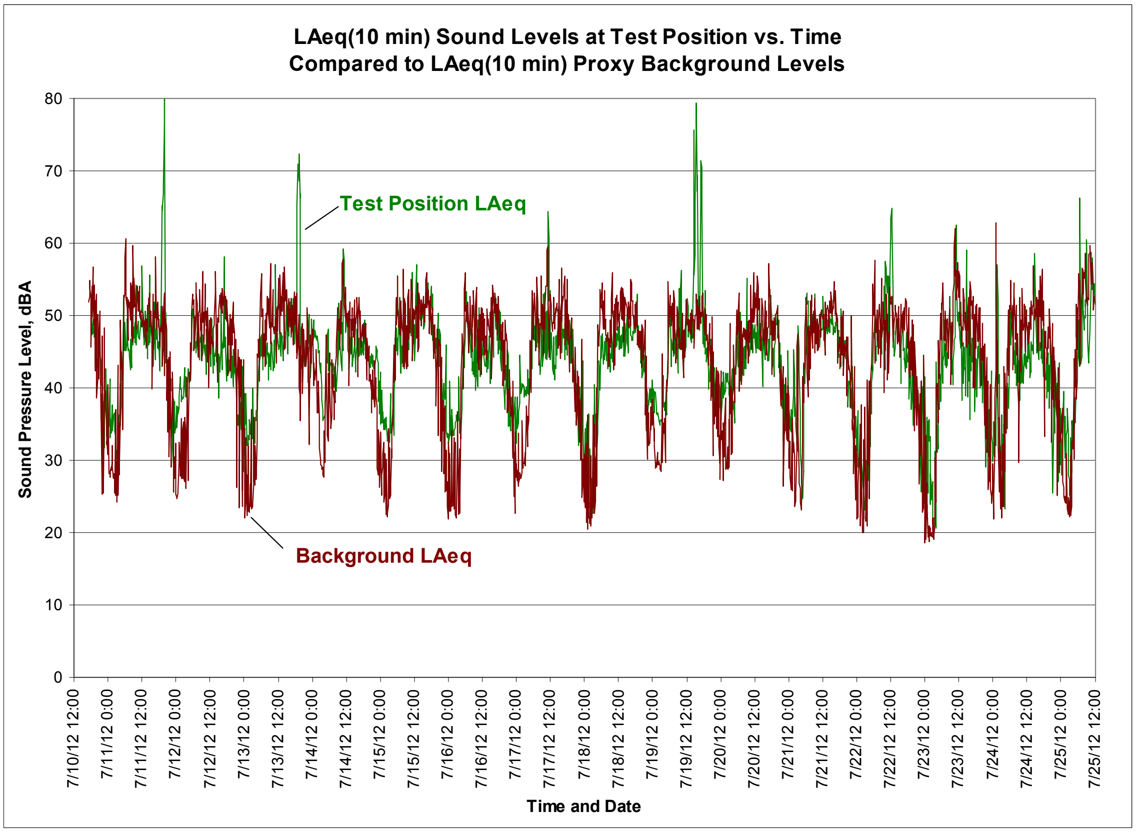

Figure 5.1.8.2

The $L_{Aeq,\ 10\ min}$ sound levels at both positions are virtually indistinguishable meaning that the project-only sound level simply cannot be deduced. Furthermore, it could even be reasoned that project noise is utterly inconsequential at this location because the on-site level is about the same or even lower than the off-site level, which is entirely free of any turbine noise, but, as we shall see later, that is not at all the case at this particular test position.

Finally, it is desirable to use instruments capable of measuring the frequency spectrum in 1/3 octave bands at one or two key locations with, usually Type 2, monitors measuring overall A-weighted levels at the majority of positions. The use of one or more frequency analyzers at key positions allows for some frequency analysis, although great caution must be exercised with the lower frequency bands, as discussed later, since wind-induced false signal noise is largely inevitable and the low frequency results cannot be taken at face value. Fortunately, this phenomenon does not significantly affect the measurement of A-weighted sound levels, however.

The use of 1/3 octave band analyzers is largely essential for surveys that, for one reason or another, must be conducted during summertime conditions when insect, frog or cicada noise is present. Measurements taken under these unfavorable conditions can be "corrected" to a certain extent by smoothing the high end of the frequency spectrum, where this kind of noise is usually obvious, and then recalculating the overall A-weighted sound level as shown in the (generic) example below.

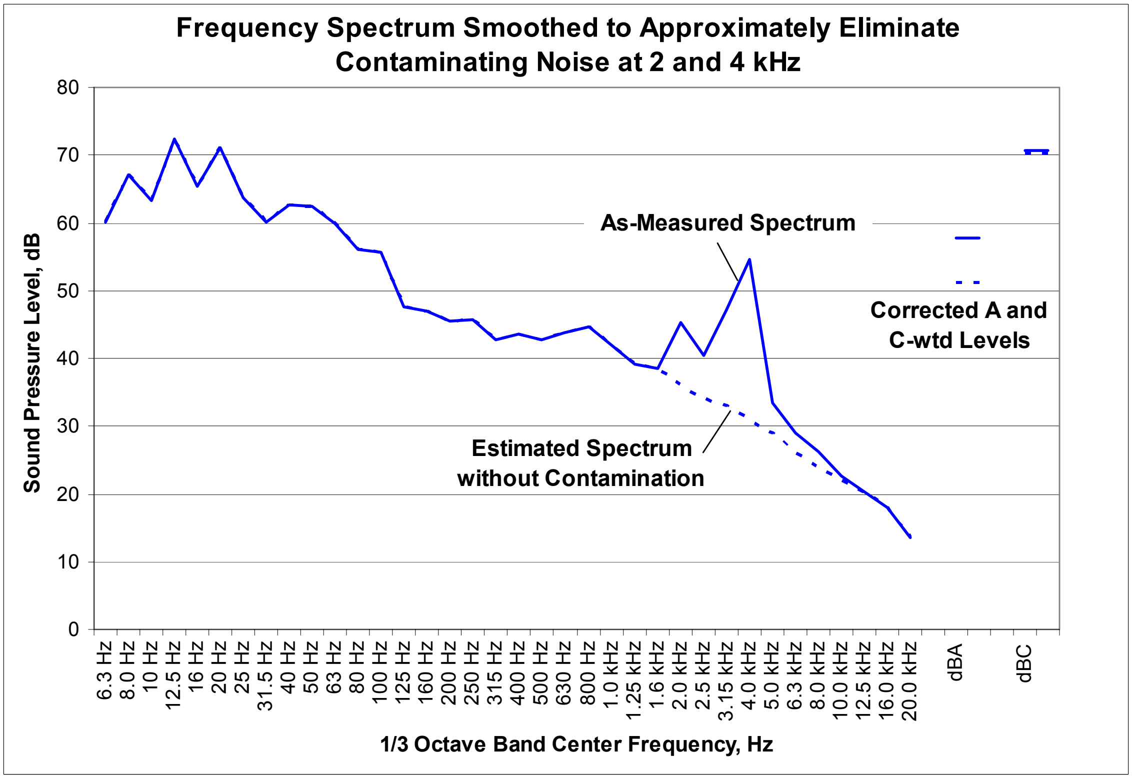

Figure 5.1.8.2

Of course, this correction would be laborious to perform for thousands or even just dozens of measurements so it is usually necessary to determine a typical correction, such as the -7 dBA adjustment that resulted in the example above, and apply that to all periods when this noise was apparently present. This is, of course, an imperfect remedy and the best policy is to avoid, if possible, measuring under these circumstances in the first place.

A solution to this common problem is currently being proposed by Hessler[33] and Schomer[34] in the form of a modified A-weighted network, termed "Ai-weighting", where all of the measured sound above 1000 Hz, or the 1250 Hz 1/3 octave band, is disregarded in situations where insect noise is present and an adjusted A-weighted sound level is calculated from the truncated spectrum.

5.1.9 *Wind-induced Microphone Distortion*

One of the principal errors in measuring wind turbine noise is false signal noise from wind blowing through the windscreen and over the microphone tip, which is manifested in the form of artificially elevated sound levels in the lower frequency bands. Taken at face value any measurement made in moderately windy conditions will ostensibly indicate relatively high levels of low frequency noise, irrespective of whether a wind turbine is present or not. This measurement error is probably one of the principal reasons wind turbines are mistakenly believed to produce high, if not harmful, levels of low frequency and infrasonic noise.

Some degree of distortion is essentially inevitable in any measurement taken above ground level when the wind is blowing, even when using an extra-large windscreen. It is in an effort to minimize this error that the IEC 61400-11 test procedure prescribes measuring on a reflective plate at ground level, where the wind speed is theoretically, although often not actually, zero. As previously mentioned, this ground plate technique is fine for short-term, attended measurements but is impractical for long-term surveys due to the potential for rain or melted snow to damage the microphone. Consequently, for lengthy compliance and evaluation surveys it is necessary to measure above ground level using a large, weather-treated windscreen - perhaps augmented with a very large secondary windscreen, although the practicality of such devices is questionable in harsh winter conditions.

Because environmental sound measurements of most other sources apart from wind turbines are not generally conducted in windy conditions as mandated by applicable standards, the significance and even existence of this measurement error has long gone unnoticed. Although this phenomenon and its physical basis were theorized decades ago by Strasberg[35,36] it is only fairly recently that its relevance to wind turbine sound measurements has been examined in detail and quantified. In particular, the subject of wind generated self-noise was thoroughly reviewed in 2006 by van den Berg[37] where he showed that the magnitude of the distortion depends not only on the mean incident wind speed but also on the amount of atmospheric turbulence present at the microphone position (largely a function of the local surface roughness) and on atmospheric stability. Measurements taken at 1 or 2 m above a smooth surface during stable, nighttime atmospheric conditions, when the surface winds are usually light, generally contain the least amount of self-generated noise ultimately replicating the case where the principal noise generation mechanism is wake turbulence trailing off the windscreen. In other less ideal circumstances self-noise levels can be developed by estimating the local surface roughness and atmospheric turbulence factor, Ψ, from wind speed measurements at two heights and/or from observations of cloud cover, time of day, general wind conditions, or meteorological data, if available.

The minimum level of false-signal noise due to wind, excluding the effect of atmospheric turbulence, can be estimated based on an empirical wind tunnel study carried out by Hessler and Brandstätt in 2008[38] in which conventional ½" microphones fitted with an array of common windscreens and were subjected to known wind velocities in a massively silenced wind tunnel. The measured sound levels during each test were essentially a direct measure of the false-signal noise – although for more or less laminar flow conditions corresponding to an outdoor setting with a very low surface roughness in neutral atmospheric conditions. Nevertheless, for the specific windscreens examined it is possible to generally estimate both the overall A-weighted or un-weighted (dBZ) sound level of the distortion from the microphone height wind speed and then subtract it from the total measured level to *largely* reverse the error.

An example is shown in Figure 5.1.9.1 where the overall A-weighted level of self-noise is calculated as a function of wind speed and subtracted from the as-measured sound level. The plot is a three day detail of a wind turbine survey where oversized 175 mm (7") diameter treated windscreens (ACO Model WS7-80T) were used. This particular windscreen was found to be the best performer, in terms of minimizing wind-induced self-noise, in the wind tunnel study.

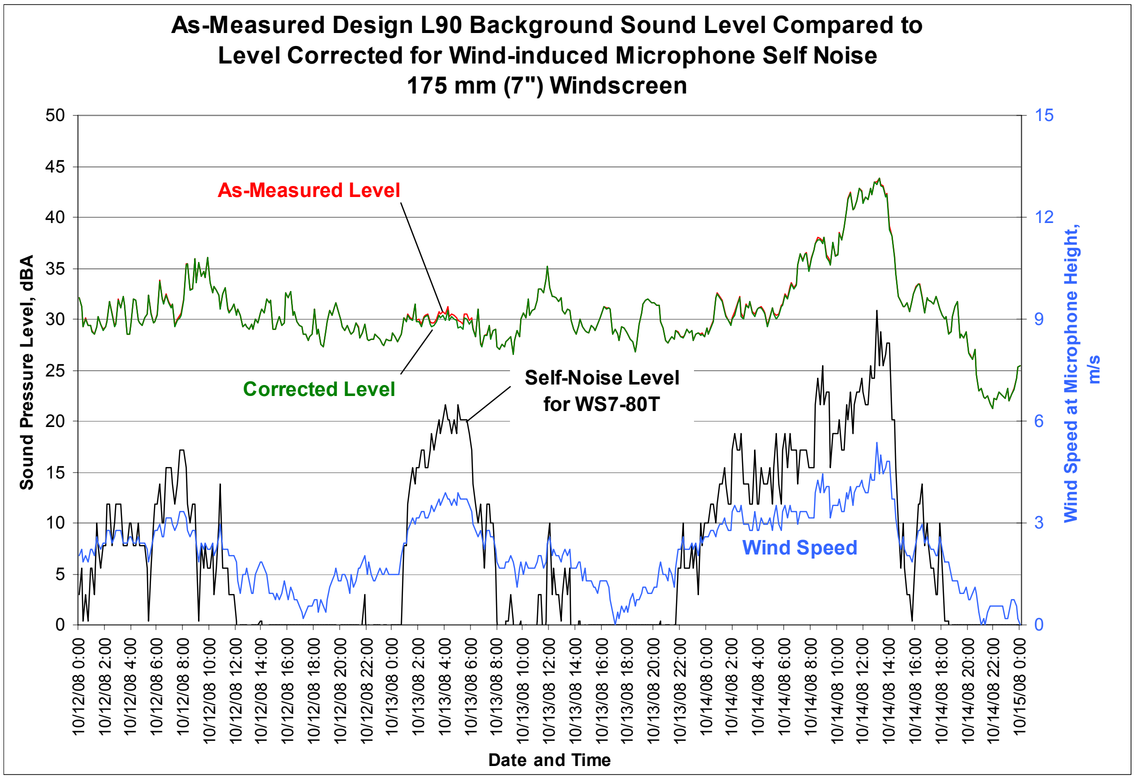

Figure 5.1.9.1

This figure shows the very typical result, at least where extra-large windscreens are used, that the correction is insignificant and can be essentially neglected when it comes to A-weighted sound levels. This is because with a large windscreen the distortion is confined to the very lowest frequencies where it has almost no impact on the A-weighted sound level. With a conventional 75 mm (3") windscreen, on the other hand, wind-induced noise begins to become significant in the mid-frequency region, between about 63 and 400 Hz, where it has much more influence on the A-weighted sound level. Consequently, standard windscreens are not recommended for this type of survey and windscreens with a minimum diameter of 7" are recommended for wind turbine field work.

The empirical wind tunnel study results for 175 and 75 mm treated windscreens are shown below.

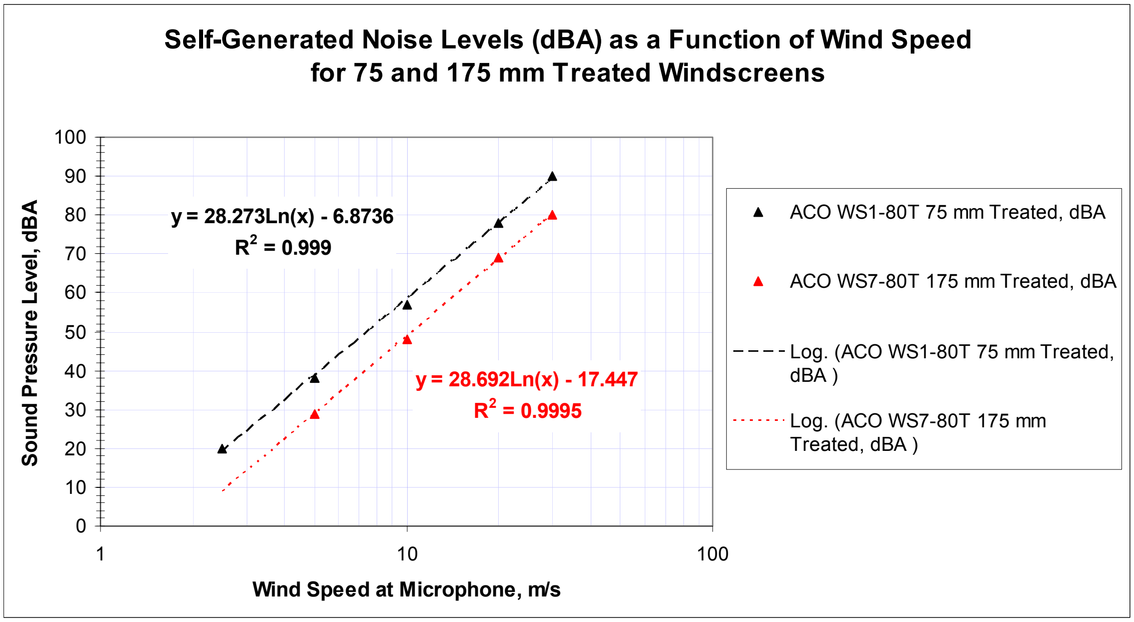

Figure 5.1.9.2

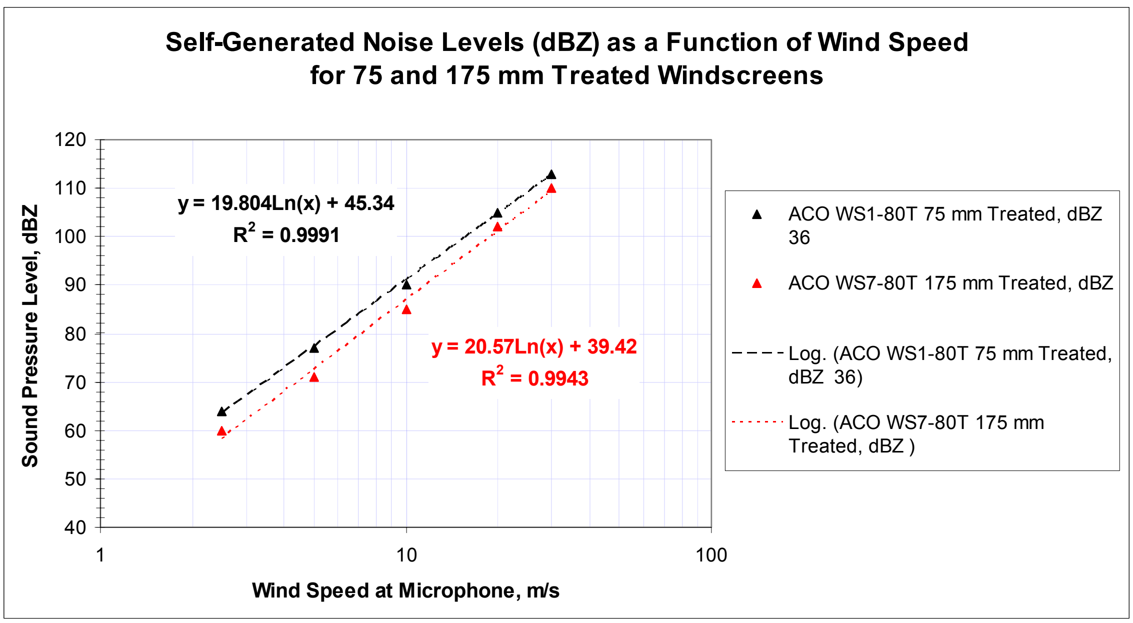

Figure 5.1.9.3

The overall level of self-generated noise for these windscreens may be estimated from the general expression below with the understanding that local atmospheric turbulence is not accounted for and a neutral atmosphere is assumed.

$$L_{p,self} = A \ln(v) + C, \text{ dB} \quad \text{for } v>1.5 \text{ m/s} \quad (1)$$

Where A and C are constants given in the table below and v is the normally incident wind speed at the microphone in m/s.

Table 1 *Constants for A and Z-wtd Self-Noise Calculation Algorithm (Neglecting Atmospheric Turbulence)*

Windscreen Type	A-weighted Sound Level, dBA		Un-weighted Sound Level, dBZ	
	A	C	A	C
75 mm (3") Treated	28.273	-6.8736	19.804	45.34
175 mm (7") Treated	28.692	-17.447	20.57	39.42

In a real atmosphere the sound level may be higher or lower than given in Table 1, depending on the turbulent energy present, which again depends on the stability of the atmosphere. In a neutral atmosphere, which occurs at higher wind speeds (> 6 m/s at 10 m height) or in very clouded conditions, the wind-induced level might be anywhere from 5 to 9 dB higher than the levels shown above. After sunset, when the atmosphere is more prone to be stable, the wind-induced noise levels will be more similar to the values given above.

5.1.10 *Correction for Background Noise*

Once a design L_{A90} background sound level has been developed from averaging the data collected at the off-site proxy positions it can then be subtracted in the usual logarithmic manner[d] from the levels measured at each of the on-site positions to deduce the project-only sound level. However, this correction process is only relevant to samples recorded while the turbines were actually in operation and not necessarily to all samples; consequently, the data must be sifted to ignore all periods of calm winds. This can be accomplished by dealing only with data sets collected above the effective cut-in wind speed for the turbine model in question (bearing in mind whether that wind speed is measured at 10 m or hub height) or, more preferably, by comparing the measured data to a time history of project electrical output obtained from the SCADA, or project control system. For this latter option it is best to compare the operational output of the 2 or 3 units closest to each on-site measurement position rather than the total project output because this not only accurately defines the on and off times at each monitoring station but also may reveal, the fairly common occurrence, that certain units were temporarily down for maintenance or due to some unexpected malfunction. The relevance of this, of course, is that the measurements of project noise during this period would not have captured the maximum possible sound level.

Because the proxy background level is, for practical reasons, an inexact estimation of the site-wide background level, there will usually be instances when the background level exceeds the total measured level at certain on-site positions. Under this circumstance, and when the background level is below but within 3 dB of the total level, the project-only sound level would normally be considered indeterminate. While the calculation of

[d] $Lp_{Project} = 10 \log [10\text{^}(Lp_{Total}/10) – 10\text{^}(Lp_{Background}/10)]$, dBA

the project-only sound level is mathematically possible when the background level is below but within 3 dB of the total level, doing so tends to create spurious mathematical artifacts where the project level can be estimated at unrealistically low and obviously incorrect sound levels. Since most standards, such as ISO 3746[39], essentially disallow this calculation it is best to follow that policy here as well.

5.1.11 *Typical Test Results and Comparison to Model Predictions*

Representative examples from typical test positions within two different wind projects using two different turbine models and located in two different states are discussed below as a way of illustrating the outcome of the test methodology outlined above.

Example 1

The first example is from a test position at a residence within a project in a rural area in the Eastern United States where the turbines and homes are thoroughly mixed together – a common situation in this region and the Midwest. This location is surrounded in nearly all directions by a number of turbines at various distances, the closest being about 490 m (1600 ft.) away from the home with another 10 lying within a 1500 m (4900 ft.) radius. The terrain is gently rolling hills with a mixture of open fields and wooded areas. Mild complaints about noise had been received by the project from the residents of this home, which is the primary reason it was selected as a monitoring position.

The overall test results from a two week measurement survey in terms of the total measured level at the test point, the design background level derived from proxy positions and the normalized 10 m wind speed, are shown in Figure 5.1.11.1. This is same test position that was previously discussed in conjunction with Figure 5.1.8.2 and L_{Aeq} sound levels.

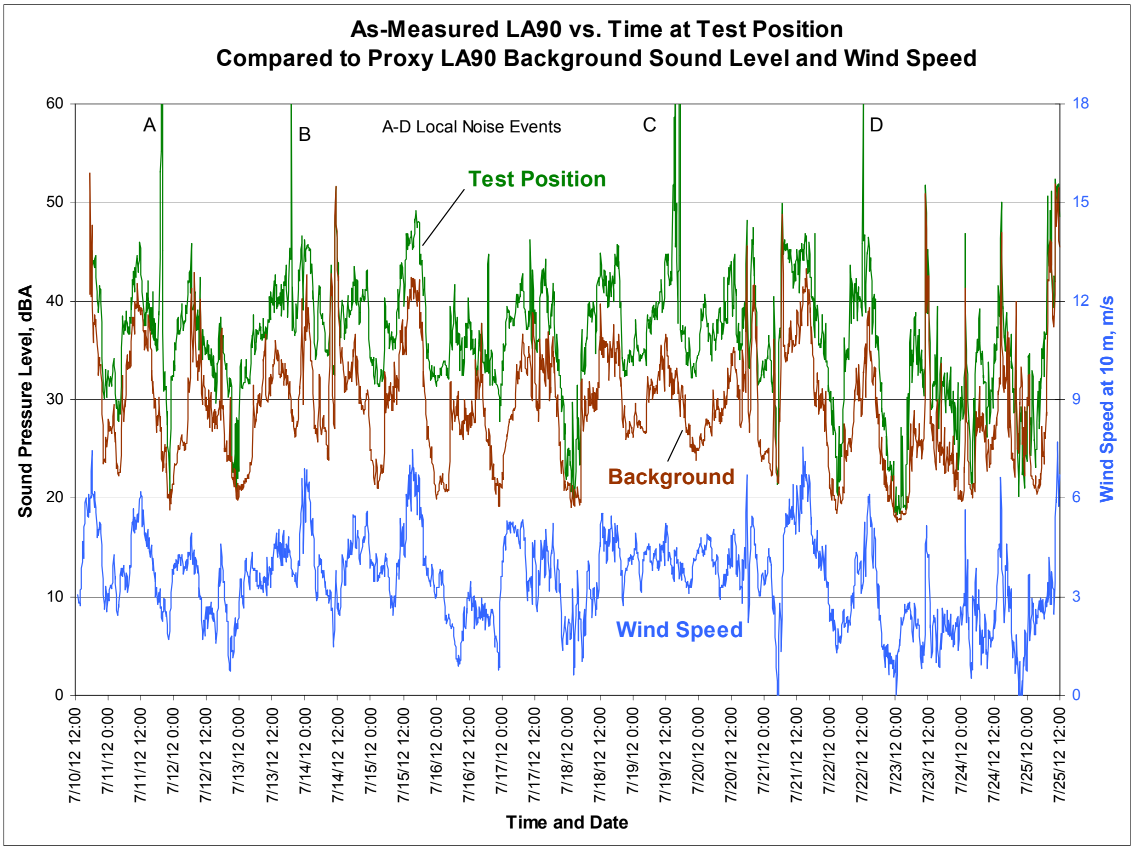

Figure 5.1.11.1

Although the raw results may appear unintelligible at first glance, a closer look reveals that the design background level (developed from an average of three off-site measurement positions) and the sound level at the test position both generally parallel the wind speed indicating that the measured levels are due to wind-induced sounds associated with the natural environment in the first case and to both natural and wind turbine sound in the second. As expected, the on-site level at the position surrounded by almost a dozen turbines is usually substantially higher than the background whenever a moderate wind is blowing and, also as expected, the on-site level is similar to the background during calm conditions when the project is not operating. It is the difference between these two levels during windy conditions that essentially constitutes and quantifies the noise impact of the project. As is evident from the plot, it is an ever-changing dynamic situation where the project sound level variously exceeds the background by anywhere from 0 to 10 dBA. This figure graphically points up the inadequacy of attempting to determine the project's noise emissions from a few short-term manned samples. The greatest differentials between the on- and off-site level tend to occur at night but it is important to note that while the project level may be quite a bit higher than the background, the sound level at the receptor point often remains very low in absolute terms with unadjusted raw levels commonly in low to mid 30's dBA.

Taking these test results through the next steps of correcting the on-site level for background noise and parsing out the low wind periods when the project was idle produces the following plot where the nominal project-only sound level is shown as a function of time over the survey period.

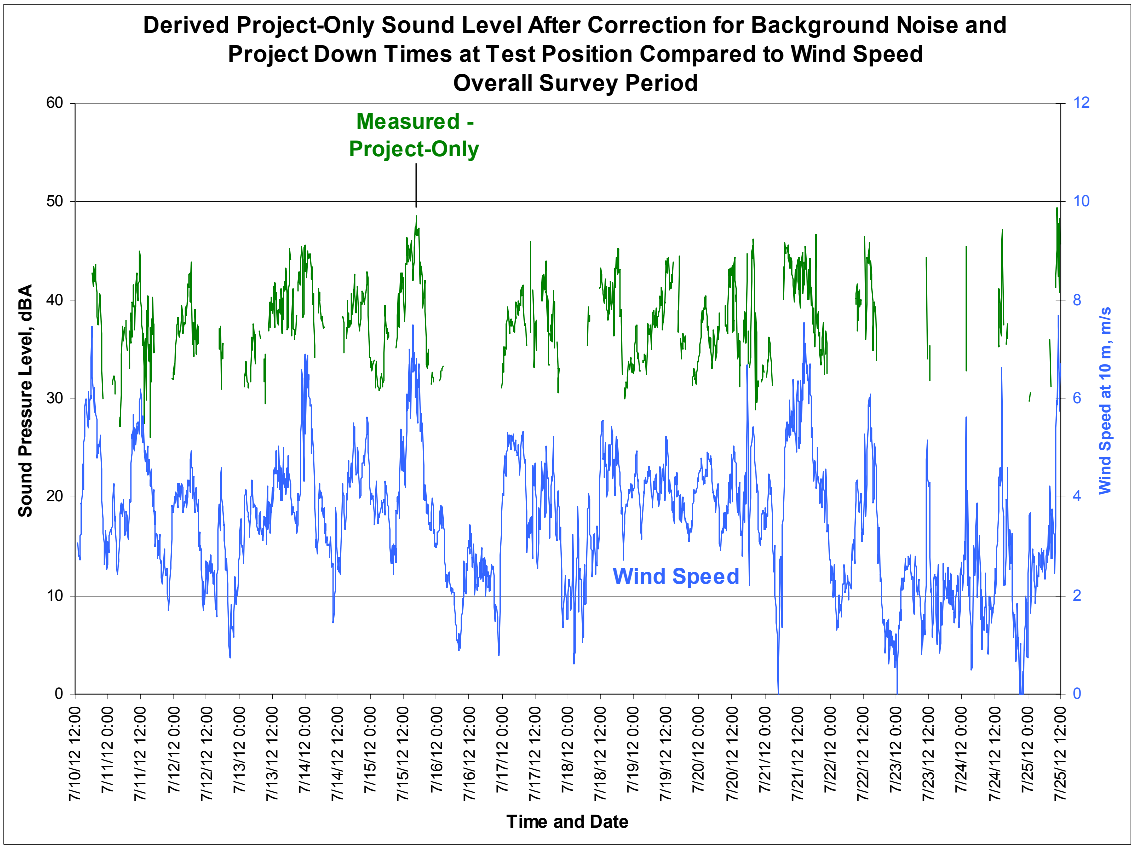

Figure 5.1.11.2

In terms of magnitude the project apparently generates sound levels ranging from 30 to 49 dBA at this location, depending largely but not only on wind speed. The fact that the project sound level does not exactly parallel the wind speed (which was derived from high elevation, rotor height anemometers) indicates that other atmospheric factors play a significant role in determining exactly how loud the project is at this location at any given moment.

What Figure 5.1.11.2 is technically showing is the baseline - L_{A90} - project sound level that is consistently present during each 10 minute measurement period. This means that somewhat higher sound level excursions lasting a few seconds to a few minutes are possible, if not probable, but it is not practical to capture the moment to moment variation over the lengthy survey period needed to adequate evaluate long-term project sound levels. However, comparing these results to model predictions based on the turbine sound power level indicates that the L_{A90} approach does not inadvertently underestimate project levels, as might be suspected. Figure 5.1.11.3 plots the modeled project sound level at this test position (using the procedures outlined in Section 4.1) against the measured project-only sound level. For clarity a detail of a representative three day period from the third to the sixth day of the survey is shown.

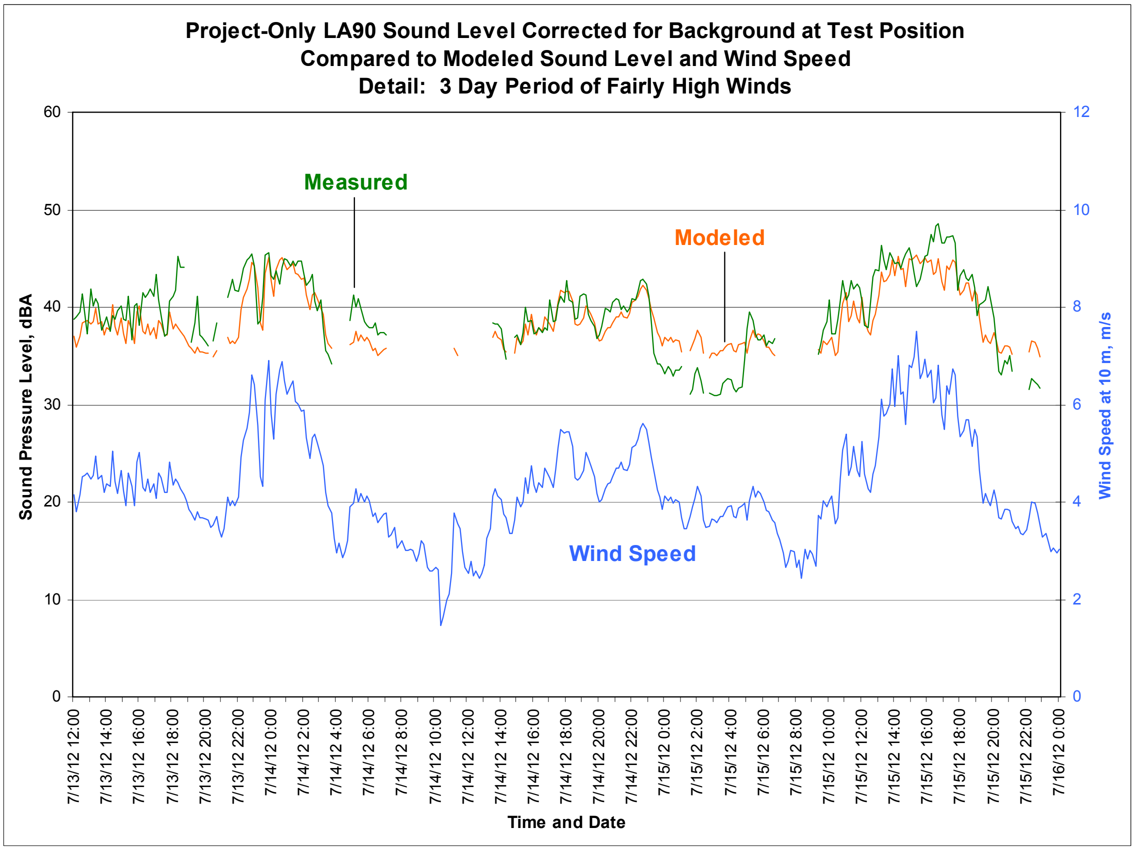

Figure 5.1.11.3

The modeled level is derived using a curve-fit polynomial function based on the predicted project sound level at integer wind speeds, which in turn is based on the turbine sound power level at those wind speeds taken directly from an IEC 61400-11 field test report. In general, the plot shows that the model prediction, based solely on the turbine's sound power level at specific wind speeds, provides a reasonably good approximation of the actual observed sound level.

Example 2

The second example is from a site in the Midwestern United States where the turbines are again intermixed with scattered homes and farms in a rural setting. This particular test location was adopted in response to, what turned out to be understandable, complaints about noise from a participant's "own" turbine that had been sited at the unfortunate distance of only 180 m (600 ft.) from the house. The raw test results are summarized in Figure 5.1.11.4.

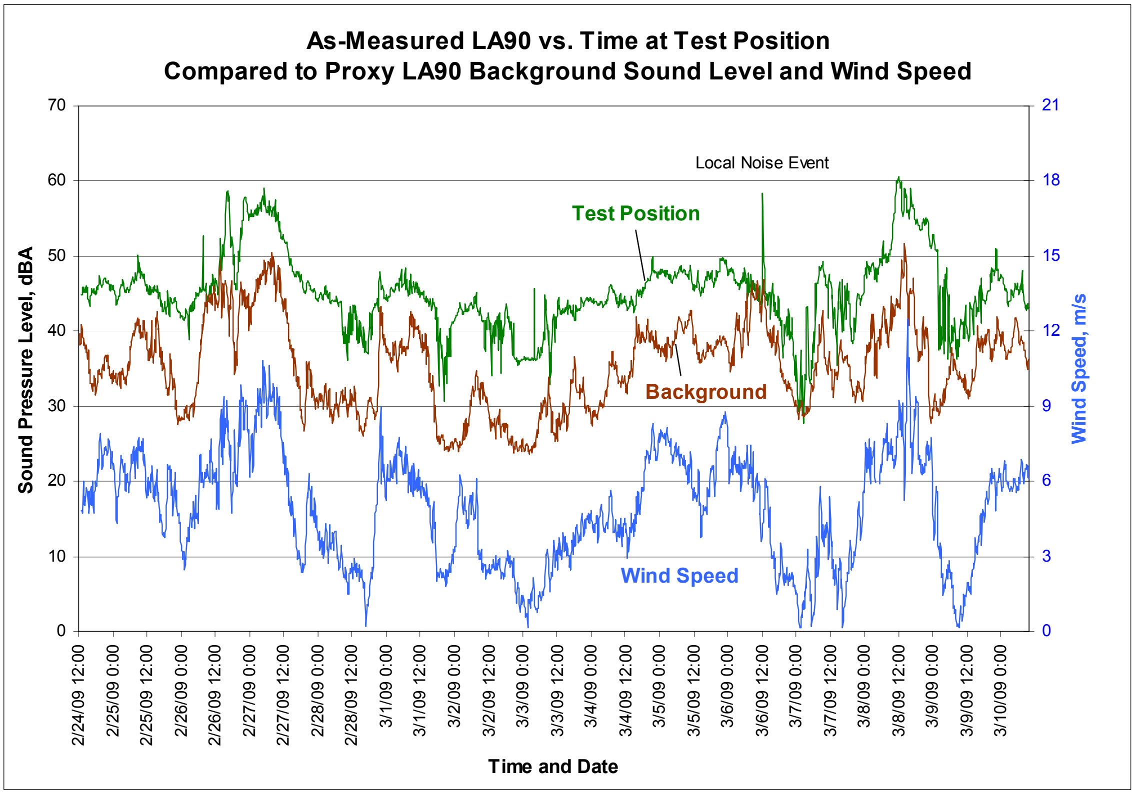

Figure 5.1.11.4

In this instance, the total sound level at the house is consistently and not surprisingly well above the background level developed from four off-site monitoring stations, meaning that much of the time background noise was largely insignificant, if not inaudible. The corrected project-only sound level for a three day windy period near the beginning of the survey is shown below compared to model predictions.

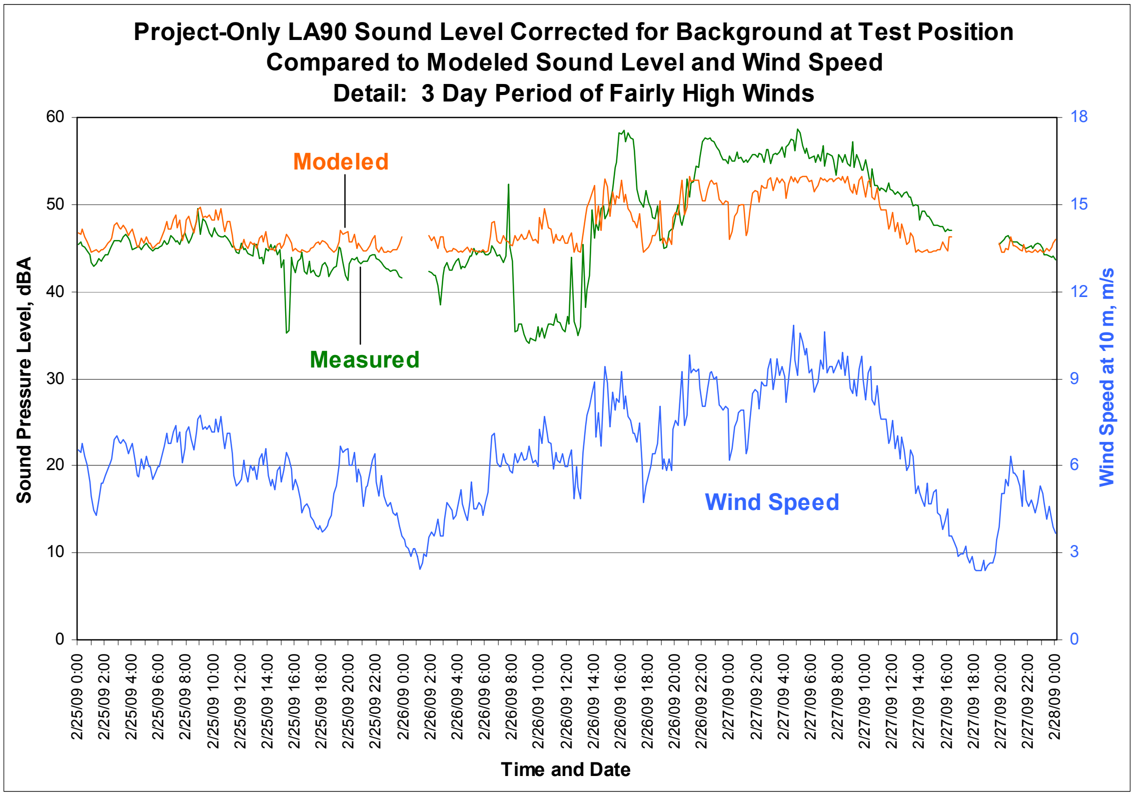

Figure 5.1.11.5

In this instance, as with Example 1, the predicted level intertwines with the measured level, sometimes over-estimating, sometimes underestimating but generally capturing the mean project sound level. The variation above and below the predicted level is largely a measurement of how all other factors beyond the simple wind speed are affecting the total sound level perceived at this location. One of these factors may be unique to the turbine model used at this site, which, based on other surveys and observations, appears to have a tendency to produce sound levels in excess of the manufacturer's stated performance in high wind conditions, which may be part of the reason the actual level significantly exceeds the expected levels in the second half of this sample period. This same departure between the predicted and measured levels also appears in the regression analysis below for the entire survey period where the project-only sound levels are plotted as a function of wind speed.

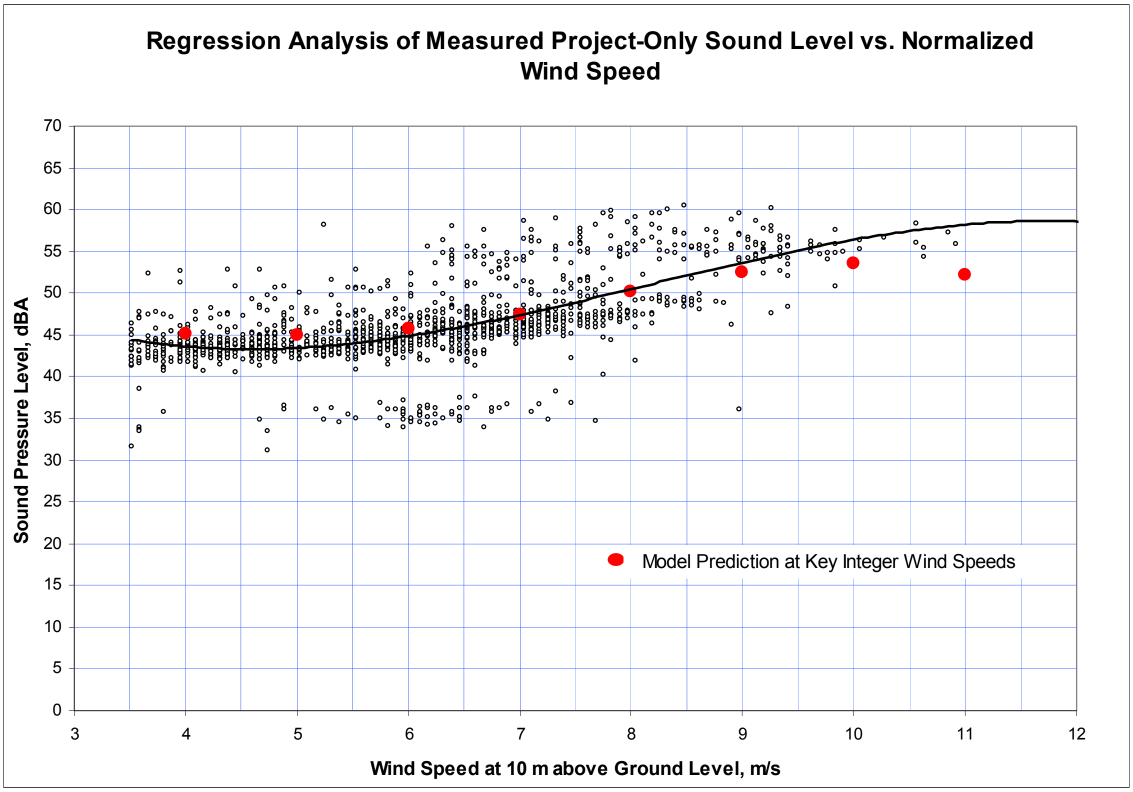

Figure 5.1.11.6

Good agreement with the mean trend is evident up to about 9 m/s but not beyond it.

These two examples are presented to illustrate the outcome of the test methodology and are generally representative of the typical results obtained at a number of test positions over a number of such surveys. That is not to say, however, that the method is infallible and that mismatches between measured and predicted levels will never be found. Testing wind turbine noise is challenging and inherently imprecise because the sound sources themselves and the propagation of sound from them to a given point of interest is dependent on the environment in general and amorphous wind and atmospheric conditions in particular.

5.1.12 *Interpretation of Test Results Relative to Permit Limits*

The regression plot above (Figure 5.1.11.6) exhibits the typical behavior where there is a scatter to the test results and the project sound level is not a perfectly fixed quantity at a given wind speed. This is an unavoidable consequence of the nebulous atmospheric conditions mentioned above. The question that this raises, however, is how to interpret the results of the survey relative to the absolute, or in some cases relative, noise limits contained in planning consent or permit conditions. Excursions, sometimes very substantial excursions, above the mean project sound level are inevitable and under all normal circumstances it would be a complete impossibility to design and lay out a project so that the sound level never exceeded a specific value at a particular point or, more realistically, at a large number of residences within the vicinity of the project. Only projects in obviously remote locations could ever be comfortably designed to such a limit. Consequently, the possibility, even likelihood, that project noise will occasionally spike for short periods should be factored in to regulatory limits. That this issue is not addressed in current laws or limits pertaining to wind turbines is simply a result of the understandable fact that few are aware that it is even an issue.

As a suggestion, it seems reasonable to conclude that a project is in compliance with an absolute regulatory limit if the measurements indicate that the project-only sound level is lower than the stated limit at least 95% of the time, taking that number from the commonly used statistical confidence interval.

5.2 Single Site Investigations

In addition to evaluating operational sound levels on a project-wide basis with regard to regulatory compliance, it is sometimes necessary to carry out dedicated field surveys, usually in response to complaints, that are focused only on a specific point. Although each of these situations is certainly unique, the general test approach outlined above can generally be applied with the exception that more resources can be brought to bear on understanding the project sound level at that particular location.

5.2.1 *General Test Design*

The general test set up for a diagnostic or investigative sound survey at a single point would follow the procedures described for a site-wide test in terms of survey length, equipment and measurement technique with the following enhancements.

The primary measurement position will be outside the residence or point of interest where it is usually prudent to use multiple instruments for redundancy and/or increased functional capability. For example, it is highly desirable to measure the overall A-weighted sound level, the frequency content in 1/3 octave bands and to store audio recordings whenever an appropriate trigger level is reached. While all three of these things can be achieved by some instruments, it would be safer to use the 1/3 octave band analyzer to store numerical data and use a second instrument to store both back-up A-weighted data and the audio files. In any case, having multiple instruments can also allow for additional time resolutions (beside the standard 10 minute periods) to be recorded at the same time; 1 minute or 1 hour data, for instance. In addition to the sound recording equipment a weather station recording wind speed at microphone height, wind direction and rainfall, among other common parameters, should be set up nearby.

The specific measurement position should be at a location with exposure to all of the nearest turbines or at a place that replicates the exposure of the residence to the project but is removed from any sources of local contaminating noise (HVAC equipment, farm machinery, human activities, etc.).

As with a more general survey, the background level is still of just as much concern so 2 to 3 proxy background measurement positions should be found in opposite directions that are remote from any turbines and, in this particular case, replicate as closely as possible the setting of the principal test location in terms of terrain, exposure to wind and exposure to other noise, such as from a road.

The principal and proxy background positions above will theoretically determine what the project sound level is at the residence but may not indicate why it is. To this end several additional monitoring stations close to the 3 or 4 nearest turbines are recommended that are ideally located in line with the principal position at the standard IEC 61400-11 test distance of the hub height plus half the rotor diameter (typically around 125 m, or 400 ft.). A hypothetical test set up involving four nearby turbines is shown in Figure 5.2.1.1.

Figure 5.2.1.1

Note that several of the intermediate positions are slightly off the direct sight line to keep them in open and reasonably accessible areas. Although this hypothetical example was conveniently conducive to this test set up, additional complications are likely to arise; in particular access to private property, which may call for some creativity in designing the test layout. Nevertheless, the idea is to gauge the individual contribution from all of the nearest units over a variety of wind directions and weather conditions to determine if the problematic noise levels are principally associated with perhaps one unit or a particular set of wind conditions. Moreover, the principal purpose for measuring the noise emissions of all the nearest units is to be able to estimate the actual sound power level of each unit and analytically calculate, by means of a simple spreadsheet model, or modeling software, the total sound level at the house for comparison to the measured level there. This approach allows the individual contribution from each unit to be quantified for different conditions and also helps confirm, in a manner independent from the proxy monitoring approach, how much of the received signal at the principal measurement location is due to the project and how much is background noise. In addition, the sound power level of each unit can be informally checked against the manufacturer's warranty value.

While the ground board technique specified in IEC 61400-11 is not practical for long-term, unattended measurements - mainly because of concern about rain - a comparable, if somewhat less rigorous, result can be obtained from measuring at 1 m above grade by placing the microphone or monitor on a tripod or temporary post at the appropriate distance. In Figure 5.2.1.2, for example, measurements were made simultaneously at 1 second resolution with a microphone on a ground plate and with two additional microphones at 1 and 2 m above it. The average and consistent differential between both above ground positions and the microphone on the reflective plate was 2.7 dB, which is close to the ideal 3 dB differential that one would expect.

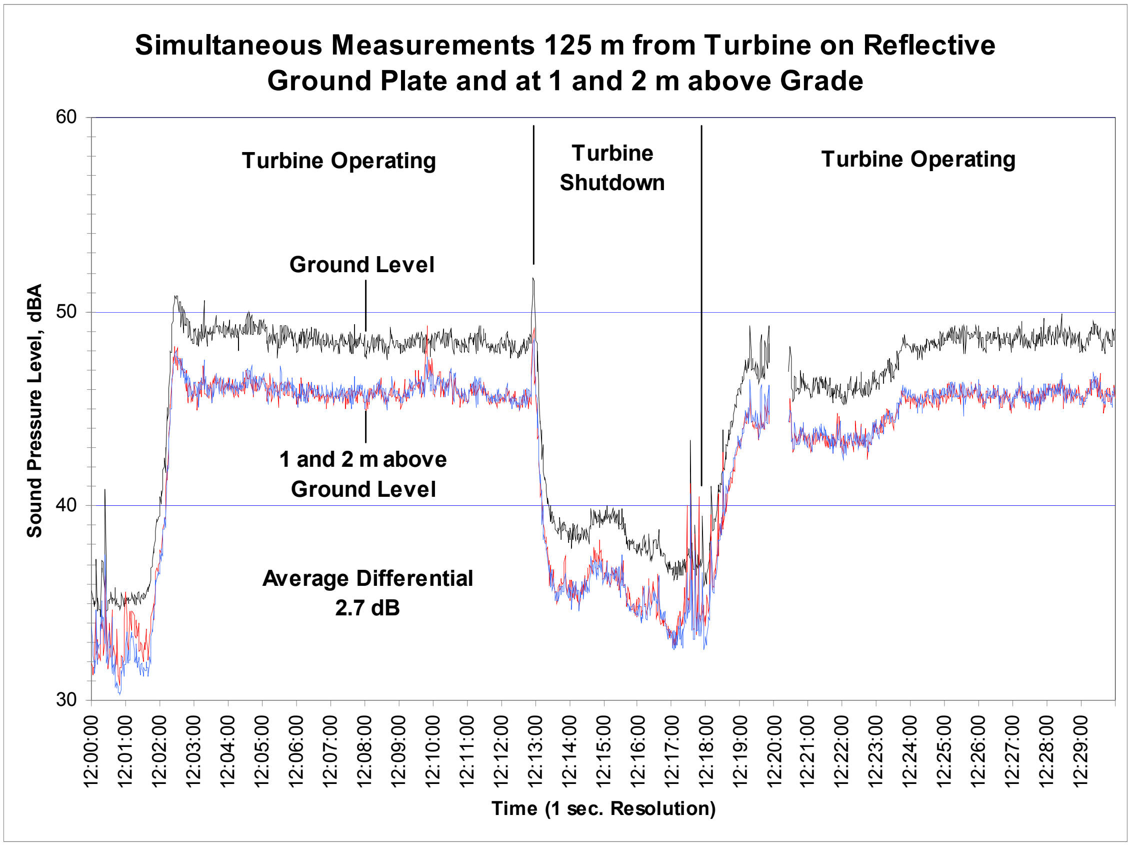

Figure 5.2.1.2

This example illustrates that it is possible under certain circumstances to reasonably measure the apparent A-weighted turbine sound power level above ground level without serious degradation due to wind distortion. Of course, this may not be true when it is particularly windy at 1 m above ground level. Another potential complication arises when multiple turbines are in unusually close proximity to each other, as they are in Figure 5.2.1.1, and background noise or cross-contamination from one unit to another must be taken into account in such cases. In general, however, the only substantive modification to the IEC 61400-11 process for calculating sound power level would be to change the constant "6" to "3" in Eqn. (9) of the standard since above ground measurements are being used.

As suggested by Figure 5.2.1.2, an additional tool that is normally useful and practical for single site investigations is to temporarily shutdown, for 10 to 20 minutes, the nearest turbines to the point of interest, if not all those that could conceivably be affecting the sound level there, in order to obtain direct measurements of the background level so the project-only level can be derived with some confidence from the operational sound levels occurring just before or after the shutdown. A short-duration shutdown helps ensure that the wind and weather conditions are essentially identical for both the on and off measurements. This technique also offers a way of verifying the validity of the levels measured at the off-site background positions. It is usually during the times of peak noise that it is most desirable to have an exact measurement of project's sound level, since these are the noise levels that most likely engendered the complaint in the first place. Consequently, it becomes a matter of either being there when these conditions occur, which is frequently at night, to organize the shutdown - or putting control over the shutdown in the hands of the resident who can call in by pre-arrangement to the control room if and when the noise becomes objectionable in terms of its overall magnitude and/or begins to exhibit some adverse character, such as from amplitude modulation. Although this latter approach of allowing the resident identify the time of maximum noise has been used successfully to quantify the overall magnitude of project noise and its frequency content in 1/3 octave bands, one must really be on hand to manually measure amplitude modulation, since it calls for the use of an extremely fine time resolution, on the order of milliseconds, to capture the sound oscillations that normally have a period of roughly 1 second. Such manual measurements can be taken indoors, where this kind of noise is most often observed to be objectionable, as well as outdoors.

Only with attended measurements it is possible, and then only occasionally, to measure indoor sound levels in any kind of meaningful way because contaminating noises can be observed and, hopefully, factored out. Long-term monitoring is effectively limited to the outdoors for the fundamental reason that there is no way to ascertain the background sound level inside of a dwelling at a particular time with the project operating. This is because the background sound level indoors is driven by a unique set of seemingly minor but significant sound sources that cannot be replicated by a proxy measurement position. Indoor background sound levels are partially a function of the outdoor conditions, particularly when it is windy or raining, but are also driven by such things as air flow from the heating and air conditioning system, appliances, computers and, of course, human activity even when it is in a distant part of the house. These usually very minor sounds are significant because the intruding noise level from the project is often very low or extremely low in terms of the A-weighted sound level. For example, it would not be unusual for a project sound level to be in the vicinity of 30 dBA inside of the house (perhaps being in the 40 to 45 dBA range outdoors). The successful measurement of the project-only sound level would then require the indoor background level to be 20 dBA or less, which is usually not the case. Sound levels in a bedroom at night are commonly at least 30 dBA even when no wind project is present.

In any event, it is sound level outside of dwellings that is normally (but not always) restricted by regulations or permit conditions and this level can typically be measured with the long-term monitoring methodology described above.

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COMPARISON OF PREDICTED AND MEASURED WIND FARM NOISE LEVELS AND IMPLICATIONS FOR ASSESSMENTS OF NEW WIND FARMS

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To maximise the energy output of wind farms whilst still meeting the relevant noise regulations, it is important that an accurate environmental noise prediction method be used during the planning stage. This paper presents a comparison of predicted noise levels from four commonly applied prediction methods against measured noise levels from the operational wind farm conducted in accordance with the applicable guidelines in South Australia. The results indicate that the methods typically over-predict wind farm noise levels but that the degree of conservatism appears to depend on the topography between the wind turbines and the measurement location.

INTRODUCTION

An environmental noise assessment is an important component of the planning stage for new wind farms located near to noise sensitive receivers. Noise criteria defined by regulatory authorities will often constrain the layout and number of turbines within the wind farm.

A key part of the assessment is the environmental noise prediction method used to predict wind turbine noise levels at nearby sensitive receivers. A prediction method that under-predicts noise levels, even marginally, could lead to turbines being shut down during the operational phase in order to achieve compliance with the noise criteria. Conversely, a prediction method that over-predicts noise levels could result in available land for wind energy production being under-utilised.

This paper presents a comparison of predicted noise levels from commonly applied noise prediction methods against measured operational wind farm noise levels from 13 sites at six wind farms. Noise levels from each of the sites have been analysed in accordance with the South Australian *Wind Farms Environmental Noise Guidelines* (SA Guidelines) [1].

In order to minimise the effect of other factors that could result in a difference between predicted and measured noise levels, predictions have been carried out using:

- measured sound power levels for the installed turbines
- topographical contours for each wind farm
- GPS-determined co-ordinates for measurement sites
- hub height measured wind speeds.

Similarly, the measurement sites and analysis processes have been selected to minimise the contribution of background noise to the measured noise levels.

The findings of this paper complements those of the authors' other paper in this issue [2]. The noise measurement and analysis process, outlined briefly in this paper, is discussed in more detail in the other paper.

PREVIOUS INVESTIGATIONS

A number of investigations into the accuracy of environmental noise prediction methods for wind farms have been undertaken both in Australia and internationally, with key ones discussed briefly in this section.

Bass et al. [3] conducted a study into the development of a wind farm noise propagation prediction model by measuring noise levels from a loudspeaker of known sound power level across three different sites. The loudspeaker was situated at a height between 15 to 30 metres above ground, with measurements conducted up to 900 metres away. It was concluded that the prediction model defined by International Standard ISO 9613-2:1996 [4] provided "impressive" accuracy between the predicted and measured noise levels but that this could be improved through the application of corrections depending on topographical conditions. Following this, Bullmore et al. [5] conducted measurements around three European wind farm sites and found the ISO 9613-2 prediction method provided an upper limit of measured noise levels under downwind conditions. This modelling assumed either completely reflective ground or 50% absorptive ground depending on the particular site.

A comparison of measured and predicted noise levels for two wind farms as part of the Portland Wind Energy Project has also recently been carried out [6]. For this assessment, post-construction L_{95} noise levels were measured in accordance with New Zealand Standard NZS 6808:1998 [7] and compared to the sum of the predicted noise levels and the average pre-construction background noise levels. It was found that the ISO 9613-2 prediction method, using 50% absorptive ground, provided the best correlation to the measurement data across the two wind farms. However, the paper identified potential concerns regarding the contribution of background noise levels to the overall measured noise levels.

A number of standards and guidelines also provide recommendations on prediction methods to be used for wind farms. NZS 6808:1998 and the updated 2010 version [8] both outline acceptable methods. A stakeholder review of NZS 6808:1998 [9] concluded that:

In cases where the distances between turbines and receivers are significant and have significant terrain features, the ISO9613 model produces more accurate results. As typical setbacks to NZ wind farms are 800 metres or more, ISO9613 would appear to most accurately predict measured sound levels.

The SA Guidelines recommend the use of either the ISO 9613-2 or CONCAWE [10] prediction methods.

The discussed previous studies have typically focussed on comparing individual attended measurements (under known conditions) with predicted noise levels, or on assessing whether prediction methods provide an upper limit for any measured noise level at the site. This limits the ability to directly compare the results from these studies with the compliance measurement procedures typically carried out for Australian wind farms, as these procedures involve determination of an average noise level across a number of data points at each integer wind speed.

While the Portland Wind Energy Project study was carried out based on the NZS 6808:1998 assessment methodology, this method has only been used within Victoria and has recently been superseded by the NZS 6808:2010.

In our study, measured noise levels from wind farms in South Australia and Victoria have been determined in accordance with the SA Guidelines, or the earlier 2003 SA Guidelines [11] which use the same measurement process. This requires determination of an average measured noise level under all downwind periods. For future wind farms assessed in this manner, it is important that the accuracy of the environmental noise prediction method be understood to both improve the planning of the wind farm and to address concerns about noise prediction accuracy.

SITE DESCRIPTIONS

Six wind farm locations and 13 measurement sites have been selected for comparison in this paper as measurements collected at these sites appear to be controlled by noise from the wind turbines across a reasonable wind speed range.

The measurement sites were selected based on their higher than typical exposure to noise from the wind farms, or due to the low background noise levels at the site. They are typically representative of the closest receivers to wind farms in South Australia, although several of the measurement sites were not actually at a residence. However, one measurement site has been selected that is located approximately 3,000 metres from the nearest turbine.

For commercial reasons, the names and locations of the wind farms have not been disclosed and the wind farms will be designated as Wind Farm A through to F. The turbines at the farms are rated between approximately 1.5 MW and 2 MW. Based on compliance monitoring conducted at each site, all of these wind farms are in compliance with the environmental noise criteria.

Wind Farm A

Wind Farm A involves a line of turbines stretching about 10 kilometres along the top of a range of hills. The turbines are spaced approximately 400 metres apart. Three noise measurement sites have been considered as part of this comparison (A1, A2 and A3). Each site is located between 800 and 1000 metres from the nearest turbine, and situated 50 to 70 metres lower than the base height of that turbine.

The ground between Sites A1 and A2 and the nearest turbine to each site slopes steadily down from the turbine, with a slight rise in the ground relative to the straight line between the turbine base and the measurement site within about 100 metres of the receiver location. The ground between Site A3 and the nearest turbine slopes sharply down from the turbine initially, reaching a height of 5 metres above the measurement point less than 400 metres from the turbine before sloping gently for the remainder of the distance.

Wind Farm B

Wind Farm B also involves a line of turbines stretching about 10 kilometres along the top of a range of hills. The turbines are spaced approximately 300 metres apart. Four noise measurement sites have been considered as part of this comparison (B1, B2, B3 and B4). B1, B2 and B3 are located approximately 1,000 to 1,500 metres from the nearest turbine, with B4 located approximately 3,000 metres away. All sites are situated 130 to 200 metres lower than the base height of the nearest turbine.

The ground between Sites B1 and B3 and the nearest turbine to each site initially slopes sharply down from the turbine to the measurement site, with an 80% decrease in elevation before the midpoint between is reached. The topography between Site B4 and the nearest turbine is similar to that of B1 and B3, but the 80% decrease in elevation occurs within 800 metres of the turbine (approximately 25% of the total horizontal distance to the measurement point). The ground between Site B2 and the nearest turbine slopes relatively evenly down for the entire distance, with a slight concave nature to the slope.

Wind Farm C

Wind Farm C involves a group of turbines distributed over about 20 square kilometres, and spaced approximately 350 metres apart. Three measurement sites have been considered as part of this comparison and have been designated C1, C2 and C3. The measurement sites are located between 300 and 700 metres from the nearest turbine.

The ground around the wind farm is relatively flat, with no change in elevation from the turbine base to the measurement site greater than 10 metres.

Wind Farms D, E and F

Wind Farms D and E both involve turbines arranged in a line, while the turbines at Wind Farm F are arranged into a group. One noise measurement site has been selected for each wind farm and designated D1, E1 and F1 respectively. The distance from each site to the nearest turbine is 300 metres for D1, 1,200 metres for E1 and 700 metres for F1.

The ground between the nearest turbines and the measurement site at each of these wind farms is relatively flat, with no change in elevation from the turbine base to the measurement site greater than 10 metres.

Summary

Table 1 provides a general description of the topography for each site. At none of the measurement sites was the line of sight from receiver to the nearest turbine hubs and blades (controlling the overall noise levels) interrupted by the local topography.

MEASURED NOISE AND SOUND POWER LEVELS

Environmental Noise Measurements

A-weighted $L_{90,10min}$ noise levels from the wind farms were measured at each site over a period of three to four weeks. Both the measurements and subsequent data analysis were undertaken in accordance with the 2009 SA Guidelines [1]. The measured noise levels were correlated with wind speeds for the period, measured at the most representative hub height meteorological mast. A single 'measured' noise level value for each integer wind speed was determined by fitting a polynomial regression line to the data.

Only those measured noise levels that coincided with wind directions within 45° of the worst case wind direction (i.e. the direction from the nearest wind turbine to the measurement site) were considered for the analysis. Measurements that were obviously affected by extraneous noise sources or that did not coincide with wind speeds between the cut-in and cut-out of the turbines were excluded from the analysis. At eleven of the locations, over 500 valid data points remained in the worst case wind direction. At the other two locations (C1 and C2) approximately 200 valid data points remained although these were confined mainly to the small range of wind speeds where measured sound power data for the installed turbines was available.

A significant issue that can affect measurement results from operational wind farms is the contribution of the background noise environment. While this can be somewhat overcome by subtracting the measured pre-construction noise levels, Delaire and Walsh [12] showed this method is susceptible to error as background noise levels can change across seasons and years. The pre- and post-construction measurement locations may also be different, another possible inaccuracy with this method. To address this, each measurement site was selected such that it was as far away as possible from potential sources of background noise (e.g. trees, occupied dwellings), and such that the noise level at the site was typically controlled by turbine noise. In addition, only wind speeds where the L_{A90} noise level appears to be consistently controlled by turbine noise were considered in our analysis. These wind speeds have been selected based on analysis of the measurement data and supported by observations made on site during the measurements. Wind speeds where there was a significant spread in the measured noise levels were excluded, as observations on site indicated this variation was the result of extraneous noise sources affecting measured levels.

As an example, Figure 1 presents measurement results for Site B3, indicating a wind speed range of 4 to 12 m/s where the measured noise level is controlled by turbine noise. This is evident due to the small spread of the measurement data when compared to wind speeds above 12 m/s where background noise causes significant variation between measured noise levels at the same integer speed. At lower wind speeds, there are also a number of measurements where the turbine clearly cut-out due to low wind speed during the measurement period. These have been excluded from further analysis. For each measurement site, between three and six integer wind speeds were identified as being in the turbine-controlled wind speed range.

Table 1. General description of topography

Site	Topographical description	Approximate distance to nearest turbine
A1	Steady downward slope	1000 m
A2	Steady downward slope	800 m
A3	Concave downward slope	800 m
B1	Concave downward slope	1500 m
B2	Slight concave downward slope	1000 m
B3	Concave downward slope	1000 m
B4	Concave downward slope	3000 m
C1	Flat	600 m
C2	Flat	300 m
C3	Flat	700 m
D1	Flat	300 m
E1	Flat	1200 m
F1	Flat	700 m

Sound Power Level Measurements

Sound power levels for typically two of the turbine models installed at each site were measured in general accordance with International Standard IEC 61400-11 Edition 2.1 [13]. Minor deviations from IEC 61400-11 Edition 2.1 at each site were not considered likely to affect the measured sound power levels. There was generally little difference between the measured sound power levels for different turbines at the same site but the average measured sound power level has been used for this comparison.

The measured sound power levels were compared against the measured compliance noise levels at each of the sites. At every site, the change in measured compliance noise level across the turbine-controlled wind speed range demonstrated good correlation with the change in sound power level across that range. This suggests that there is no noticeable change in the propagation of noise from the turbines to the measurement locations due to changes in the wind speed.

Figure 2 compares the measured noise levels for Site B3 against the measured sound power levels (reduced by approximately 60 dB) for the turbines at that wind farm. Similar results were obtained for all of the measurement sites.

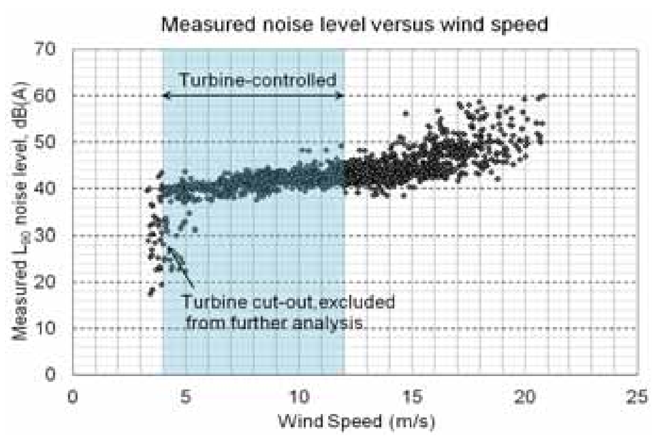

Figure 1. Example of measured noise levels versus wind speed with turbine-controlled wind speed range

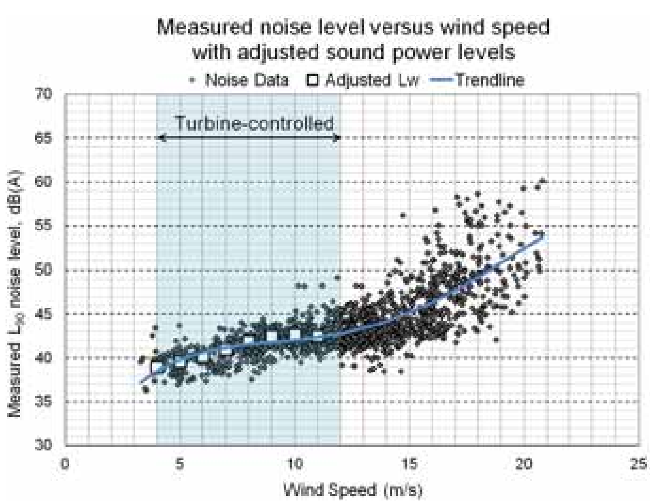

Figure 2. Comparison of measured noise levels and measured sound power levels

ENVIRONMENTAL NOISE PREDICTION METHODS

ISO 9613-2

The ISO 9613-2 prediction method, as implemented in the SoundPLAN Version 7.0 software (produced by Braunstein + Berndt GmbH), has been selected for comparison with the measured noise levels in this paper. It is recommended by both NZS 6808:2010 and previous investigations as providing appropriate accuracy for predictions of wind farm noise levels. ISO 9613-2 states a prediction accuracy of ± 3 dB for sources of heights up to 30 metres above ground and for distances up to 1000 metres from the source. However, outside of these conditions, no indication of accuracy is provided.

Two different ground absorption values (G=0 and G=0.5) have been adopted for the ISO 9613-2 method. No meteorological correction factor has been applied, such that the predicted levels can be considered to reflect the typical downwind noise level.

CONCAWE

The CONCAWE prediction method, as implemented in the SoundPLAN Version 7.0 software, has also been selected. It was developed based on sources of heights up to 25 metres above ground and is typically applied up to distances of 2,000 metres from the source.

Predictions with the CONCAWE method have been carried out assuming worst case meteorological conditions (Weather Category 6) apply from all wind turbines to each measurement site. Completely absorptive ground (G=1) has been assumed as the use of reflective ground has previously been found to result in significant over-predictions with the CONCAWE methodology [9]. The air absorption values specified by ISO 9613-2 have been used for the CONCAWE predictions.

NZS 6808:1998 method

The simplified hemispherical prediction method outlined in NZS 6808:1998 has been widely used in Australia and New Zealand, has also been used in this paper. The method is independent of topography and the noise level (L_R) at a height of 1.5 metres and distance R from each turbine is calculated based on Equation (1):

$$L_R = L_W - 10\log(2\pi R^2) - \alpha_a R \quad (1)$$

L_W is the sound power level of the turbine and α_a is the attenuation of sound due to air absorption in dB(A)/m. Two different air absorption values have been used to calculate noise levels using this method:

- a constant value of 0.005 dB(A)/m as recommended by NZS 6808:1998
- the octave band air absorption values outlined in ISO 9613-2.

Nord2000 method

The Nordic environmental noise prediction method, referred to herein as the Nord2000 method, has been validated for the prediction of wind turbine noise [15]. This method, as implemented in the SoundPLAN Version 7.0 software, has been selected for comparison. The Nord2000 method represents the only prediction method used where the wind speeds have been altered accordingly to predict noise levels at each speed within the turbine-controlled wind speed range. This is as the Nord2000 method allows for specific wind speeds to be input at particular heights, which can vary the propagation. Other inputs specific to the Nord2000 prediction method included:

- average roughness length of 0.05 metres
- downwind conditions
- average temperature gradient of +5 K/km (temperature inversion), with standard deviation of 1 K/km
- turbulence constants: C_V^2 of 0.012 $m^{4/3}s^{-2}$ and C_T^2 of 0.0008 Ks^{-2}
- average ambient pressure measurements for the meteorological masts at each site
- flow resistivity for the site of 80 $kNsm^{-4}$
- medium roughness class.

Further information on each of these inputs and how they affect the predicted noise levels from the Nord2000 method can be found in the *Nordic Environmental Noise Prediction Methods, Nord 2000 Summary Report* [15].

Additional Model Inputs

Each noise model within the SoundPLAN software included the measured sound power levels for the installed turbines, topographical ground contours, turbine co-ordinates provided by the site operator and measurement site co-ordinates determined using a handheld GPS unit. The search radius in the SoundPLAN calculation module was set to 20 kilometres.

At Wind Farms A and B where the topography varied considerably between turbine and receiver, one metre elevation contours were used to develop the digital ground model. For Wind Farms C, D, E and F, 10 metre contours were used as this was the most accurate topographical data available. However, given the relatively flat nature of these sites, this was considered unlikely to affect the predictions. For the simpler NZS 6808:1998 method, only the measured sound power levels and the turbine and receiver co-ordinates were used as additional inputs. Based on the 2009 SA Guidelines, an average temperature of 10°C and average humidity of 80% was assumed for each site.

COMPARISON BETWEEN MEASURED AND PREDICTED NOISE LEVELS

Table 2 summarises the average difference between the predicted and measured noise levels at each site. A positive difference indicates over-prediction of the noise levels, while a negative difference indicates under-prediction. The differences have been averaged across the turbine-controlled wind speed range for the site, but the variation between differences at each wind speed is typically less than 0.2 dB(A) due to the good agreement between the change in measured sound power levels and the change in measured noise levels. The results indicate that, except for concave topographies, nearly all of the prediction methods over-predict wind farm noise levels at receivers when the measured levels are assessed in accordance with compliance methodology specified by the SA Guidelines.

Based on the comparison for the thirteen different measurement locations, it appears that topography plays an important role in the accuracy of predicted noise levels. This is most clearly evident at Wind Farm A where measurement sites A2 and A3 are located on different sides of the same small group of wind turbines. The only significant difference between the two sites is the topography from the nearest turbines to the measurement site.

As an example of the effect of topography, the ISO 9613-2 method with 50% absorptive ground is typically within ±1 dB(A) of the measured noise levels at Wind Farms C, D, E and F where the topography is relatively flat. Yet at Wind Farm B, where the topography is concave between the nearest turbines and receivers, this method can under-predict noise levels by up to 4 dB(A).

Considerable under-predictions appear to occur only at sites with concave slopes, with the NZS 6808:1998 (constant αa) and ISO 9613-2 (G=0.5) methods typically under-predicting by 2 to 5 dB(A). The exception is at B4, where the NZS 6808:1998 (constant α_a) method resulted in an under-prediction of approximately 15 dB(A). This is considered to be an effect of the significant distance to the measurement site (over 3,000 metres) at which the assumption of constant air absorption across the entire frequency range does not hold.

However, the relatively commonly used ISO 9613-2 (G=0) method only marginally under-predict noise levels at these locations. This finding is consistent with that of Bass et al. [3] who stated with reference to the ISO 9613-2 method:

Where the ground falls away significantly between the source and receiver ... it is recommended that 3 dB(A) be added to the calculated sound pressure level.

IMPLICATIONS FOR ASSESSMENTS OF NEW WIND FARMS

Effects of Topography

The comparison between measured and predicted noise levels suggests that the topography between the turbines and the assessment location can be an important factor in the accuracy of particular prediction methods. The difference in accuracy of a particular method between a site with a steady slope to the nearest turbine and one with a concave slope can be 6 to 7 dB(A), even where the turbine hub is still clearly visible from the receiver.

Figure 3 shows the topographical cross-section for Site A2 (steady slope) from the nearest turbine, with the line of direct sight from the turbine hub to measurement site shown in red and the line from the turbine base to the measurement base shown in blue. Figure 4 shows the same cross-section for Site B1 (concave). It is clear that the line of sight from both measurement sites to the turbine is not broken despite the significant variance in the prediction accuracies at both sites.

A number of different factors based on the topographical cross-section have been calculated and compared to the differences between measured and predicted noise levels for each method in order to determine a correction factor that could be applied to predicted noise levels.

For Wind Farms A and B, dividing the area beneath the topographical cross-section by the area beneath the line connecting the turbine base to the measurement base appears to provide a reasonable correlation to the differences obtained

Table 2. Average difference between predicted and measured noise levels at sites (turbine-controlled speeds only)

Prediction method	**Predicted - measured noise levels, dB(A)**			
Wind Farm A	**A1 - Steady**	**A2 - Steady**	**A3 - Concave**	
ISO 9613-2 (G=0)	5.8	5.4	-0.4	
ISO 9613-2 (G=0.5)	2.2	2.2	-3.5	
CONCAWE (G=1)	6.2	6.5	1.3	
NZS 6808:1998 (constant α_a)	2.5	3.1	-1.9	
NZS 6808:1998 (ISO 9613 α_a)	6.2	6.5	1.2	
Nord2000	3.7	4.5	-0.8	
Wind Farm B	**B1 - Concave**	**B2 - Slight concave**	**B3 - Concave**	**B4 - Concave**
ISO 9613-2 (G=0)	-0.7	1.0	-0.4	-0.3
ISO 9613-2 (G=0.5)	-3.8	-2.4	-3.4	-4.8
CONCAWE (G=1)	-1.2	1.6	0	-5.2
NZS 6808:1998 (constant α_a)	-5.4	-2.5	-2.9	-14.7
NZS 6808:1998 (ISO 9613 α_a)	-0.1	1	-0.4	-1.2
Nord2000	-1.4	0.4	-1.4	-2.2
Wind Farm C	**C1 - Flat**	**C2 - Flat**	**C3 - Flat**	
ISO 9613-2 (G=0)	2.9	2.9	2.6	
ISO 9613-2 (G=0.5)	1.0	0.1	-0.6	
CONCAWE (G=1)	3.5	3.6	2.5	
NZS 6808:1998 (constant α_a)	2.5	1.8	0.1	
NZS 6808:1998 (ISO 9613 α_a)	3.2	3.4	2.5	
Nord2000	1.4	0.6	-0.3	
Wind Farm D, E and F	**D1 - Flat**	**E1 - Flat**	**F1 - Flat**	
ISO 9613-2 (G=0)	3.2	2.5	2.1	
ISO 9613-2 (G=0.5)	0	-1.2	-1.0	
CONCAWE (G=1)	3.7	1.8	2.6	
NZS 6808:1998 (constant α_a)	1.6	-2.5	-0.6	
NZS 6808:1998 (ISO 9613 α_a)	3.2	3.1	3.3	
Nord2000	1	0.2	2.0	

with the ISO 9613-2 prediction method. However, this relationship does not hold for the flat topography of the other wind farms.

At this stage, no single topographical correction factor has been identified that can be applied to each of the situations. Additional reliable measurement data from other sites with varying topography is still required to determine an appropriate correction factor for the standard prediction methods.

Uncertainty

The predictions and measurements in this paper have been undertaken in an attempt to reduce potential uncertainty as much as possible. Some of these, such as uncertainty associated with the accuracy of measurement equipment, will be reduced due to the large number of measurements used to determine an overall 'measured' noise level. Similarly, slight topographical changes that are not accounted for in the noise models are unlikely to affect predicted noise levels at distances of over 300 metres. Nonetheless, some uncertainty in both the prediction and measurement of noise levels still remains.

A key source of uncertainty relates to the wind shear and variance of wind speed across a wind farm. To minimise this, all wind speeds have been based on hub height wind speeds and taken at a nearby meteorological mast or the nearest turbine to each measurement site. However, some uncertainty remains with regard to the difference between the measured wind speed and the actual wind speed at each wind turbine contributing to the overall measured noise level.

Measurement of the sound power level included calculation of an uncertainty value which is typically less than 1 dB(A) at those speeds considered for this comparison. While this can affect the actual difference between predicted and measured noise levels, most noise assessments undertaken at the planning stage of a new wind farm will use guaranteed sound power levels for turbines provided by the manufacturer. Guaranteed sound power levels are typically higher than actual sound power levels as the uncertainty is sometimes added to them by the manufacturer as a safety factor. For new assessments using guaranteed sound power levels, any prediction method will therefore be more likely to over-predict actual noise levels.

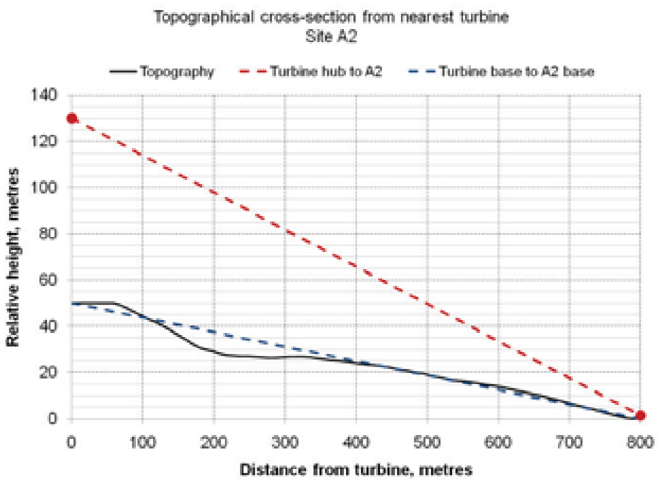

Figure 3. Topographical cross-section from nearest turbine to Site A2 (steady slope)

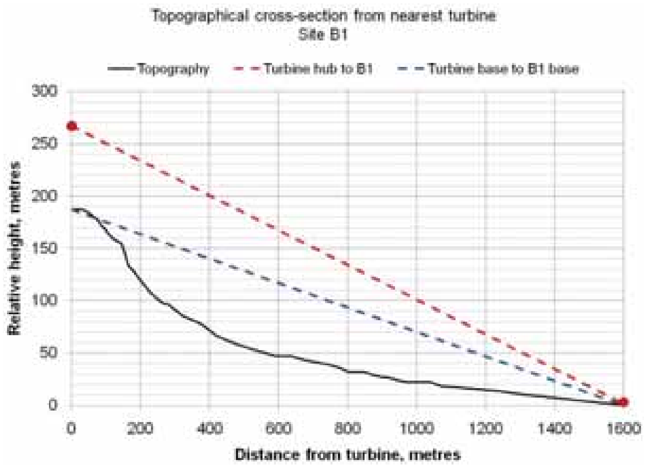

Figure 4. Topographical cross-section from nearest turbine to Site B1 (concave)

The contribution of background noise to the measured noise levels also requires consideration. Although this paper has identified wind speed ranges where turbine noise appears to control overall noise levels, there will still be some contribution to the measured noise levels from background noise. No attempt has been made to correct for the influence of background noise, such that actual turbine noise levels would have been slightly lower than the levels used in this assessment.

Similarly, the noise monitor at Site A3 was located approximately 10 metres from a building structure. This was the only monitor to be located near to a structure, and the measured noise levels may have included a relatively small contribution from reflected noise caused by the presence of the building.

However, any contribution to the measured noise levels from either background noise or reflected noise would lead to an underestimate of over-predictions (and an overestimate of under-predictions) of the different methods. Hence, the analysis provided here may be considered slightly conservative.

Overall Prediction Accuracy

The results in Table 2 indicate that none of the considered prediction methods can be considered suitably accurate for all wind farms. None of the methods appear to appropriately account for effects caused by topographical changes between the turbines and the measurement sites. While the ISO 9613-2 method with completely reflective ground may provide a typical upper limit for the measured noise level across all of the considered sites, it will also significantly over-predict noise levels at sites with flat topography or steady downward slopes.

The CONCAWE method (with G=0) also appears to provide a typical upper limit for the measured noise levels at each site, with the exception of B4 where it under-predicted noise levels by approximately 5 dB(A). B4 is the furthest measurement site from a turbine at a distance of over 3,000 metres and the measured noise levels are in the order of 30 dB(A), considerably below applicable noise criteria. The CONCAWE method therefore seems suitable for predicting noise levels to distances up to approximately 2,000 metres from a wind farm but not for accurately predicting noise levels at distances further than this.

Overall, the comparison of prediction methods in this paper indicates that predicted noise levels for wind farms are generally conservative. None of the measurement results from the sites indicate that the most commonly used methods in South Australia would under-predict noise levels by more than 1 dB(A).

It should also be noted that wind farms represent a relatively rare situation where the noise source is located greater than 60 metres above the ground height. Prediction methods such as CONCAWE and ISO 9613-2 have generally not been developed or tested considering noise sources at these heights, which may explain why they do not appropriately account for topography in this situation.

It is also important to note that the predicted noise levels are A-weighted $L_{eq,10min}$ noise levels which are being compared to measured A-weighted $L_{90,10min}$ noise levels. Our other paper [2] finds that the typical difference between L_{eq} and L_{90} noise levels for wind farms is approximately 1.5 dB(A). This indicates that both the ISO 9613-2 method (with G=0) and the CONCAWE method (with G=1) provide quite accurate predictions of L_{eq} noise levels for wind farms where the topography is relatively flat. Yet for Wind Farms A and B, where the topography varies more significantly, these prediction methods appear to either under- or over-predict L_{eq} noise levels by approximately 2 dB(A).

Recommended Prediction Methods For New Wind Farms

For many other noise sources, exceedances of the noise criteria of 1 to 2 dB(A) are often considered acceptable as humans do not generally perceive a change of 1 to 2 dB(A) in field conditions. However, a 1 dB(A) exceedance of the criteria for a wind farm could often result in a regulatory authority requesting mitigation and it could be considered important should wind farm noise levels be under-predicted by even 1 dB(A) during the planning stage.

Based on the comparisons presented in this paper, the prediction methods that would minimise the risk of a potential exceedance of the criteria would be the ISO 9613-2 method with completely reflective ground or the CONCAWE method with completely absorptive ground and Weather Category 6. However, care should be taken with both of these methods when considering turbines on a raised ridgeline where the ground slopes sharply down from the turbines to the receiver. The analysis in this paper has shown that these methods could under-predict noise levels in this scenario by up to 1 dB(A).

The NZS 6808:1998 method using the ISO 9613 air absorption factors may also be suitable to provide a prediction with minimal risk but is overly conservative on sites with a flat topography or steady downward slope from turbine to receiver.

It is also important to recognise that, in scenarios where the topography is relatively flat or there is a steady slope away from turbines located on a hill, these methods can over-predict noise by up to 6 dB(A) even where line of sight from the receiver location to the turbine hub is not broken. An understanding of the topography is therefore important for any environmental noise assessment of new wind farms.

It appears that the other common prediction methods presented in this paper (NZS 6808:1998 with constant α_a, ISO 9613-2 with 50% absorptive ground and Nord2000) should only be used with due consideration as they can result in considerable under-predictions of noise levels in certain situations.

Due to the relatively large number of possible inputs required for the Nord2000 method to determine meteorological conditions, it may be possible to improve the accuracy of this method through appropriate variation of these inputs. However, this would require further investigation and would also require the environmental noise assessment for a wind farm to analyse much more detailed meteorological data than is currently done.

Other Compliance Assessment Methodologies

The comparison in this paper has focussed on measured wind farm noise levels analysed in accordance with the methodology outlined in the SA Guidelines. For some other Australian and New Zealand wind farms, compliance measurements may also be required to be measured in accordance with NZS 6808:1998 or NZS 6808:2010. These standards require measurement of A-weighted L_{95} and L_{90} noise levels respectively and consider all wind directions. Cooper et al. [2] demonstrated that measured noise levels analysed under these Standards were typically 0 to 2 dB(A) lower than those measured under the 2009 SA Guidelines. This occurred as these other methods consider all wind directions and not only the worst case wind direction, and NZS 6808:1998 also requires measurement of L_{A95}, rather than L_{A90}, noise levels.

The implication of this is that, for wind farms assessed under NZS 6808:1998 or NZS 6808:2010, under-prediction appears unlikely even in the case of a concave slope. Similarly, where the topography is relatively flat around a wind farm or there is a steady downward slope between turbines on a hill and receivers below, the prediction methods considered in this paper would be expected to result in larger over-predictions than shown in Table 2.

Another compliance assessment method that may be used more extensively in the future is that contained in Australian Standard 4959-2010 [16], where the measured average L_{eq} noise level from the wind farm is required to comply with the noise criteria. The Standard assumes that the average L_{eq} noise level from a wind farm will be at least 1.5 dB(A) above the measured L_{90} noise level. The implication of this is that under-prediction of wind farm noise levels would become more likely for flat and concave topographies (unless this 1.5 dB(A) difference is taken into account during the assessment process) should the compliance assessment from AS 4959-2010 be required by regulatory authorities.

CONCLUSIONS

Measured noise levels from 13 measurement sites at six different wind farms have been compared to predicted noise levels using commonly applied noise prediction methods. The measurements and subsequent analysis have been carried out in accordance with the 2009 SA Guidelines. The sites and wind speed ranges have been selected to minimise the influence of background noise on the measured noise levels.

The comparison has indicated that the commonly used ISO 9613-2 (with completely reflective ground) and CONCAWE (with completely absorptive grounds) generally over-predict noise levels from the wind farm. However, the degree of over-prediction appears dependent on the topography around the wind farm. At sites with a relatively flat topography or a steady slope from the turbines to the measurement sites, the over-prediction can be in the order of 3 to 6 dB(A). However, at sites where there is a significant concave slope from the turbines down to the measurement sites, these commonly used prediction methods are typically accurate, with the potential of marginal under-prediction in some cases.

Other commonly used prediction methods, such as the NZS 6808 method with constant air absorption or the ISO 9613-2 method with 50% absorptive ground, can under-predict noise levels in some situations and should only be used with caution.

The implication of this for the assessment of new wind farms is that the topography around the site is an important consideration to estimate the degree of conservatism provided by the prediction method.

At this stage, no clear correction factor based on the topography has been identified that could be reliably applied across any wind farm site to improve the accuracy of noise prediction methods. Additional measured noise levels for wind farms with varying surrounding topography are required in order to improve the available data set.

ACKNOWLEDGEMENTS

We thank the South Australian EPA and our other commercial clients for their support in the preparation of this paper by allowing us to use data gathered for them.

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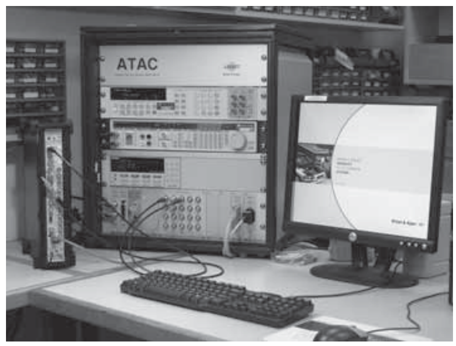

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Propagation Modeling Parameters for Wind Power Projects

Kenneth Kaliski and **Eddie Duncan**, Resource Systems Group, Inc., White River Junction, Vermont

Noise modeling of wind turbines can be problematic in that they generate sound over a large area, from a high elevation, and make the most noise in very high wind conditions. For ISO 9613, these factors directly relate to how ground attenuation and meteorology are accounted for.

To study how ground attenuation and wind speed affect the accuracy of propagation modeling for wind turbines, data were gathered at an existing industrial-scale wind farm, and propagation modeling was conducted using Cadna A modeling software by Datakustik, GmbH for the same site under the same operating conditions in which monitoring was carried out. By adjusting the type of ground attenuation used in the model and the meteorological conditions, the best combinations for modeling propagation for wind turbines were determined with comparisons to the monitored data.

Standards Background

ISO 9613-2 (1996)[1,2] provides two methods for calculating ground effect (A_{gr}). The first method, known as spectral ground attenuation, divides the ground area between the source and the receiver into three regions: a source region, a receiver region, and a middle region. The source region extends from the source toward the receiver at a distance equal to 30 times the height of the source. For a tall wind turbine, this can be up to 2 to 3 km. The receiver region extends from the receiver toward the source at a distance equal to 30 times the height of the receiver. If the source and receiver regions do not overlap, the distance between the two regions is defined as the middle region. The ISO standard goes on to define ground attenuation for each octave band utilizing a ground factor (G) for each region depending on how reflective or absorptive it is. For reflective, hard ground, G=0; and porous, absorptive ground suitable for vegetation, G=1. If the ground is a mixture of the two, G equals the fraction of the ground that is absorptive. The ISO standard states that "This method of calculating the ground effect is applicable only to ground that is approximately flat, either horizontally or with a constant slope."

The second method provided in ISO 9613-2, known as nonspectral ground attenuation, is for modeling A-weighted sound pressure level over absorptive or mostly absorptive ground; but the ground does not need to be flat. Using the alternative method also requires an additional factor (D_{Ω}) be added to the modeled sound power level to account for reflections from the ground near the source.

To show the effect of using spectral vs. nonspectral ground attenuation for a source at a reasonable wind turbine hub height of 80 m, the ground attenuation (A_{gr}) was calculated using both methods for a source height of 80 m and 1 m over a range of distances from 0 to 3.5 km with the ground factor, G, set to zero. In a third scenario, G was set to 1, and an 80-m source height was used. In each example, the receiver height was set at 1 meter. The results for spectral ground attenuation are shown in Figure 1, and nonspectral ground attenuation results are shown in Figure 2.

As shown in the graphs, over soft, porous, spectral ground, attenuation for an 80-meter source is approximately 2 dB less than a 1-meter source. For nonspectral ground attenuation, an 80-m source height actually has negative ground attenuation over the first 750 m due to reflections from the ground.

ISO 9613-2 is only valid for moderate nighttime inversions or downwind conditions. The valid range of wind speeds is 1 to 5 m/s at 3 to 11 m high. For wind turbines, it may be more accurate to consider adjustments such as those presented by CONCAWE[3] or HARMONOISE.[4] These adjustments account for propagation at various wind speed, wind directions, and atmospheric stability. The CONCAWE meteorological adjustments are built into Cadna A and were used in this study.

Based on a paper presented at Noise-Con 2007, Institute of Noise Control Engineering, Reno, NV, October, 2007.

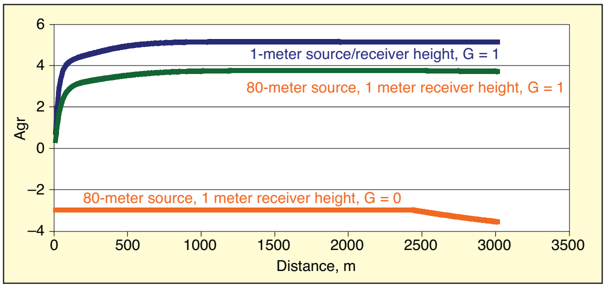

Figure 1. Spectral ground attenuation (A_{gr}) over distance for an 80-m and 1-m-high source; 1-m-high receiver and ground factor set to 1 (soft) and 0 (hard).

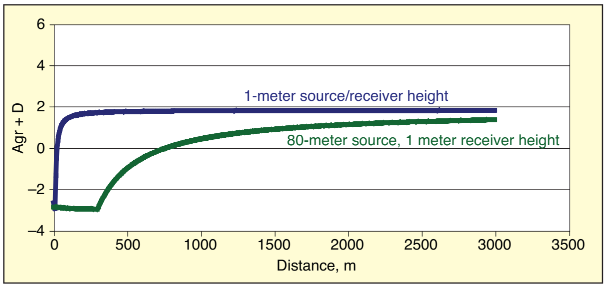

Figure 2. Nonspectral ground attenuation (A_{gr}) over distance for an 80-m and-1 m source and 1-m receiver height. Nonspectral ground attenuation is not a function of ground hardness.

Figure 3. Rural 100-MW wind farm used to study ground attenuation and meteorological modeling factors.

Wind Farm Background

The wind farm in this study is situated on nearly 8 square miles of flat farm land. There are a total of 67 wind turbines that are capable of producing about 100 megawatts of electricity. Each turbine hub is 80 m tall, and the rotation path of the three blades is 80 m in diameter. The turbines are roughly 1,000 ft apart, but there is a wide variation for individual pairs. An image of the terrain and some of the turbines is shown in Figure 3, and Figure 4 shows the layout of the wind farm.

Sound Monitoring

Two sound level meters were set up at 120 m and 610 m from the northern edge of the wind farm. Each sound level meter was an IEC Type I Cesva SC310 fitted with windscreens. The sound level meter at 120 m was placed flat on a 1-m-square ground board,

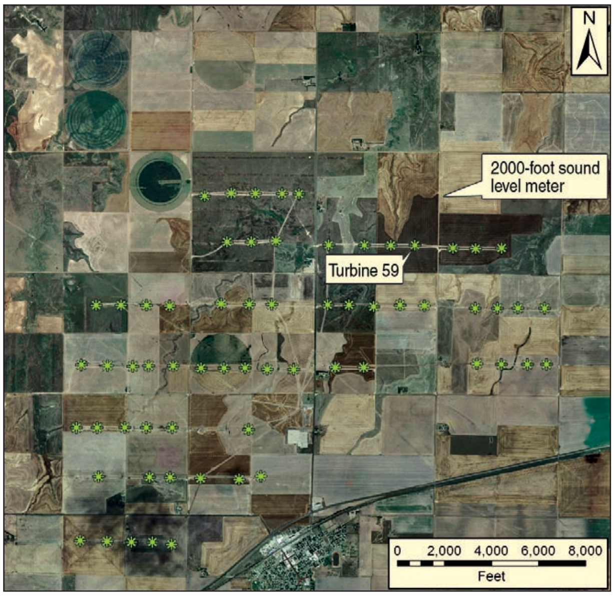

Figure 4. Map of wind farm used for study ; asterisks = wind turbines.

while the meter at 610 m was mounted on a stake at approximately 1 m off the ground.

The measurement period was at night from approximately 10 p.m. to 10 a.m. Each meter logged 1-minute equivalent average sound levels in 1/3-octave bands. In addition, recordings of WAV files were made at certain points.

At the same time, spot measurements of wind speed and direction at hub height, blade rotational frequency, and energy output for each wind turbine were made at 10-minute intervals.

Since we could not obtain background sound levels, we assumed that much of the localized noise from wind passing through the surrounding wheat field would be at and above 2,000 Hz. This was confirmed by listening to and analyzing the WAV file recordings. Therefore, to isolate the wind turbine sound, we created a virtual low-pass filter eliminating sound at frequencies above 2 kHz. In addition, assuming that the wind turbines operated within a narrow range of sound power over any one 10-minute period, we used the 90th-percentile, 1-minute equivalent average sound level for each 10-minute period for comparison to modeled results. This minimized the localized effects of noise from wind gusts.

Sound Monitoring

The Cadna A sound propagation model made by Datakustik GmbH was used to model sound levels from the wind farm. Cadna A can use several standards of modeling, including ISO 9613 with or without CONCAWE meteorological adjustments.

A model run was conducted for every 10-minute period of turbine operation during the monitoring period. This was done by running Cadna A for the following scenarios:

- Standard meteorology with spectral ground attenuation and G=1.
- Standard meteorology with spectral ground attenuation and G=0.
- Standard meteorology with nonspectral ground attenuation.
- Standard meteorology with no ground attenuation.
- CONCAWE adjustments for D/E stability with winds from the south at greater than 3 m/s and spectral ground attenuation, assuming G=1.
- CONCAWE adjustments for D/E stability with winds from the south at greater than 3 m/s and nonspectral ground attenuation.
- CONCAWE adjustments for D/E stability with winds from the south at greater than 3 m/s and no ground attenuation.

For each scenario, a "protocol" was run that listed the ISO 9613-2 attenuation and propagation factors by frequency between each turbine and receivers at 120 m and 610 m from the northern end of the wind farm; that is, the receivers represented by the sound

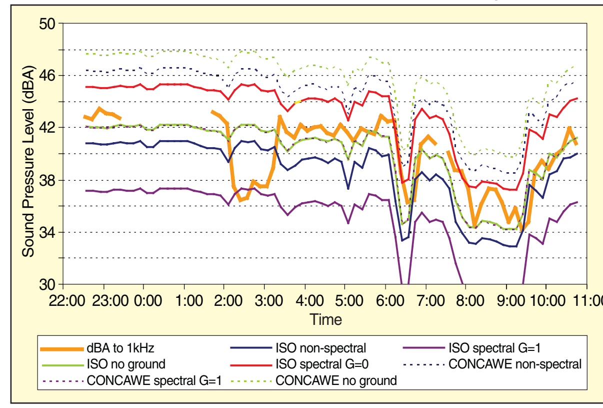

Figure 5. Comparison of monitored sound levels over time at 610 m (shown in orange) with modeled sound levels under various combinations of ground attenuation and meteorological factors.

monitoring locations. These attenuation factors were then put into a spreadsheet model that looked up the manufacturer sound power level for each turbine for each 10-minute period based on actual measured wind speeds at each turbine. The spreadsheet model then calculated the sound level from each turbine by subtracting the attenuation factors from the sound power levels and then combining each turbine to get an overall sound pressure level at the 610-m receiver.

Results

A comparison of the modeled results to monitored sound levels over time is shown in Figure 5. The orange line toward the middle is the actual monitored sound levels. As shown, these monitored levels ranged from about 34 dBA to 43 dBA. Except for the period between 2:00 and 3:00 a.m., the sound levels were highly correlated with wind speed.

We conducted further regression analyses to determine which method achieved the best fit to the modeled data. The results are shown in Figures 6 and 7. Starting with Figure 6a, we found that the CONCAWE meteorology combined with spectral ground attenuation had a coefficient close to 1.0 and, on average, underestimated sound levels by only 1%. The CONCAWE meteorology along with the nonspectral ground attenuation consistently overestimated monitored sound levels. The ISO meteorology with nonspectral ground attenuation yielded a good fit. The coefficient of 0.957 indicates that average modeled levels underestimated monitored levels by about 4%. On the opposite end of the scale, the ISO meteorology along with spectral ground attenuation and G=1 significantly underestimated modeled sound levels by an average of 13%.

Starting with Figure 7a, the CONCAWE meteorology with no ground attenuation overestimated monitored sound levels by approximately 13%, while the ISO meteorology with no ground attenuation provided the best fit of all the runs, with a coefficient of 0.9924. Finally, the ISO meteorology with spectral ground attenuation and G=0 yields moderately accurate results but overestimates by approximately 3%. All trend lines were statistically significant with probabilities greater than 99%.

Discussion and Conclusions

The results of the study indicate the modeling of wind turbines in flat and relatively porous terrain may yield results that underestimate actual sound levels when using the standard ISO 9613-2 algorithms with spectral ground attenuation and G=1. We found that the best fit between modeled and monitored sound levels for this case occurs when using ISO meteorology and no ground attenuation. The second-best model fit was with the CONCAWE adjustments for wind direction and speed along with spectral ground attenuation and G=1. Using the ISO methodology with nonspectral ground attenuation also yielded good results.

While the ISO 9613-2 methodology specifically recommends spectral ground attenuation for flat or constant-slope terrain with G=1, in this case, it underestimated the sound levels. This may be due to the height of the hub (80 m) as compared with typical noise

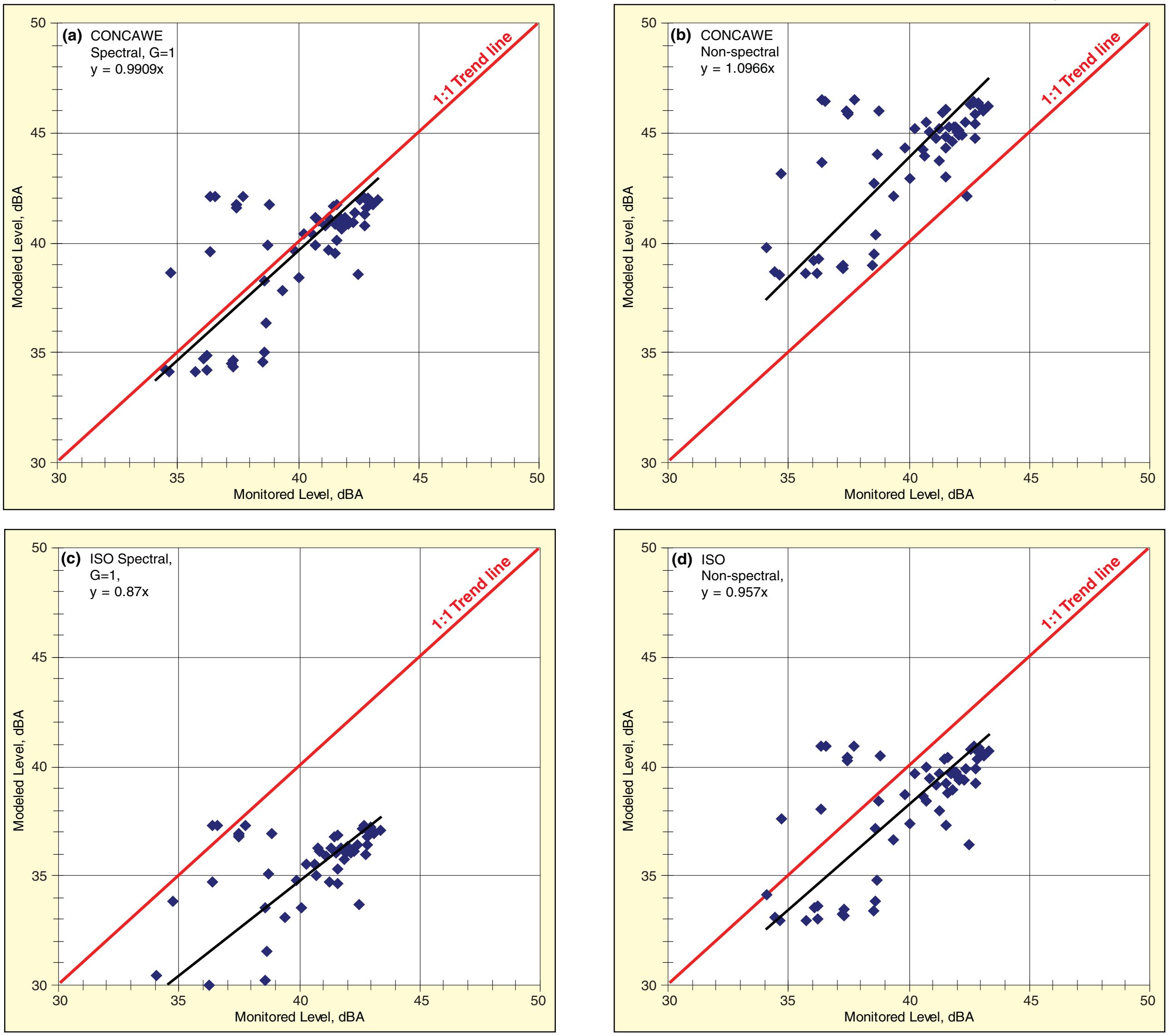

Figure 6a-d. Comparison of modeled and monitored sound levels for four meteorological and ground attenuation combinations. Regression coefficients are shown in the upper left-hand corner. Regression trendline shown in black; 1:1 trendline, indicating a match between monitored and modeled sound levels, is shown in red. N = 60.

sources. That is, the sound waves may not significantly interact with the ground over that distance. It may also be due to the fact that sound from wind turbines comes not from a single point – we assumed a single point at hub height – but is more likely to be similar to a circular area source. Finally, wind turbines often operate with wind speeds that are higher than ISO 9613-2 recommends. The combination of higher wind speeds and an elevated noise source may result in greater downward refraction.

To be more representative, a larger dataset should be obtained. Some improvements to the methodology and study would include:

- Improved accounting for background sound levels.
- Measurements of ground impedance so that the ISO 9613-2 G factor can be better estimated.
- Monitoring over a larger range of wind speeds.
- Using ground boards for the measurement microphone to minimize self-induced wind noise.
- Using larger wind screens.
- Measuring at distances greater than 610 m.
- Applying the methodology to other ground types and terrain.

Care should be taken in applying this methodology in other projects that are not similar. Overall, the ISO 9613-2 methodology is appropriate for propagation modeling of wind turbines, but modeling parameters should be adjusted appropriately to account for this source's unique characteristics.

Acknowledgments

We acknowledge gratefully the project sponsor, Iberdrola, its project manager, Krista Jo Gordon, and the wind farm operator, enXco, for funding and cooperation. We also thank all those who attended Noise-Con 2007 and Acoustics '08 who provided valuable feedback on our methodology and many suggestions for further study.

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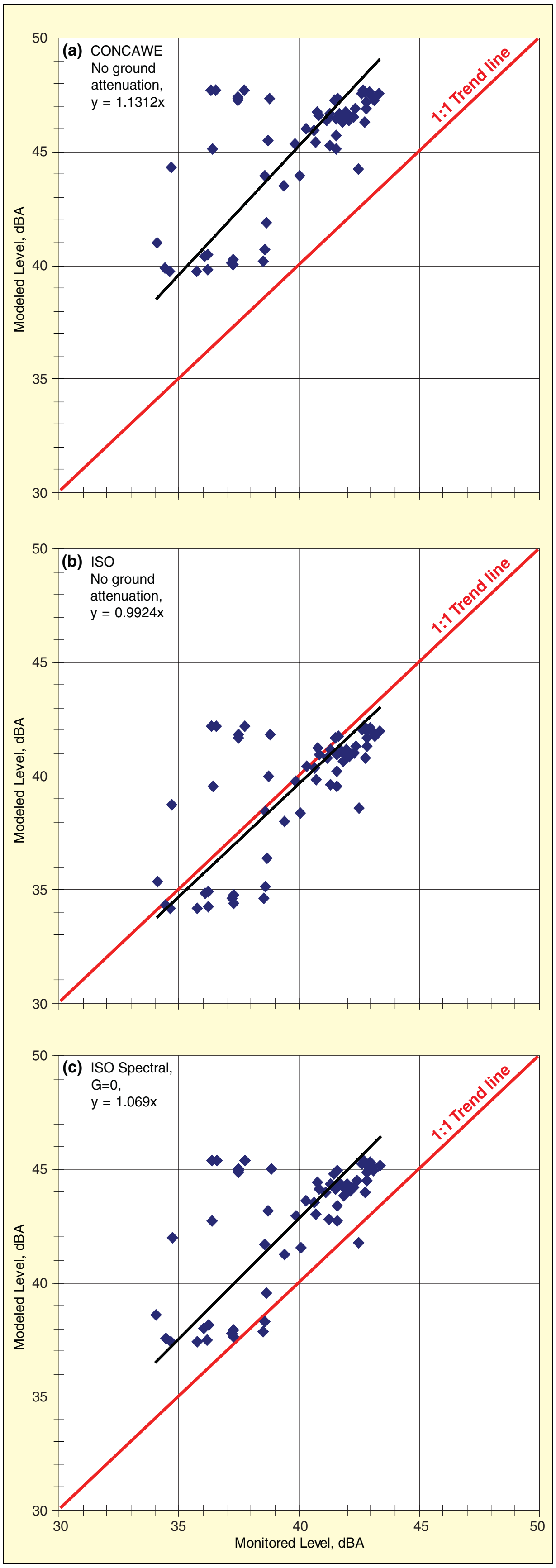

Figure 7a-c. Comparison of modeled and monitored sound levels for three meteorological and ground attenuation combinations. Regression coefficients shown in upper left-hand corner. Regression trend line shown in black; 1:1 trend line, indicating a match between monitored and modeled sound levels, is shown in red. N = 60.

2012

Wind Energy & Wind Park Siting and Zoning Best Practices and Guidance for States

NARUC Grants & Research

NARUC

January 2012

The National Association of Regulatory Utility Commissioners

A report for the Minnesota Public Utilities Commission Funded by the U.S. Department of Energy

The report you are reading was created under the State Electricity Regulators Capacity Assistance and Training (SERCAT) program, a project of the National Association of Regulatory Utility Commissioners (NARUC) Grants & Research Department. This material is based upon work supported by the Department of Energy under Award Number DE-OE0000123.

The report was authored by Tom Stanton. Throughout the preparation process, the members of NARUC provided the author(s) with editorial comments and suggestions. However, the views and opinions expressed herein are strictly those of the author(s) and may not necessarily agree with positions of NARUC or those of the U.S. Department of Energy.

Special thanks to the Commissioners and staff at the Minnesota Public Utilities Commission for guiding this work, and to the Office of Electricity Delivery and Energy Reliability and the National Energy Technology Lab for their continued technical assistance to NARUC.

Please direct questions regarding this report to Miles Keogh, NARUC's Director of Grants & Research, mkeogh@naruc.org; (202) 898-2200.

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National Regulatory Research Institute

Put It There! – Wind Energy & Wind-Park Siting and Zoning Best Practices and Guidance for States

Tom Stanton
Principal for Electricity

January 2012
12-03

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Acknowledgments

This material is based upon work supported by the Department of Energy, National Energy Technology Laboratory under Award Number(s) DE-OE0000123.

This paper results from a National Association of Regulatory Utility Commissioners (NARUC) grant for State Electricity Regulators Capacity Assistance and Training (SERCAT). Funding for the NARUC SERCAT program is provided under a cooperative agreement between NARUC and the U.S. Department of Energy (DOE) and National Energy Technology Laboratory (NETL). NRRI is grateful to NARUC, the DOE, and NETL for supporting SERCAT and this project.

The author wishes to thank these colleagues from the National Regulatory Research Institute. Without their assistance, this project would not have been possible.

- **Deborah Luyo**, Research Assistant, assiduously obtained, edited, and verified current information for the survey of wind siting and zoning practices presented in Appendix A and helped check the accuracy of the summary of the state surveys reported in Part II.
- **Leah Goodwin** supported this project with her expert editing and desktop-publishing skills.

In addition to those colleagues from NRRI, I wish to thank:

- **Tricia DeBleeckere**, staff at the Minnesota Public Utilities Commission, for her continuing consultation.
- **Ben Hoen** from Lawrence Berkeley National Laboratory, for his careful reading and helpful suggestions.
- **James McElfish** of the Environmental Law Institute, whose 2011 report, *State Enabling Legislation for Commercial-Scale Wind Power Siting and the Local Government Role,* was an important resource for understanding practices in the states, and for helping us to correct several errors in our initial survey work.
- **Charles McKeown** of Michigan State University, **Martin ("Mike") Pasqualetti** of Arizona State University, and **Roopali Phadke** of Macalester College, who generously shared reference materials and provided encouragement for this work.
- **Victoria Pebbles** and the staff and my colleagues who participate in the Great Lakes Wind Collaborative, whose excellent work in summarizing practices in the Great Lakes states (and the neighboring Canadian provinces of Ontario and Quebec) and important *Best Practices* guidebook helped inform this project.
- My colleagues who participate in Michigan's **State Wind Outreach Team** (SWOT), for their ongoing efforts to provide the best available information and educate the Michigan public, including me, about wind energy technology, policy, and implementation.
- **Paul Gipe**, keeper of the website www.wind-works.org, for his long-standing diligence in indexing news items and sharing references about wind energy.

Any inaccuracies, mistakes, or omissions are my responsibility. Comments, corrections, editorial guidance, and new information to update this report and the survey results are welcome. Comments can be submitted to:

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Executive Summary

Siting and zoning of new utility-scale wind energy facilities (called "wind parks" in this report) can be complicated and is often contentious, due to local opposition. Citizens are frequently worried about the changes to the landscape that will occur if utility-scale wind turbines are sited nearby. Such wind turbines are tall, rather imposing structures. Their construction often represents a significant change to what were previously open rural and agricultural landscapes.

Wind siting and zoning are influenced by preexisting laws and administrative rules, renewable energy support policies, and public acceptance. But often, planning and zoning officials with no previous expertise in wind energy systems have to develop the rules and regulations that will ultimately guide local wind power siting and zoning decisions. Those rules then, for better or worse, directly affect the planning, design, development, construction, and operations of wind parks.

Development of wind parks in areas with promising wind resources is economically favorable when compared with other types of renewable energy sources. In part because 37 states have adopted policies that set either mandates or goals for increasing the use of renewable energy, wind-park development in the U.S. has been growing steadily. The growth continues, despite controversy in specific jurisdictions. By late 2011, the U.S. had 42,432 MW of installed wind energy capacity and 14 states had more than 1,000 MW each.

This report summarizes the wind energy siting and zoning practices in all 50 states and the District of Columbia. Part I briefly reviews the current status of wind energy development in the U.S.

Part I.A reports on a survey conducted of each state's wind energy siting and zoning practices. The completed surveys are presented in Appendix A. Table ES-1 (pp. ES-3–7) summarizes the survey data. Specific data reviewed and reported in Part I.A includes:

- What agencies have responsibility for wind siting and zoning decisions, and are they state or local government agencies, or both?

Summary data is shown in Table ES-1, columns 3, 4, and 5. The primary decision-making authority, as reported in column 3, resides with local governments in 26 states and state governments in 22 states. Florida and Iowa have shared local and state responsibility. Column 4 includes a "(P)" to indicate that a state agency has primary siting authority. Many states have a clearly defined secondary authority, as indicated by "(S)" in Column 4. In six states plus the District of Columbia the public utility commission (generically, the PUC) is responsible for siting and zoning utility-owned wind parks. Altogether, 23 states and the District of Columbia require a certificate to be issued by the PUC prior to wind park construction. Eleven other states, indicated with a "Y" in column 5, have an energy facility siting authority that is separate from the PUC. Data reported in columns 3 or 4 reports if the state-level jurisdiction is contingent upon the size of the wind park.

- Which overriding rule, established by the state's constitution, governs the division between state and local government jurisdiction in the state? Is it "Home Rule," where local governments retain all decision-making authority except that explicitly granted to the state? Or is it "Dillon's Rule," where the state government retains all decision-making authority except that explicitly granted to the local governments?

That data is reported in Table ES-1, column 6. A general expectation might be that Home Rule states would tend to have local authority and Dillon's Rule states would tend to have state authority for wind siting and zoning. In practice, though, Home Rule states are evenly split in terms of local versus state authority, but more Dillon's Rule states (20 of 31) have already delegated wind siting and zoning authority to local units of government.

- How many and which states have developed mandatory evaluation criteria, voluntary guidelines, model ordinances, and setback or sound standards for wind parks? How many local governments in each state have already adopted wind siting and zoning ordinances?

These data are shown in Table ES-1, columns 7 through 12. Slightly more than half the states have published lists of the criteria that are used to evaluate wind siting and zoning conditions. Ten states have published voluntary guidelines for wind parks. Table ES-2 (p. ES-8) reports on the major factors included in each state's guidelines.

Five states, labeled "Y" in Table ES-1, column 9, have published model ordinances intended to guide local governments. As shown in Table ES-1, columns 10 and 11, a handful of states have published setback standards, sound standards, or both. Both of these columns differentiate between mandatory standards, indicated as "Y," and recommended or advisory standards for local government consideration, indicated as "Model." Table ES-1, column 12, reports the number of local ordinances that have been discovered and included in a database being assembled by the National Renewable Energy Laboratory.

- How many and which states have supporting policies, such as clean energy portfolio standards and goals, policies promoting the development of in-state wind energy facilities, and renewable energy zones?

These data are shown in Table ES-1, columns 13, 14, and 15. As shown in column 13, 29 states and the District of Columbia have renewable energy portfolio standard (RPS) mandates (M), and eight states have renewable energy goals (G). Of those 37 states with RPS mandates or goals, 29 have enacted policies that are specifically intended to promote the development of in-state renewable resources, including wind parks. Those policies are encoded with one, two, or three letter codes. In column 14: "B" means a "bonus" credit for at least some in-state facilities; "D" means electricity must be delivered into the state (or "DR" means delivered into the region) in order to qualify as eligible to count for RPS compliance; "L" means a maximum limit on energy from out-of-state facilities or conversely a minimum limit (often called a "carve-out") on energy from particular kinds of in-state resources; "M" means a mandate for in-state generators; "R" means a mandate for regional generators (usually, in the territory served by a regional transmission organization, RTO); "S" means qualifying facilities must be in the service territory of a utility providing retail service in the state; and "U" means a mandate for a utility serving the state to own or contract for the qualifying renewable energy.

Another policy that indirectly supports wind-park siting and zoning is the development of renewable energy zones. This is reported in Table ES-1, column 15. Typically, a renewable energy zone (REZ) is identified through a planning process that includes a general review of wind resources and broad-based, regional land-use compatibility with wind-park development, combined with electric transmission system modeling and planning. In most REZ processes, once specific zones are identified, transmission will be built to interconnect the zone to electricity loads, in anticipation that wind-park development will follow. States with explicit state-level REZ processes include California, Colorado, Michigan, and Texas. These are indicated with a "Y" in column 15. Many other states and utilities are participating in REZ-like transmission modeling and planning under the auspices of regional transmission organizations. These include the Midwest Independent [Transmission] System Operator Regional Generation Outlet Studies (RGOS), and the Western Renewable Energy Zone (WREZ) initiative.

Table ES-1: Summary of State Wind Siting and Zoning Practices

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
State	**MW Installed**[1]	**Primary Authority (Limit)**[2]	**Primary (P) or Secondary (S) State Authority**	**State Energy Siting**[4]	**Primary Rule**[3]	**Evaluation Criteria**[5]	**Voluntary Guidelines**[5]	**Model Ordinance**	**Setback Standard**[6]	**Sound Standard**[6]	**Local Ordinances**[7]	**RPS**[8]	**RPS In-State "Tilt"**[9]	**REZ**[10]
Alabama	0	State	CPCN from PSC (P)		Dillon's									
Alaska	10	State	CPCN from RCA (P)		Home						1			
Arizona	128	Local			Dillon's	Y	W				1	M	BD	WREZ
Arkansas	0	Local	CPCN from PSC (S)		Home									
California	3,599	Local	California Environmental Quality Act (S)		Dillon's	Y					6	M	L	Y, WREZ
Colorado	1,299	Local	CPCN from PUC (>2MW) (S), PUC consults with Division of Wildlife (S)		Dillon's	Y						M	BL	Y, WREZ
Connecticut	0	State (>1 MW)	CECPN from Siting Council (>1 MW) (P), DEEP checks congruence with IRP (S)	Y	Home	Y						M	LR	
Delaware	2	Local	Certification from PSC (S)		Dillon's	Y			Y	Y		M	B	
District of Columbia	0	PUC	Approval from PSC (P)		n/a							M	DL	
Florida	0	State (<75MW)	DOT, FAW (<75MW) (P)	Y[12]		Y								
Georgia	0	Local			Dillon's		YW	Y	Model	Model				
Hawaii	93	Local	Permit from PUC (S)		Dillon's							M	M	
Idaho	471	Local			Dillon's						1			WREZ
Illinois	2,436	Local	DNR (S)		Home						5	M	LR	RGOS
Indiana	1,339	Local	CON from URC (S)		Home						13	G	L	RGOS

[1] See all table notes at the end of the table, on page ES-7. See Appendix A for more detailed information about each state's practices.

Table ES-1 (Continued): Summary of State Wind Siting and Zoning Practices

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
State	**MW Installed**[1]	**Primary Authority (Limit)**[2]	**Primary (P) or Secondary (S) State Authority**	**State Energy Siting**[4]	**Primary Rule**[3]	**Evaluation Criteria**[5]	**Voluntary Guidelines**[5]	**Model Ordinance**	**Setback Standard**[6]	**Sound Standard**[6]	**Local Ordinances**[7]	**RPS**[8]	**RPS In-State "Tilt"**[9]	**REZ**[10]
Iowa	3,675	Both (>25MW)	Certification from Iowa Utilities Board (>25MW)		Home	Y					5	M	U	RGOS
Kansas	1,074	Local			Dillon's		YW				3	M	B	
Kentucky	0	State	Siting Board Approval (>10MW) (P)		Dillon's									RGOS
Louisiana	0	Local	Permit from DEQ (S)		Dillon's									
Maine	266	State (>20 acres)[13]	Permit from DEP (>20 acres) (P), Permit from LURC (for "unorganized" areas)[13] (P)		Dillon's	Y					8	M	BL	
Maryland	120	State (≥70MW)	CPCN from PSC (≥70MW) (P), 7 state agencies notified (S)	Y	Dillon's	Y	W				15	M	LR	
Massachusetts	38	State (≥100MW)	Permit from Energy Facilities Siting Board (≥100MW) (P)		Home	Y		Y	Model	Model	2	M	L	
Michigan	164	Local	PSC checks utility-owned and PPA projects for compliance with a utility's renewable energy plans (S)	Y	Home		Y	Y			11	M	BS	Y, RGOS
Minnesota	2,518	State (>5MW)	Permit from PUC (>5MW) (P)		Dillon's	Y		Y		Y	2	M		RGOS
Mississippi	0	State	CPCN from PUC (P)		Dillon's									
Missouri	459	Local			Dillon's						1	M		RGOS
Montana	386	Local			Home	Y						M	D	RGOS, WREZ

Table ES-1 (Continued): Summary of State Wind Siting and Zoning Practices

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
State	**MW Installed**[1]	**Primary Authority (Limit)**[2]	**Primary (P) or Secondary (S) State Authority**	**State Energy Siting**[4]	**Primary Rule**[3]	**Evaluation Criteria**[5]	**Voluntary Guidelines**[5]	**Model Ordinance**	**Setback Standard**[6]	**Sound Standard**[6]	**Local Ordinances**[7]	**RPS**[8]	**RPS In-State "Tilt"**[9]	**REZ**[10]
Nebraska	294	State (>80MW)[12]	Approval from Nebraska Power Review Board (>80MW)[12] (P)		Dillon's	Y					4			
Nevada	0	Local	Permit from PUC (≥70MW) (S)	Y	Dillon's							M		Y, WREZ
New Hampshire	26	State (≥30 MW)	COSF from Site Evaluation Committee (≥30MW) (P)		Dillon's	Y						M	DR	
New Jersey	8	Both	Interconnection authority falls to PJM RTO (S) (see New Jersey survey)	Y	Home	Y					10	M	DLR	
New Mexico	700	State (>300MW)	CPCN from PRC (P)		Home	Y	W					M		WREZ
New York	1,349	Local	CPCN from PUC (>25MW) (S)		Dillon's	Y	YW	Y	Model	Model	1	M	L	
North Carolina	0	Local	CPCN from NCUC (S)		Dillon's	Y		Y			9	M	L	
North Dakota	1,424	State (>0.5MW)	CSC from PSC (P), 21 State Agencies notified (S)		Dillon's	Y					3	G		RGOS
Ohio	67	State (≥5MW)	CECPN from Power Siting Board (≥5MW) (P)		Home	Y						M		RGOS
Oklahoma	1,482	Local		Y	Dillon's							G	M	
Oregon	2,305	State (>105MW)	Certification from Energy Facility Siting Council (>105MW) (P)		Home	Y					1	M	BR	GBS, WREZ
Pennsylvania	751	Local		Y	Dillon's	Y		Y	Model	Model	4	M	LR	
Rhode Island	2	State (≥40 MW)	Approval from Energy Facility Siting Board (≥40 MW) (P)		Home	Y	Y		Y	Y		M		

Table ES-1 (Continued): Summary of State Wind Siting and Zoning Practices

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
State	**MW Installed**[1]	**Primary Authority (Limit)**[2]	**Primary (P) or Secondary (S) State Authority**	**State Energy Siting**[4]	**Primary Rule**[3]	**Evaluation Criteria**[5]	**Voluntary Guidelines**[5]	**Model Ordinance**	**Setback Standard**[6]	**Sound Standard**[6]	**Local Ordinances**[7]	**RPS**[8]	**RPS In-State "Tilt"**[9]	**REZ**[10]
South Carolina	0	State (>75MW)	CPCN from PSC (>75MW) (P)	Y	Dillon's									
South Dakota	784	Local	Permit from PUC (>100 MW) (S)	Y	Dillon's	Y	Y	Y	Y		4	G		RGOS
Tennessee	29	Local			Dillon's									
Texas	10,135	Local	Projects must register with PUC (S)		Dillon's				Model	Model	2	M	M	Y
Utah	325	Local	CCN from PSC (S)		Home	Y		Y	Model	Model	3	G	R	Y, WREZ
Vermont	6	State	COPG from PSB (P)		Dillon's		Y					G	M	
Virginia	0	Local	Permit from DEQ ≤100 MW (S), SCC >100 MW (S)		Dillon's			Y	Y	Y	3	G		
Washington	2,356	State (>350MW)	Site Certification Agreement from Energy Facility Site Evaluation Council (>350MW) (P)		Dillon's	W						M	DR	GBS, WREZ
West Virginia	431	State	CPCN from PSC (P)	Y	Dillon's							G	BR	
Wisconsin	469	Local	CPCN from PSC (>100MW) (S)		Dillon's			Y[10]			4	M	D	RGOS
Wyoming	1,412	State (±30 turbines)	Permit from Industrial Siting Council (±30 turbines) (P)		Dillon's	Y			Y					WREZ

Table ES-1 (Continued): Summary of State Wind Siting and Zoning Practices

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
State	**MW Installed**[1]	**Primary Authority (Limit)**[2]	**Primary (P) or Secondary (S) State Authority**	**State Energy Siting**[4]	**Primary Rule**[3]	**Evaluation Criteria**[5]	**Voluntary Guidelines**[5]	**Model Ordinance**	**Setback Standard**[6]	**Sound Standard**[6]	**Local Ordinances**[7]	**RPS**[8]	**RPS In-State "Tilt"**[9]	**REZ**[10]

Table Notes: See also the individual survey reports for each state, presented in alphabetical order by state name, in Appendix A.

[1] Source data for Column 2 is Figure 1 (p. 3).

[2] Column 3 indicates "Local" when the primary siting authority rests with the local (county or municipal) government or "State" when primary authority is with the state. Any "Limit" means that a wind-park size criterion (number of turbines in Wyoming, acres in Maine, or capacity – number of MW – in 14 states) determines jurisdiction. In those circumstances, wind parks larger than the expressed limit trigger state authority. "Both" applies to Iowa and New Jersey, where siting authority is held by both the state and local units of government.

[3] Column 5: "Y" for yes indicates there is a state energy facility siting council or board separate from the state public utility commission.

[4] Column 6 distinguishes between "Home Rule" states and "Dillon's Rule" states. See p. 10 for the discussion.

[5] Columns 7 and 8: "Y" means yes, the state does have mandatory evaluation criteria (Column 7) or voluntary guidelines (Column 8). A "W" in either column means primarily or exclusively for wildlife. States with both Y and W in either column means multiple documents exist, one focused explicitly on wildlife.

[6] Columns 10 and 11: "Y" indicates that standards are included in evaluation criteria. "Model" means that criteria are included in a model ordinance.

[7] Column 12: The number in Column 12 represents the ordinances included in a database being assembled by the National Renewable Energy Laboratory, available from http://www.windpoweringamerica.gov/policy/ordinances.asp, retrieved 22 Dec 2011.

[8] Column 13: "M" means the state has a mandatory renewable energy portfolio standard. "G" means the state has a voluntary goal for renewable energy. See Database of State Incentives for Renewables & Efficiency, 2011, *Portfolio Standards/Set Asides for Renewable Energy* [web page] and *RPS Policies* [map], http://www.dsireusa.org/incentives/index.cfm?SearchType=RPS&&EE=0&RE=1, retrieved 22 Dec 2011.

[9] Column 14: Many state RPS programs include provisions to promote in-state renewable energy facilities, such as wind parks. A recent NRRI Report (Grace, Donovan, & Melnick, 2011) calls this a "tilt" policy (intended to tilt the playing field towards certain technologies). In Column 14: "B" means a "bonus" credit for at least some in-state facilities; "D" means electricity must be delivered into the state (or "DR" means delivered into the region) in order to qualify; "L" means a maximum limit on energy from out-of-state facilities or conversely a minimum limit on energy from particular kinds of in-state resources; "M" means a mandate for in-state generators; "R" means a mandate for regional generators; "S" means qualifying facilities must be in the service territory of a utility providing retail service in the state; and "U" means a mandate for a utility serving the state to own or contract for the qualifying renewable energy. Source: Database of State Incentives for Renewables & Efficiency, 2011, http://www.dsireusa.org/incentives/index.cfm?SearchType=RPS&&EE=0&RE=1, retrieved 5 Jan 2012.

[10] Column 15: REZ means Renewable Energy Zone(s). Coding indicates "Y" if there is a specific state process for determining zones (in Texas, Colorado, Utah, Michigan, and Nevada). Other codes include: "WREZ" for the Western Renewable Energy Zones process for 5 states); "RGOS" for the Regional Generation Outlet Study process at the Midwestern Independent [Transmission] System Operator (MISO) for parts or all of 12 states; "GBS" for the Gorge Bi-State Renewable Energy Zone, which includes six counties near the Columbia River in both Oregon and Washington.

[11] Wisconsin's Model Ordinance applies only for small wind systems, <100kW in capacity.

[12] Nebraska's >80MW limit applies only if the planned capacity would cause the utility's total renewable energy production to exceed the company's goal.

[13] Maine's state authority applies if the proposed wind park involves more than 20 acres of land, or if the wind park will be sited in an "unorganized" area.

Table ES-2: Factors Included in State Wind Siting and Zoning Guidelines

State	Wildlife	Aesthetics	Birds	Bats	Noise	Setbacks	Mitigation	Decommissioning
Arizona	Y							
Georgia	Y	Y	Y	Y	Y			
Kansas	Y	Y	Y				Y	Y
Maryland	Y		Y	Y				
Michigan	Y	Y	Y	Y	Y	Y	Y	Y
New Mexico	Y		Y	Y				
New York	Y	Y	Y		Y	Y		Y
Rhode Island					Y	Y		
South Dakota	Y				Y	Y		Y
Vermont	Y		Y	Y				

Part I.B briefly reviews the nature of wind-park opposition and lists the major concerns that are usually raised. When engaging in siting and zoning procedures, anti-wind groups and individuals arm themselves with information obtained from anti-wind web sites. Examples include AWEO (www.aweo.org), Industrial Wind Action Group (www.windaction.org), and National Wind Watch (www.wind-watch.org).[1]

Ubiquitous internet access among local activists facilitates the dissemination of anti-wind documents and thereby tends to focus all local anti-wind groups on the same basic issues and concerns. Table ES-3 summarizes many of the objections raised by opposition groups. In Table ES-3, *italic font* denotes recommendations for the role that each set of objections ought to play in siting and zoning decisions.

Part II summarizes best practices for the procedures used to manage wind energy siting and zoning. The report recognizes that best practices are subject to refinement over time, as more knowledge is gained and as wind generator technologies change and improve. These recommendations are based on data reported from the survey of state policies and procedures, literature review, and the knowledge and experience of the author. The recommendations are summarized in Table ES-4.

Part III presents guidelines for wind power development, including recommended approaches to critical issues: noise; shadow flicker; ice throw; wildlife; aesthetics; competing land uses; permit requirements for meteorological (met) towers, construction, and facility safety; and decommissioning. Table ES-5 summarizes recommended approaches towards and applying setback distances in response to each of those major criteria.

[1] Website home pages retrieved 12 Dec 2011.

Table ES-3: Typology of Anti-Wind Park Arguments

Topics and Subtopics	Example of anti-wind characterization. *Siting and Zoning Relevance.*
Human Health, Nuisance, and Annoyance Factors Noise Infrasound Shadow flicker	"[W]ind farms produce a noise that's hard to comprehend and even more dangerous to live close to. The beating of the blades have not only their own throbbing sounds, but beat harmonically together to create a cacophony of audible confusion…" (Brougher, 2008). "[B]ased on our knowledge of the harmful effects of noise on children's health and the growing body of evidence to suggest the potential harmful effects of industrial wind turbine noise, it is strongly urged that further studies be conducted…before forging ahead in siting industrial wind turbines." (Bronzaft, 2011). "Dizziness (specifically, vertigo) and anxiety are neurologically linked phenomena. Hence the anxiety and depression seen in association with other symptoms near wind installations are not a neurotic response to symptoms, but rather a neurologically linked response to the balance disturbances people experience from shadow flicker or low-frequency noise... . Based on these health effects and hazards, turbines should not be placed within 1700 feet of any road or dwelling. Those living within 1/2 mile (2640 ft) should be apprised that they are likely to experience very bothersome levels of noise and flicker, which continue (though to a lesser degree) to a mile or more from the turbines." (Pierpont, 2005). *Windparks should not be singled out for special noise criteria. Siting and zoning can apply noise criteria, but noise limits should apply equally to all sources. Separate consideration should be given to construction noise.* *It is a simple matter to calculate the precise locations and maximum annual duration of shadow-flicker effects. A siting standard can limit shadow flicker.* *Both noise and shadow-flicker complaints can be amenable to mitigation, and an escrow account subject to independent management by an objective, disinterested arbitrator can be established for this purpose.* *Neighbors should have the right to waive noise and shadow-flicker standards.*
Safety Ice-throw Blade failure Tower failure	"The bottom line is that ice, debris or anything breaking off the wind turbine blades (including the blades themselves) can impact a point almost 1,700 feet away from the base of the turbine" (Matilsky, 2011). "Especially in the mountainous sites or in the northern areas icing may occur frequently and any exposed structure – also wind turbines – will be covered by ice under special meteorological conditions. This is also true if today's Multi Megawatt turbines with heights from ground to the top rotor blade tip of more than 150 m can easily reach lower clouds with supercooled rain in the cold season, causing icing if it hits the leading edge." (Siefert, Westerhellweg, & Kroning, 2003). "[W]ind turbines are being whipsawed and hammered to pieces constantly, and the public is not being made aware of this real and present danger, for fear there will be a grass-roots uprising against it before they are saddled with [wind parks] and don't have any more say-so in the matter." (Brougher, 2008). *Tower failure for utility-scale turbines is characterized by vertical collapse (like a beverage can crushing when stepped on), rather than tipping over from the base. Tower construction standards should guide setback distances, rather than the remote possibility of tower tip-over.* *Ice throw and blade failure resulting in parts hurtling through the air are increasingly rare. Modern turbines are continuously monitored in real time and will shut themselves down if ice accumulates on blades. Ice shedding is thus almost exclusively limited to the zone directly underneath the turbine.*

Table ES-3 (Continued): Typology of Anti-Wind Park Arguments

Topics and Subtopics	Example of anti-wind characterization. *Siting and Zoning Relevance.*
Safety (continued) Ice-throw Blade failure Tower failure	*Setback distances of 1.5 times turbine height (tower plus blade) should be considered maximal. Neighbors should have the right to waive setback distances from "participating" buildings and property lines. Wind-park owners (and insurers) should be liable for damages caused by ice throw, blade failure, and tower failure. An escrow account should cover potential liability and decommissioning costs.*
Property Values Visual amenity Sense of place, of community Industrial appearance Tourism impacts	"The days on market was more than double for those properties inside the windmill zones. The sold price was on average $48,000 lower inside the windmill zones than those outside. The number of homes not absorbed (not sold) was 11% vs. 3%." (Luxemburger, n.d.). "There are people who can't sell their homes and are forced to rent other living accommodation and people who sell their homes to the wind energy companies at much reduced prices and then are 'gagged' from talking about any of the negative health effects" (Chevalier, n.d.). "The degradation these enormous sprawling industrial complexes bring to our cultural and visual resources is least understood. Our colleagues… describe West Texas today as an alien landscape where one can drive for miles and miles and miles (and miles) and see nothing but wind turbines. The nighttime experience is even more surreal with the blinking red lights." (Industrial Wind Action Group, 2005). *An escrow account should cover potential liability and decommissioning costs.*
Wildlife and Natural Features Avian mortality (birds and bats) Habitat destruction, fragmentation	"Where'd all the animals go? My guess is as far away from those things as they can get." (Brougher, 2008). "Save the Eagles International wishes to warn the international community about the threat that windfarms and their power lines represent for biodiversity. Unlike cars, buildings, and domestic cats, wind turbine blades and high tension lines often kill protected or endangered birds like eagles, cranes, storks, etc. Cumulatively and over the long term, 3.5 million wind turbines to be installed worldwide will cause the extinction of many bird species, some of them emblematic." (Duchamp, 2011). *Exclusion zones should be identified in concert with state and federal wildlife agencies based on the best available scientific information and pre- and post-construction monitoring. Mitigation measures should be identified and included in siting stipulations. Mitigation funds should be included in escrow accounts as necessary to ensure compliance.*
Energy Policy Capacity factor Emissions effects Integration costs Reliability	"The erratic nature of the wind means that turbines simply cannot supply the base load that other forms of generation do. Those other generators will continue to be needed to back up the wildly variable output of wind turbines, with the probability that in so doing these plants will actually emit more pollution for each kilowatt-hour they generate than if they were allowed to operate normally." (Roberson, 2004). "[S]ome reliable, dispatchable generating unit(s) must be immediately available at all times -- and operating at less than peak efficiency and capacity -- to "back up" the unreliable wind generation. The reliable, backup unit(s) must ramp up and down to balance the output from the wind turbines. … Wind turbines have virtually no 'capacity value.' Thus, electric customers pay twice: once for the wind energy and again for reliable capacity." (Schleede, 2005).

Table ES-3 (Continued): Typology of Anti-Wind Park Arguments

Topics and Subtopics	Example of anti-wind characterization. *Siting and Zoning Relevance.*
Energy Policy (continued) Capacity factor Emissions effects Integration costs Reliability	"Peak power… during the hottest summer months… [is] far more demanding on the power grid, yet the wind power available in the winter months… is on average greater than in the summer. That's a huge contradiction… . Nor can we store wind power… . So for the most part, winter winds and spring storms must either be wasted, or they will create surges which blow out the transformers, power equipment, and burn up their own generators, and set the grid back hundreds of millions of dollars, as has happened by wind surges in Oregon, and many times in Denmark, Germany, and other nations… ." (Brougher, 2008). "In high winds, ironically, the turbines must be stopped because they are easily damaged." (Brougher, 2008). "A nuclear plant is tens of times cheaper and thousands of times safer per [terawatt-hour] than gigantic air turbines will ever be – even if we learn someday how to prevent them from burning up, blowing the grid, and folding in half under a high wind load, and blending our birds with the landscape." (Brougher, 2008). *The only relevance to siting and zoning might be for substations and transmission facilities, which also need approvals. None of these other issues are siting and zoning issues, per se.*
Economic Development Subsidies Employment	"Tax avoidance – not environmental and energy benefits – has become the prime motivation for building 'wind farms.' … 'Wind farms' produce few local economic benefits and such benefits are overwhelmed by the higher costs imposed on electric customers through their monthly bills. … When the expected contribution of wind energy toward supplying US energy requirements is taken into account, wind energy is among the most heavily subsidized of all energy sources." (Schleede, 2005). "[I]nvestment dollars going to "renewable" energy sources would otherwise be available… for other purposes that would produce greater economic benefits. 'Wind farms' have very high capital costs and relatively low operating costs compared to generating units using traditional energy sources. They also create far fewer jobs, particularly long-term jobs, and far fewer local economic benefits. 'Wind farms' are simply a poor choice if the goals are to create jobs, add local economic benefits, or hold down electric bills." (Schleede, 2011). "[B]illions of [federal grant] dollars… – all of it exempt from federal corporate income taxes – is being used to fatten the profits of some of the world's biggest companies" (Bryce, 2011). *These are not relevant siting and zoning concerns.*

Table ES-4: Best Practices for Procedures

Recommendation	Description
1. Develop procedures that result in clarity, predictability, and transparency	Jurisdictions with locations suitable for commercial wind development should anticipate interest and proceed to develop and publish siting and zoning procedures, principles, and guidelines.
2. Establish a one-stop, pre-submission consultation	Provide basic information for applicants in a single meeting, identifying and explaining the basics of all necessary permits and approvals.
3. Identify and map constrained and preferred wind energy development zones	Make available and accessible to the interested public GIS maps of exclusion, avoidance, and preferred development zones.
4. Include preferred development zones in transmission plans	Begin modeling and planning for wind power interconnections in preferred development zones as soon as the zones are identified.
5. Prepare and make available guidelines for participants	Explain procedures and timelines for when, where, and how to participate in public hearings. Provide information about decisions already completed through rulemaking.
6. Prepare and make available for local siting and zoning officials guidelines, checklists, and model ordinances	Support local government decision makers by providing the best available technical resources.
7. Ensure the sequence for obtaining permits and approvals meets requirements to allow development of suitable projects	The sequence of events leading to approval or rejection of an application should entail a logical progression through the planning and design stages, prior to siting and zoning approval that allows construction to begin.

Table ES-5: Wind-Park Siting and Zoning Criteria, Recommended Approaches and Setback Distances

Criterion	Recommended approach
Noise, sound, and infrasound	• Noise standards should allow some flexibility. • Noise standards should vary depending on the area's existing and expected land uses, taking into account the noise sensitivity of different areas (e.g., agricultural, commercial, industrial, residential). • Determine pre-construction compliance using turbine manufacturer's data and best available sound modeling practices. • Apply a planning guideline of 40 dBA as an ideal design goal and 45 dBA as an appropriate regulatory limit (following Hessler's proposed approach, 2011). • Allow participating land owners to waive noise limits. • Establish required procedures for complaint handling. • Identify circumstances that will trigger, and techniques to be used for: (a) mandatory sound monitoring; (b) arbitration; and (c) mitigation. • Do not regulate setback distance; regulate sound.
Shadow flicker	• Restrict to not more than 30 hours per year or 30 minutes per day at occupied buildings. • Allow participating land owners to waive shadow-flicker limits. • Allow the use of operational practices and mitigation options for compliance. • Do not regulate setback distance; regulate the duration of shadow flicker.

Table ES-5 (Continued): Wind Park Siting and Zoning Criteria, Recommended Approaches and Setback Distances

Criterion	**Recommended approach**
Ice throw	• Authorize demonstrated ice control measures. • Require wind-park to provide insurance and escrow funds to ensure compensation for proven damages resulting from ice throw. • Do not regulate setback distance; regulate ice throw.
Wildlife and habitat exclusion zones	• Responsible wildlife protection agencies should use the best available scientific knowledge and data to determine exclusion and avoidance zones and appropriate buffers (that is, setback distances) beyond those zones. • Permits should specify required pre-, during-, and post-construction monitoring. • Permits should specify how mitigation requirements will be determined and what mitigation techniques will be considered. • Regulate setback distances as required by responsible wildlife protection agencies and do not authorize siting in exclusion and buffer zones.
Aesthetic requirements	• Require neutral paint color and minimal signage. • Require the minimum of nighttime lighting necessary to achieve FAA compliance. • Require that realistic visual impact assessments, accessible to the public, be included in wind park planning and applications. • Manage visual impact through setbacks and exclusions from critical competing land uses.
Critical competing land uses	• Map as excluded zones any special cultural, anthropological, “sacred” lands, and highly valued scenic vistas. • Apply reasonable setbacks from non-participating property lines, occupied buildings, scenic vistas, and transportation and utility rights-of-way. • Allow participating properties to at least partially waive setback requirements from property lines and occupied buildings, in writing.
Permit requirements for met towers, construction, and facility safety	• Predetermine requirements and simplify procedures for approving meteorological (met) towers. • Regulate heavy construction requirements the same as any other heavy construction project, using the regulatory permitting system (e.g., for stormwater, surface water, transportation, noise, and wetlands permits). • Check for all required approvals for potential interference with radio and TV reception or radar. Provide for testing and mitigation of radio and TV interference problems that do occur. • Regulate structural safety (against, e.g., tower tip-over or blade failure) through construction codes, combined with minimal setback requirements. • Regulate facility safety (e.g., preventing climbing towers, ensuring electrical safety, providing fencing around electrical gear).
Decommissioning	• Set clear requirements for what triggers and what constitutes decommissioning and restoration or reclamation. • Establish a decommissioning escrow fund, to ensure adequate resources will be available at the end of a project’s useful life or in the event the development fails.
Dispute resolution and mitigation	• Establish procedures for dispute resolution and mitigation.

The report ends with a **summary and conclusions.** This part reviews important literature on wind siting and zoning and asks: (1) Is there a middle ground that does not require compromises where everyone loses? and (2) Are there opportunities for improvement in wind-park siting and zoning procedures that are most likely to lead to a more rapid accumulation of the information and wisdom needed to guide future decisions?

Among researchers studying wind-park siting, there is at least some optimism regarding finding answers to these questions. For example: Wolsink (2007a) suggests that better solutions will be found through collaborative, community-based planning; Upham (2009) proposes that solutions might be found through focused attention on the field of environmental psychology; Sovacool (2009) advises attention to a broader research agenda about both social and technical aspects of decision making; and Sengers, Raven, & Van Venrooij (2010) recommend a concentrated study of news media and the potential role of news media in public education regarding decisions about our energy future. Any and all of these paths might prove advantageous.

For the time being, the most sensible recommendation is for communities to work together to make decisions about future energy systems development, not only wind energy development, in their local area. There are multiple paths to this goal, insofar as wind energy development is concerned. Some developers work extensively with host communities, prior to seeking siting and zoning approval, to create macro- and micro-siting plans that engender little, if any, public opposition. Some land owners form associations and hire their own developers, so that the owners can directly guide decisions about setback distances and micro-siting. Some governments simultaneously develop specific plans that identify both areas where wind parks will be excluded or should be avoided and also those areas where wind parks will be welcomed. Hindmarsh (2010, p. 560) holds that making good decisions about wind turbine siting requires "collaborative approaches," including "the technical mapping of wind resources… [and] community qualifications and boundaries for wind farm location." He argues that community-based decision making is likely to result in "improved problem framing and decision making concerning wind farm location, and thus development." The goal, as Hindmarsh notes, is a process that will be perceived as legitimate and fair, and thus sustainable. Reaching that goal might be considered overly optimistic, but at least some communities have shown a willingness to give it a try. There is at least a good prospect that these approaches can reduce contentiousness and move towards consensus on how to guide wind-park siting and zoning.

Introduction

Wind-park siting and zoning present serious challenges. Modern utility-scale wind turbines are tall, rather imposing structures. Their construction often represents a significant change to what were previously open rural and agricultural landscapes. In many circumstances, modern wind turbine towers, which are roughly 25 stories tall, are by far the tallest structures being constructed in landscapes that have previously been rural and agricultural in character, containing no structures taller than silos.

Wind-park siting and zoning is frequently contentious, due to a variety of concerns regarding public acceptance and opposition. Already, wind siting and zoning cases have been heard in courts of appeals and supreme courts in multiple states.[2]

Often, officials with no previous expertise in wind energy systems have been tasked with developing the rules and regulations that ultimately guide wind power siting and zoning decisions, which then directly affect the planning, design, development, construction, and operations of wind parks.

It is axiomatic that all energy sources known today come with some unintended consequences, and perhaps also unanticipated consequences, and cause some negative side effects. Thus, the siting and zoning of any new energy facility is likely to raise concerns among potential neighbors. Local opposition groups form and try to influence siting and zoning for practically all new power plants, transmission lines, and substations. Thus, public officials who are charged with the task of recommending and making siting and zoning decisions often face competing, widely divergent views of the benefits and costs, pros and cons associated with new energy facilities. Wind generators and wind parks are a prominent example, perhaps *the* prominent example, of this local opposition phenomenon.

Is the ideal siting and zoning hearing one that has no controversy, where full consensus is reached on the part of all stakeholders? That goal can be impossible to achieve. The goal of the siting and zoning decision maker should be fact finding to support objective decision making, in keeping with the enabling siting and zoning laws and rules.

The purpose for this report is to provide guidelines about how best to manage the siting and zoning process and apply siting and zoning principles to wind-park decision making. Part II.A covers the siting and zoning process, and Part III covers recommendations about the specific criteria and principles used in making wind-park siting and zoning decisions. Applying best practices will enable policymakers to accelerate as much as practical the time requirements for siting and zoning procedures, while simultaneously helping to develop the full potential of wind energy and minimizing project risks.

This paper summarizes knowledge about the state of the art in wind-park[3] and wind-turbine siting and zoning, to support decisionmakers' efforts to develop and implement good siting and zoning practices. It draws on a survey of practices in all 50 states plus some U.S. territories and protectorates to explicate and report on current practices and principles. The survey results are presented in Appendix A.

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[2] Wind siting and zoning cases have already appeared in state supreme courts in Kansas, New York, Texas, Vermont, Washington, and West Virginia, and in state appeals courts in California, Indiana, Maryland, Minnesota and Wisconsin (Google Scholar, Advanced Scholar Search for legal opinions, retrieved 7 Dec 2011; Minnesota Appeals Court, Cases Nos. A112228 and A112229, http://macsnc.courts.state.mn.us/ctrack/publicLogin.jsp, retrieved 5 Jan 2012).

[3] In this document, the term "wind park" is used to refer to installations of multiple utility-scale wind turbines. Frequently used synonyms are "wind development," "wind farm," or "wind project." "Utility-scale" does not have any certain definition. For the purposes of this paper, "utility-scale" can be understood to mean wind generators that are typically about 1.5 megawatts (1,500 kilowatts) or larger, mounted on towers that average about 80 meters (roughly 250 feet) in height or taller.

As Ellenbogen et al. (Jan 2012, p. ES-8) explain,

> Implicit in the term [“best practice”] is that the practice is based on the best information available at the time of its institution. A best practice may be refined as more information and studies become available.

Though this research has been informed by the survey of states, the goal was not to determine best practices simply by popularity. As much as possible: (a) best practices for procedures are determined by a review of literature about public decision-making processes, with particular focus on procedural justice and public participation; and (b) best practices for the criteria and principles involved are determined by a review of the literature about siting and zoning law and the best available information about the relationships between wind parks and siting and zoning.

The focus for this project is almost exclusively on utility-scale wind turbines and wind parks for siting and zoning on the land. A few of the state survey reports (California, Minnesota, New Hampshire, Oregon, and Wisconsin) include information specifically about siting and zoning for small wind turbines.[4] Those states provide detailed information about siting and zoning standards and procedures exclusively for small wind. Off-shore wind energy development is not included in this study either, though it is a topic of interest in Atlantic, Gulf Coast, Pacific, and Great Lakes states.

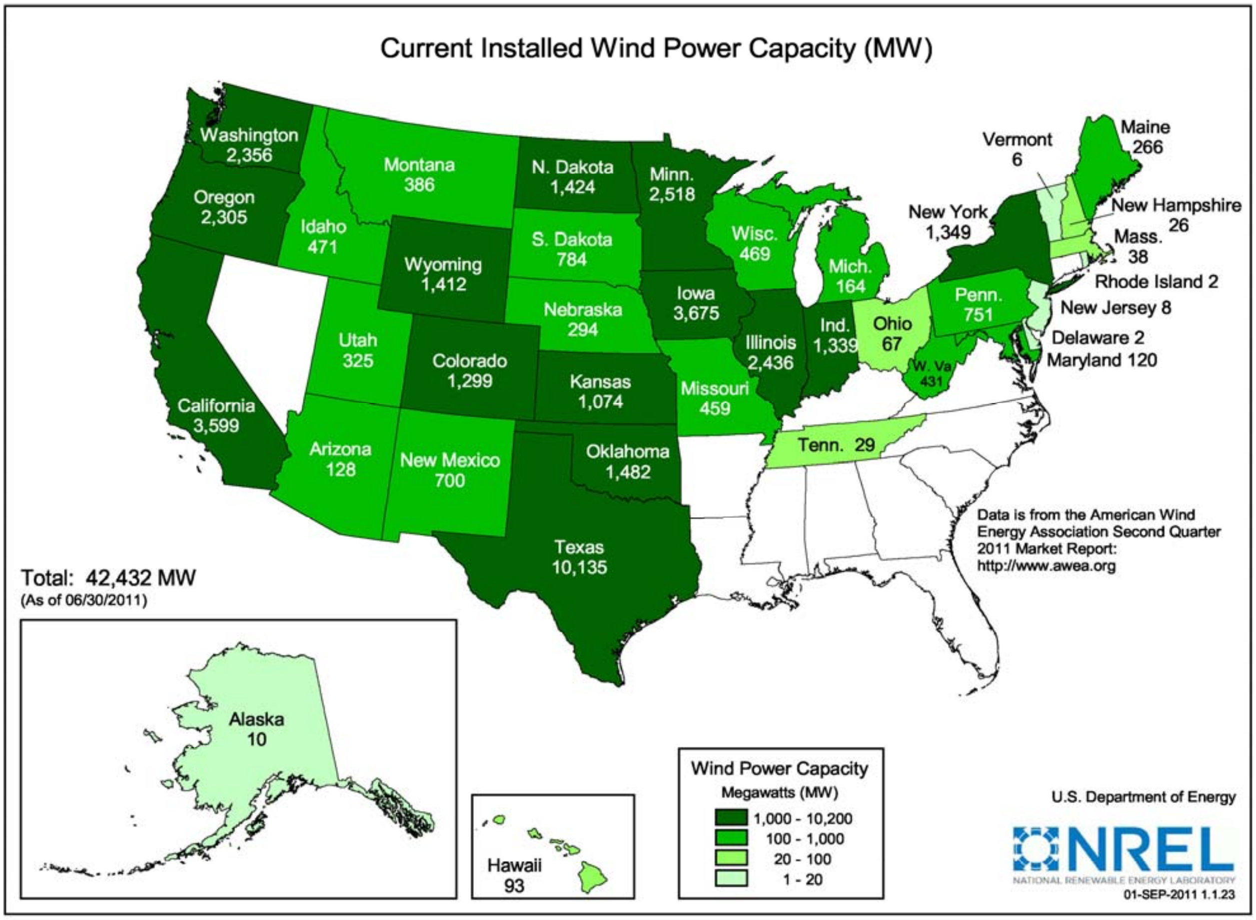
Part I of this paper reports on the current status of wind siting and zoning, based on a survey of states and other jurisdictions and information gleaned from a review of published literature about wind siting and zoning. Part II reviews and identifies best practices for the procedures used in wind energy siting and zoning. Part III presents guidelines for addressing the specific criteria used to determine wind-park siting and zoning. That part of the report identifies the criteria commonly used and includes the best available information about applying those criteria to determine siting and zoning practices. That discussion is followed by a brief summary and conclusions.

[4] “Small wind” does not have a certain definition. Generally, small wind systems are those that might be installed in a residential or commercial area to produce electricity for on-site use by a single residence, farm, or commercial facility. Typical small-scale wind generators produce less than a few hundred kilowatts, sometimes as few as one to ten kW, and they are mounted on towers no taller than about 150 feet. For more information see http://www.windpoweringamerica.gov/small_wind.asp, retrieved 7 Jan 2012.

I. Current Status

Taken as a whole, the experience with wind-park development has been quite positive. Given the large numbers of turbines installed and operating, and experience in some locations totaling 20 years and more, there have been relatively few complaints. As shown in Figure 1, 42,432 MW of wind generation had already been installed in the U.S. by late 2011.[5]

Figure 1: NREL Map of Currently Installed Wind Capacity by State



Source: http://www.windpoweringamerica.gov/images/windmaps/installed_capacity_current.jpg.
See also http://www.windpoweringamerica.gov/wind_installed_capacity.asp.

By September 2011, 14 U.S. states had more than 1,000 MW of installed wind capacity (California, Colorado, Iowa, Illinois, Indiana, Kansas, Minnesota, North Dakota, New York, Oklahoma, Oregon, Texas, Washington, and Wyoming). Survey data from these states is summarized in Table 1, with the states ranked installed capacity (as reported in Figure 1). Among the 14 states with over 1,000 MW of installed capacity, only Wyoming has neither a mandatory renewable portfolio standard nor a voluntary

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[5] Data sources used to generate Figure 1 focus almost exclusively on commercial, utility-scale wind generators. Small-scale (residential or small commercial) wind generators are typically not included. This map's data for each state is copied into Table 1, Column 2.

renewable portfolio goal. Indiana, North Dakota, and Oklahoma have voluntary goals. The other ten states that are leaders in installed capacity have mandatory standards. Eleven of these 14 states have RPS policies that promote in-state facility development.

Another 14 states had between 100 and 1,000 MW (Arizona, Idaho, Maine, Maryland, Michigan, Missouri, Montana, Nebraska, New Mexico, Pennsylvania, South Dakota, Utah, Wisconsin, and West Virginia). Five states had between 20 and 100 MW (Hawaii, Massachusetts, New Hampshire, Ohio, and Tennessee). Five states had between one and 20 MW (Alaska, Delaware, New Jersey, Rhode Island, and Vermont). A dozen states, notably many in the Southeast, had no commercial wind development at the time (Alabama, Arkansas, Connecticut, District of Columbia, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, Nevada, South Carolina, and Virginia).

In many areas, wind parks have been developed with little controversy, resulting in few if any reported problems. Where problems have occurred, though, they have attracted significant news media and public attention, sometimes followed by litigation. In particular places, wind parks have been responsible for bird and bat kills that concern wildlife conservation agencies. In others, relatively small numbers of wind-park neighbors report persistent, acute, and chronic problems and concerns.

Because of the reported problems, in many jurisdictions siting and zoning hearings become a major focal point for opposition groups, who are intent on protecting themselves and their communities from what they believe is a land-use intrusion that will result in irreversible negative effects. Although typically relatively small numbers or percentages of the population come out against wind-park development, public opposition, when it does arise, tends to be vocal and intense. It is also common that citizens who generally favor wind-park development represent what could be called a "silent majority" of people who are less motivated to participate in siting and zoning hearings.

Wind energy siting and permitting practices in the U.S. are mainly influenced by three factors in each state: (1) preexisting siting and permitting practices for other kinds of energy facilities; (2) renewable-energy support policies, especially renewable portfolio standard (RPS) or broader clean energy standard (CES) policies; and (3) public acceptance.

State-level wind siting and zoning responsibility is more likely where preexisting policies have already vested energy facility siting responsibility with a state agency. In those circumstances, state authorities are most likely to be charged with weighing applications for wind parks larger than some particular, legislated minimum capacity.

State renewable-energy support policies have focused some attention on wind-park development, especially in the 37 states that have adopted policies setting either mandates or goals for increasing the use of renewable energy.[6] Most U.S. states' renewable energy support policies use quota systems that rely on auctions to select renewable energy projects to receive power purchase agreement (PPA) contracts for the sale of electricity. Those auctions tend to favor wind parks, because the price of energy from wind parks in locations with commercially viable wind resources is generally lower than that for other renewable energy options.

Also, many state renewable energy support policies favor in-state electricity generation, one way or another.[7] These policies, especially those that focus on in-state renewable resources, have encouraged

[6] See RPS Policies at Database of State Incentives for Renewables & Efficiency, Dec 2011, *Summary maps* [web page], http://www.dsireusa.org/summarymaps/index.cfm?ee=1&RE=1, retrieved 8 Dec 2011.
[7] Various policies promote in-state renewable energy production and use. These are briefly summarized in Table 1. For details, see: Database of State Incentives for Renewables & Efficiency, http://www.dsireusa.org/rpsdata and http://www.dsireusa.org/incentives/index.cfm?SearchType=RPS&&EE=0&RE=1, retrieved 22 Dec 2011. See also the discussion about "tilt" policies in Grace, Donovan, and Melnick, 2011, especially pp. iii, 10-12.

wind prospectors to investigate opportunities in practically all of the windiest areas in the country, even areas with more potential siting and zoning obstacles.

Public acceptance, broadly speaking, depends on features of the landscapes where wind developments are proposed, such as housing density or the lack thereof, the perceived existence and importance of scenic beauty, and whether the areas are considered to be natural or already disturbed by human activity. The current status of public acceptance varies widely in different regions of the country and even in different jurisdictions within states. In states where local authorities have responsibility for wind-park siting and zoning, it is not at all unusual to find some townships or counties adopting ordinances intended to restrict or prevent development, while others are adopting development-friendly ordinances.

Unsurprisingly, wind-park developers have generally focused first on those areas with fewer obstacles to siting and zoning. The tendency is for wind parks to be built first in the windiest areas (where the economics are most favorable) and in landscapes with the fewest environmental and political obstacles to development. Barriers to development are varied, though, depending on factors such as population density and suburbanization, as well as concerns about potential negative effects on wildlife and special habitats. Barriers can also include cumbersome or uncertain and unpredictable state and local siting and zoning procedures and practices.

Part I.A of this report briefly summarizes state wind-park siting and zoning procedures and principles, based on information gleaned from the state survey data that is presented in Appendix A. Part I.B summarizes the nature of wind-park opposition, and lists the major concerns raised by opposition groups.

A. Summary information from the survey of state practices

This part of the report summarizes information gleaned from the survey of state wind energy siting and zoning practices and principles. The surveys were completed beginning in the summer of 2011. NRRI student interns and staff searched the Internet to find references about practices in each state. Once that data was compiled, preliminary surveys were circulated to in-state contacts deemed as most likely to be knowledgeable about the state's practices. The in-state contacts were asked to review and help edit the survey data and the contacts were always invited to forward the survey data to others who were likely to be familiar with the state's practices. Surveys are considered complete only after they have been reviewed and accepted as accurate by one or more in-state experts.[8]

The completed surveys are attached in Appendix A. Findings from the surveys are summarized in Table 1 (pages 6-10). The rest of Part I.A (pages 11-14) reports on the data presented in Table 1 and presents some additional summary information gathered from the survey reports. Table 2 (pages 11-12) shows a copy of the same data as Table 1, but only for those 14 states identified in Figure 1 as having more than 1,000 installed MW of wind capacity. In Table 2, the 14 states are ranked in descending order, based on installed wind capacity.

[8] Names of the individuals responsible for the original data collection and in state reviewers are shown at the end of each state's survey record. As of this publication date, reviews are yet to be completed for 12 states. The authors intend to continue efforts to update the survey reports, as needed, to keep them up to date. The most current survey data will be published on the NRRI website, in the area devoted to wind energy information.

Table 1: Summary of State Wind Siting and Zoning Practices

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
State	**MW Installed**[1]	**Primary Authority (Limit)**[2]	**Primary (P) or Secondary (S) State Authority**	**State Energy Siting**[4]	**Primary Rule**[3]	**Evaluation Criteria**[5]	**Voluntary Guidelines**[5]	**Model Ordinance**	**Setback Standard**[6]	**Sound Standard**[6]	**Local Ordinances**[7]	**RPS**[8]	**RPS In-State "Tilt"**[9]	**REZ**[10]
Alabama	0	State	CPCN from PSC (P)		Dillon's									
Alaska	10	State	CPCN from RCA (P)		Home						1			
Arizona	128	Local			Dillon's	Y	W				1	M	BD	WREZ
Arkansas	0	Local	CPCN from PSC (S)		Home									
California	3,599	Local	California Environmental Quality Act (S)		Dillon's	Y					6	M	L	Y, WREZ
Colorado	1,299	Local	CPCN from PUC (>2MW) (S), PUC consults with Division of Wildlife (S)		Dillon's	Y						M	BL	Y, WREZ
Connecticut	0	State (>1 MW)	CECPN from Siting Council (>1 MW) (P), DEEP checks congruence with IRP (S)	Y	Home	Y						M	LR	
Delaware	2	Local	Certification from PSC (S)		Dillon's	Y			Y	Y		M	B	
District of Columbia	0	PUC	Approval from PSC (P)		n/a							M	DL	
Florida	0	State (<75MW)	DOT, FAW (<75MW) (P)	Y[12]		Y								
Georgia	0	Local			Dillon's		YW	Y	Model	Model				
Hawaii	93	Local	Permit from PUC (S)		Dillon's							M	M	
Idaho	471	Local			Dillon's						1			WREZ
Illinois	2,436	Local	DNR (S)		Home						5	M	LR	RGOS
Indiana	1,339	Local	CON from URC (S)		Home						13	G	L	RGOS

[1] See all table notes at the end of the table, on page 10. See Appendix A for more detailed information about each state's practices.

Table 1 (Continued): Summary of State Wind Siting and Zoning Practices

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
State	**MW Installed**[1]	**Primary Authority (Limit)**[2]	**Primary (P) or Secondary (S) State Authority**	**State Energy Siting**[4]	**Primary Rule**[3]	**Evaluation Criteria**[5]	**Voluntary Guidelines**[5]	**Model Ordinance**	**Setback Standard**[6]	**Sound Standard**[6]	**Local Ordinances**[7]	**RPS**[8]	**RPS In-State "Tilt"**[9]	**REZ**[10]
Iowa	3,675	Both (>25MW)	Certification from Iowa Utilities Board (>25MW)		Home	Y					5	M	U	RGOS
Kansas	1,074	Local			Dillon's		YW				3	M	B	
Kentucky	0	State	Siting Board Approval (>10MW) (P)		Dillon's									RGOS
Louisiana	0	Local	Permit from DEQ (S)		Dillon's									
Maine	266	State (>20 acres)[13]	Permit from DEP (>20 acres) (P), Permit from LURC (for "unorganized" areas)[13] (P)		Dillon's	Y					8	M	BL	
Maryland	120	State (≥70MW)	CPCN from PSC (≥70MW) (P), 7 state agencies notified (S)	Y	Dillon's	Y	W				15	M	LR	
Massachusetts	38	State (≥100MW)	Permit from Energy Facilities Siting Board (≥100MW) (P)		Home	Y		Y	Model	Model	2	M	L	
Michigan	164	Local	PSC checks utility-owned and PPA projects for compliance with a utility's renewable energy plans (S)	Y	Home		Y	Y			11	M	BS	Y, RGOS
Minnesota	2,518	State (>5MW)	Permit from PUC (>5MW) (P)		Dillon's	Y		Y		Y	2	M		RGOS
Mississippi	0	State	CPCN from PUC (P)		Dillon's									
Missouri	459	Local			Dillon's						1	M		RGOS
Montana	386	Local			Home	Y						M	D	RGOS, WREZ

Table 1 (Continued): Summary of State Wind Siting and Zoning Practices

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
State	**MW Installed**[1]	**Primary Authority (Limit)**[2]	**Primary (P) or Secondary (S) State Authority**	**State Energy Siting**[4]	**Primary Rule**[3]	**Evaluation Criteria**[5]	**Voluntary Guidelines**[5]	**Model Ordinance**	**Setback Standard**[6]	**Sound Standard**[6]	**Local Ordinances**[7]	**RPS**[8]	**RPS In-State "Tilt"**[9]	**REZ**[10]
Nebraska	294	State (>80MW)[12]	Approval from Nebraska Power Review Board (>80MW)[12] (P)		Dillon's	Y					4			
Nevada	0	Local	Permit from PUC (≥70MW) (S)	Y	Dillon's							M		Y, WREZ
New Hampshire	26	State (≥30 MW)	COSF from Site Evaluation Committee (≥30MW) (P)		Dillon's	Y						M	DR	
New Jersey	8	Both	Interconnection authority falls to PJM RTO (S) (see New Jersey survey)	Y	Home	Y					10	M	DLR	
New Mexico	700	State (>300MW)	CPCN from PRC (P)		Home	Y	W					M		WREZ
New York	1,349	Local	CPCN from PUC (>25MW) (S)		Dillon's	Y	YW	Y	Model	Model	1	M	L	
North Carolina	0	Local	CPCN from NCUC (S)		Dillon's	Y		Y			9	M	L	
North Dakota	1,424	State (>0.5MW)	CSC from PSC (P), 21 State Agencies notified (S)		Dillon's	Y					3	G		RGOS
Ohio	67	State (≥5MW)	CECPN from Power Siting Board (≥5MW) (P)		Home	Y						M		RGOS
Oklahoma	1,482	Local		Y	Dillon's							G	M	
Oregon	2,305	State (>105MW)	Certification from Energy Facility Siting Council (>105MW) (P)		Home	Y					1	M	BR	GBS, WREZ
Pennsylvania	751	Local		Y	Dillon's	Y		Y	Model	Model	4	M	LR	
Rhode Island	2	State (≥40 MW)	Approval from Energy Facility Siting Board (≥40 MW) (P)		Home	Y	Y		Y	Y		M		

Table 1 (Continued): Summary of State Wind Siting and Zoning Practices

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
State	**MW Installed**[1]	**Primary Authority (Limit)**[2]	**Primary (P) or Secondary (S) State Authority**	**State Energy Siting**[4]	**Primary Rule**[3]	**Evaluation Criteria**[5]	**Voluntary Guidelines**[5]	**Model Ordinance**	**Setback Standard**[6]	**Sound Standard**[6]	**Local Ordinances**[7]	**RPS**[8]	**RPS In-State "Tilt"**[9]	**REZ**[10]
South Carolina	0	State (>75MW)	CPCN from PSC (>75MW) (P)	Y	Dillon's									
South Dakota	784	Local	Permit from PUC (>100 MW) (S)	Y	Dillon's	Y	Y	Y	Y		4	G		RGOS
Tennessee	29	Local			Dillon's									
Texas	10,135	Local	Projects must register with PUC (S)		Dillon's				Model	Model	2	M	M	Y
Utah	325	Local	CCN from PSC (S)		Home	Y		Y	Model	Model	3	G	R	Y, WREZ
Vermont	6	State	COPG from PSB (P)		Dillon's		Y					G	M	
Virginia	0	Local	Permit from DEQ ≤100 MW (S), SCC >100 MW (S)		Dillon's			Y	Y	Y	3	G		
Washington	2,356	State (>350MW)	Site Certification Agreement from Energy Facility Site Evaluation Council (>350MW) (P)		Dillon's	W						M	DR	GBS, WREZ
West Virginia	431	State	CPCN from PSC (P)	Y	Dillon's							G	BR	
Wisconsin	469	Local	CPCN from PSC (>100MW) (S)		Dillon's			Y[10]			4	M	D	RGOS
Wyoming	1,412	State (±30 turbines)	Permit from Industrial Siting Council (±30 turbines) (P)		Dillon's	Y			Y					WREZ

Table 1 (Continued): Summary of State Wind Siting and Zoning Practices

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
State	**MW Installed**[1]	**Primary Authority (Limit)**[2]	**Primary (P) or Secondary (S) State Authority**	**State Energy Siting**[4]	**Primary Rule**[3]	**Evaluation Criteria**[5]	**Voluntary Guidelines**[5]	**Model Ordinance**	**Setback Standard**[6]	**Sound Standard**[6]	**Local Ordinances**[7]	**RPS**[8]	**RPS In-State "Tilt"**[9]	**REZ**[10]

Table Notes: See also the individual survey reports for each state, presented in alphabetical order by state name, in Appendix A.

[1] Source data for Column 2 is Figure 1 (p. 3).

[2] Column 3 indicates "Local" when the primary siting authority rests with the local (county or municipal) government or "State" when primary authority is with the state. Any "Limit" means that a wind-park size criterion (number of turbines in Wyoming, acres in Maine, or capacity – number of MW – in 14 states) determines jurisdiction. In those circumstances, wind parks larger than the expressed limit trigger state authority. "Both" applies to Iowa and New Jersey, where siting authority is held by both the state and local units of government.

[3] Column 5: "Y" for yes indicates there is a state energy facility siting council or board separate from the state public utility commission.

[4] Column 6 distinguishes between "Home Rule" states and "Dillon's Rule" states. See p. 10 for the discussion.

[5] Columns 7 and 8: "Y" means yes, the state does have mandatory evaluation criteria (Column 7) or voluntary guidelines (Column 8). A "W" in either column means primarily or exclusively for wildlife. States with both Y and W in either column means multiple documents exist, one focused explicitly on wildlife.

[6] Columns 10 and 11: "Y" indicates that standards are included in evaluation criteria. "Model" means that criteria are included in a model ordinance.

[7] Column 12: The number in Column 12 represents the ordinances included in a database being assembled by the National Renewable Energy Laboratory, available from http://www.windpoweringamerica.gov/policy/ordinances.asp, retrieved 22 Dec 2011.

[8] Column 13: "M" means the state has a mandatory renewable energy portfolio standard. "G" means the state has a voluntary goal for renewable energy. See Database of State Incentives for Renewables & Efficiency, 2011, *Portfolio Standards/Set Asides for Renewable Energy* [web page] and *RPS Policies* [map], http://www.dsireusa.org/incentives/index.cfm?SearchType=RPS&&EE=0&RE=1, retrieved 22 Dec 2011.

[9] Column 14: Many state RPS programs include provisions to promote in-state renewable energy facilities, such as wind parks. A recent NRRI Report (Grace, Donovan, & Melnick, 2011) calls this a "tilt" policy (intended to tilt the playing field towards certain technologies). In Column 14: "B" means a "bonus" credit for at least some in-state facilities; "D" means electricity must be delivered into the state (or "DR" means delivered into the region) in order to qualify; "L" means a maximum limit on energy from out-of-state facilities or conversely a minimum limit on energy from particular kinds of in-state resources; "M" means a mandate for in-state generators; "R" means a mandate for regional generators; "S" means qualifying facilities must be in the service territory of a utility providing retail service in the state; and "U" means a mandate for a utility serving the state to own or contract for the qualifying renewable energy. Source: Database of State Incentives for Renewables & Efficiency, 2011, http://www.dsireusa.org/incentives/index.cfm?SearchType=RPS&&EE=0&RE=1, retrieved 5 Jan 2012.

[10] Column 15: REZ means Renewable Energy Zone(s). Coding indicates "Y" if there is a specific state process for determining zones (in Texas, Colorado, Utah, Michigan, and Nevada). Other codes include: "WREZ" for the Western Renewable Energy Zones process for 5 states); "RGOS" for the Regional Generation Outlet Study process at the Midwestern Independent [Transmission] System Operator (MISO) for parts or all of 12 states; "GBS" for the Gorge Bi-State Renewable Energy Zone, which includes six counties near the Columbia River in both Oregon and Washington.

[11] Wisconsin's Model Ordinance applies only for small wind systems, <100kW in capacity.

[12] Nebraska's >80MW limit applies only if the planned capacity would cause the utility's total renewable energy production to exceed the company's goal.

[13] Maine's state authority applies if the proposed wind-park involves greater than 20 acres of land, or if the wind-park will be sited in an "unorganized" area.

Table 2: Summary of State Wind Siting and Zoning Practices
(Top Ten States, Ranked by 2011 Installed Commercial Wind Generating Capacity in MW)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
State	**MW Installed[1]**	**Primary Authority (Limit)[2]**	**Primary (P) or Secondary (S) State Authority**	**State Energy Siting[4]**	**Primary Rule[3]**	**Evaluation Criteria[5]**	**Voluntary Guidelines[5]**	**Model Ordinance**	**Setback Standard[6]**	**Sound Standard[6]**	**Local Ordinances[7]**	**RPS[8]**	**RPS In-State "Tilt"[9]**	**REZ[10]**
Texas	10,135	Local	Projects must register with PUC (S)		Dillon's				Model	Model	2	M	M	Y
California	3,599	Local	California Environmental Quality Act (S)		Dillon's	Y					6	M	L	Y, WREZ
Iowa	3,675	Both (>25MW)	Certification from Iowa Utilities Board (>25MW)	Y	Home	Y					5	M	U	RGOS
Minnesota	2,518	State (>5MW)	Permit from PUC (>5MW) (P)		Dillon's	Y		Y		Y	2	M		RGOS
Illinois	2,436	Local	DNR (S)		Home						5	M	LR	RGOS
Washington	2,356	State (>350MW)	Site Certification Agreement from Energy Facility Site Evaluation Council (>350MW) (P)	Y	Dillon's	W						M	DR	GBS, WREZ
Oregon	2,305	State (>105MW)	Certification from Energy Facility Siting Council (>105MW) (P)	Y	Home	Y					1	M	BR	GBS, WREZ
Oklahoma	1,482	Local			Dillon's							G	M	
North Dakota	1,424	State (>0.5MW)	21 State Agencies notified (S)		Dillon's	Y					3	G		RGOS
Wyoming	1,412	State (±30 turbines)	Permit from Industrial Siting Council (±30 turbines) (P)	Y	Dillon's	Y			Y					WREZ

[1] See all table notes at the end of Table 1, on page 10. See Appendix A for more detailed information about each state's practices.

Table 2 (Continued): Summary of State Wind Siting and Zoning Practices
(Top Ten States, Ranked by 2011 Installed Commercial Wind Generating Capacity in MW)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
State	**MW Installed**[1]	**Primary Authority (Limit)**[2]	**Primary (P) or Secondary (S) State Authority**	**State Energy Siting**[4]	**Primary Rule**[3]	**Evaluation Criteria**[5]	**Voluntary Guidelines**[5]	**Model Ordinance**	**Setback Standard**[6]	**Sound Standard**[6]	**Local Ordinances**[7]	**RPS**[8]	**RPS In-State "Tilt"**[9]	**REZ**[10]
New York	1,349	Local	CPCN from PUC (>80MW) (S)		Dillon's	Y	Y	Y	Model	Model	1	M	L	
Indiana	1,339	Local	CON from URC (S)		Home						13	G	L	RGOS
Colorado	1,299	Local	CPCN from PUC (>2MW) (S), PUC consults with Division of Wildlife (S)		Dillon's	Y						M	BL	Y, WREZ
Kansas	1,074	Local			Dillon's		YW				3	M	B	

1. Responsibility for siting and zoning and certificates of necessity: state, local, or both

The factors summarized here are entered in Table 1, columns 3, 4, and 5. Column 3 indicates whether the primary wind siting and zoning authority in the state rests with the local government, state government, or both. The primary decision-making authority resides with local governments in 26 states and state governments in 22 states. Florida and Iowa have shared local and state responsibility. Column 4 includes a "(P)" to indicate a state agency has primary siting authority. Many states have a clearly defined secondary authority, as indicated by "(S)" in column 4. Often the secondary authority is responsible for determining whether a proposed wind-park meets the standards necessary to be granted a certificate of public convenience and necessity, or the equivalent. Secondary authority is frequently not explicitly for siting or zoning, but approvals from a primary siting and zoning authority can be one criterion needed to obtain approval from a secondary authority. If there is a state agency responsible for energy facility siting other than the state's public utility commission (PUC),[9] column 5 includes a "Y."

In six states plus the District of Columbia the PUC is responsible for siting and zoning utility-owned wind parks. The states include Kentucky, Minnesota, New Mexico (for facilities >300MW in capacity), North Dakota, Virginia (for facilities >100MW), and West Virginia.

Twenty-three states and the District of Columbia require a certificate from the PUC. This is typically called a "certificate of public convenience and necessity" (CPCN). It represents a determination by the PUC that the public good will be served by the construction and operation of a particular facility. CPCN hearings can include information about siting and zoning, and siting and zoning approval can be a prerequisite to a CPCN, but in many cases the CPCN approval is separate from siting and zoning approval. In those circumstances, a developer must obtain both siting and zoning approval from one agency and a CPCN from another. States requiring a CPCN from the PUC include: Alabama, Alaska, Arkansas, Colorado, Delaware, Hawaii, Indiana, Maryland, Minnesota, Mississippi, Nevada, New Mexico, New York, North Carolina, North Dakota, South Carolina, South Dakota, Texas, Utah, Vermont, Virginia, West Virginia, and Wisconsin. CPCN requirements are sometimes triggered only when a facility will be owned by a public utility, or when a facility is larger than some specific size (as indicated in Table 1, columns 3 and 4).

Eleven other states, indicated with a "Y" in column 5, have an energy facility siting authority that is separate from the PUC. These include: Connecticut, Florida, Maine, Massachusetts, Nebraska, New Hampshire, Ohio, Oregon, Rhode Island, Washington, and Wyoming. It is common for state energy facility siting to apply only to larger-capacity projects, but the limits triggering state authority range from as small as 1 MW in Connecticut and 5 MW in Ohio to as large as 300 MW in New Mexico and 350 MW in Washington. The limits are listed in columns 3 and 4. Commercial wind parks are most likely to be much larger than those smallest limits, but are often smaller than the largest limits.

No matter what criteria determine the dividing line between state and local authority, developers are prone to selecting the state or local government venue that they believe offers the greatest chance of siting and zoning success. Development plans for project size and location are quite likely to be adjusted to meet particular criteria. This issue has been addressed in a few states already, with policymakers reducing the project size limit that will trigger state review for wind projects (in Appendix A, see the *History of siting authority* reported for North Dakota and Ohio).

[9] Different states use different names for the state agency that is the public utility regulatory authority. The most common names used are "public service(s) commission" (PSC) and "public utility commission" (PUC), but several states use other names. In this paper, the generic term, PUC, is used to represent the relevant commission or board.

Whether or not it is stated explicitly in the state summaries in Appendix A, all relevant federal laws apply to wind siting and zoning decisions. Various federal agencies will have some authority, depending on the specific locations being considered. These include the following: Army Corps of Engineers (COE), Bureau of Land Management (BLM), Federal Aviation Administration (FAA), Federal Communications Commission (FCC), Environmental Protection Agency (USEPA), Fish and Wildlife Service (USFWS), and U.S. Military. In many circumstances, USEPA requirements are delegated to state (or sometimes local government) agencies. Illinois publishes this list of federal agency requirements, which is a good example for all the states:

(1) Federal Aviation Administration (FAA): (a) Determination of No Hazard to Air Navigation; (b) Notice of proposed construction (form FAA 7460-1); (c) Lighting plan; (d) Post-construction form (form FAA 7460-2).

(2) U.S. Fish and Wildlife Services (USFWS): Threatened and Endangered Species Act, Section 7 Consultation and Migratory Bird Act.

(3) U.S. Army Corps of Engineers (COE): (a) Clean Water Act: Section 404 - Discharge of Fill Materials; (b) Rivers and Harbors Act: Section 10.

(4) Federal Communications Commission (FCC): Microwave Studies.

(5) U.S. Environmental Protection Agency (USEPA): Spill Prevention, Control and Countermeasures Plan (SPCC Plan, 40 CFR112).

(6) U.S. Military: Determination of non-interference with flight operations and radar.

It is also common for state and county departments of transportation to have some oversight regarding wind-park construction, including plans for the delivery of components to the construction site, road use during construction, and the disposition of temporary roads after construction is completed.

2. A primary rule about local authority: Home Rule versus Dillon's Rule

In Table 1, Column 6 differentiates states into one of two types, according to the primary rule that governs state versus local authority: Home Rule and Dillon's Rule. The original difference would be found in the state constitution.

Home Rule states grant broad authority and autonomy to local governments. The essence of home rule is that local governments hold all authority that has not been ceded explicitly to the state or federal governments, through either the federal or state constitutions or by legislation. Alternatively, Dillon's rule generally holds that all authority not explicitly residing in the federal government is held by the state government, unless explicitly delegated to local governments through the state constitution or through state legislation. Therefore, Dillon's rule reinforces that some powers should be reserved by states in order to ensure equality for all.

In practice, though, Dillon's rule and home rule are not mutually exclusive. Legislatures in some Dillon's Rule states have explicitly authorized limited home rule for some local governments, usually counties but sometimes municipalities. Those states include Colorado, Illinois, Kansas, North Dakota, and Washington.[10] A general expectation might be that Home Rule states would tend to have local authority and Dillon's Rule states would tend to have state authority for wind siting and zoning. In practice, though,

[10] Richardson, undated; Sellers, 2010; USLEGAL.COM, *Dillon's rule law & legal definition* and *Home rule law & legal definition*, retrieved 22 Dec 2011 from http://definitions.uslegal.com/d/dillons-rule/ and http://definitions.uslegal.com/h/home-rule/.

Home Rule states are evenly split in terms of local versus state authority, but more Dillon's Rule states (20 of 31) have already delegated wind siting and zoning authority to local units of government.

3. Mandatory evaluation criteria, voluntary guidelines, model ordinances, setback and sound standards, and local ordinances

Data on these factors is included in Table 1, Columns 7 through 12. As shown in Column 7, 27 of the 50 states have published lists of the criteria that are used to evaluate wind siting and zoning decisions. Washington's criteria cover only wildlife protection concerns. For the other 23 states and District of Columbia, the survey did not discover any clear list of evaluation criteria.

Ten states have published voluntary guidelines for wind siting and zoning. Those states are indicated with a "Y" in Table 1, column 8, meaning general guidelines, a "W" meaning guidelines explicitly for addressing wildlife concerns, or both letters. The ten states include Arizona (explicitly for wildlife), Georgia, Kansas (including both a general guidelines and wildlife guidelines), Maryland (explicitly for wildlife), Michigan, New Mexico (explicitly for wildlife), New York (including both a general guidelines and wildlife guidelines), Rhode Island, South Dakota (including "natural and biological resources"), and Vermont. Table 3 indicates with a "Y" the major factors included in each state's guidelines. Michigan is the only state with guidelines for all the identified topics, but some (e.g., mitigation) are bare mentions, with no details about how the guideline might be implemented.

Table 3: Factors Included in State Wind Siting and Zoning Guidelines

State	Wildlife	Aesthetics	Birds	Bats	Noise	Setbacks	Mitigation	Decommissioning
Arizona	Y							
Georgia	Y	Y	Y	Y	Y			
Kansas	Y	Y	Y				Y	Y
Maryland	Y		Y	Y				
Michigan	Y	Y	Y	Y	Y	Y	Y	Y
New Mexico	Y		Y	Y				
New York	Y	Y	Y		Y	Y		Y
Rhode Island					Y	Y		
South Dakota	Y				Y	Y		Y
Vermont	Y		Y	Y				

Five states, labeled "Y" in Table 1, Column 9, have published model ordinances intended to guide local governments. They include Massachusetts, Minnesota, New York, Pennsylvania, Utah, and Virginia.

As shown in Table 1, columns 10 and 11, a handful of states have published setback standards, sound standards, or both. Both of these columns differentiate between mandatory standards, indicated "Y," and recommended or advisory standards for local government consideration, indicated "Model." As shown in Table 1, with the exceptions of Minnesota (mandatory sound standard only) and Wyoming (mandatory setback standard only), all of the other states identified in Table 1, columns 10 and 11, have either both mandatory or both model setback and sound criteria. Mandatory setback and sound standards are found in Delaware, Rhode Island, and Virginia. It is interesting to note that these are three states with little commercial wind energy activity. Model setback and sound standards exist for Georgia, Massachusetts, New York, Pennsylvania, Texas, and Utah.

Table 1, column 12, reports the number of local ordinances that have been discovered and included in a database being assembled by the National Renewable Energy Laboratory.

In addition to that information that is tabulated in Table 1, the survey reports in Appendix A identify two states that have published clear procedural steps for wind siting and zoning (Maine and North Dakota) and two that have published explicit standards for determining wind siting and zoning (Maine and Minnesota). The Maine and Minnesota standards are more than just lists of the criteria to be considered; they list both the criteria and how compliance with the criteria will be determined.

Also, six states report that efforts to better define wind siting and zoning practices are presently underway but incomplete. Connecticut is developing new regulations and presently prohibits acting on pending wind siting requests until the new regulations are adopted. Iowa and New York are developing new regulations based on each state's respective June 2011 legislation. Maryland has drafted but not yet implemented new voluntary guidelines that will cover more than the existing guidelines for wildlife only. Rhode Island is updating its guidelines and reports it might develop a model ordinance as a part of that effort. Texas, which presently has none, is developing guidelines.

4. Supporting policies: clean energy portfolio standards and goals, promoting in-state wind energy facilities, and renewable energy zones

As shown in Table 1, Column 13, 29 states and the District of Columbia have renewable energy portfolio standard (RPS) mandates (M), and eight states have renewable energy goals (G).[11]

Column 14 summarizes how 29 of the 37 states with RPS mandates or goals have policies intended to promote the development of in-state renewable resources, including wind parks.[12] Those policies are encoded with one, two, or three letter codes. In Column 14: "B" means a "bonus" credit for at least some in-state facilities; "D" means electricity must be delivered into the state (or "DR" means delivered into the region) in order to qualify as eligible to count for RPS compliance; "L" means a maximum limit on energy from out-of-state facilities or conversely a minimum limit (often called a "carve-out") on energy from particular kinds of in-state resources; "M" means a mandate for in-state generators; "R" means a mandate for regional generators (usually, in the territory served by a regional transmission organization, RTO); "S" means qualifying facilities must be in the service territory of a utility providing retail service in the state; and "U" means a mandate for a utility serving the state to own or contract for the qualifying renewable energy.

Only two states, Connecticut and Michigan, explicitly require utilities to demonstrate that their renewable energy procurement plans conform with their approved integrated resource plan (IRP) or renewable energy plan.

Another policy that indirectly supports wind-park siting and zoning is the development of renewable energy zones. This is reported in Table 1, column 15. Typically, a renewable energy zone (REZ) is identified through a planning process that includes a general review of wind resources and broad-based, regional land-use compatibility with wind-park development, combined with electric transmission system

[11] The distinctions between mandatory and voluntary RPSs are not always completely black and white. Many so-called mandatory programs include legislated circuit breakers or off ramps. See the details for each program at http://www.dsireusa.org/summarymaps/index.cfm?ee=1&RE=1, http://www.dsireusa.org/rpsdata/index.cfm, and http://www.dsireusa.org/summarytables/rrpre.cfm.

[12] RPS tilt policies are not the only means that states use to promote in-state renewable energy facility development. In addition to specific RPS rules or standards, all states offer at least some financial incentives for renewable energy. See: Database of State Incentives for Renewables & Efficiency, 2011, *Financial Incentives for Renewable Energy* [web page], http://www.dsireusa.org/summarytables/finre.cfm, retrieved 5 Jan 2012; and Hempling, Stanton, and Porter, 2011.

modeling and planning. In most REZ processes, once specific zones are identified, transmission will be built to interconnect the zone to electricity loads, in anticipation that wind-park development will follow.

States with explicit state-level REZ processes include California, Colorado, Michigan, and Texas. These are indicated with a "Y" in column 15. Many other states and utilities are participating in REZ-like transmission modeling and planning under the auspices of regional transmission organizations. The Midwest Independent [Transmission] System Operator (MISO) Regional Generation Outlet Studies (RGOS) have included Indiana, Illinois, Iowa, Michigan, Minnesota, North Dakota, Ohio, South Dakota, and Wisconsin, plus the Canadian province of Manitoba (MISO, 2011). The Western Renewable Energy Zone (WREZ) initiative includes Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, and Wyoming, the part of Texas near El Paso, the Canadian provinces of Alberta and British Columbia, and a small portion of northern Mexico in Baja California (Western Governors Association, 2009). In addition, the Gorge Bi-State Renewable Energy Zone is an initiative for six counties near the Columbia River in both Oregon and Washington (www.cgbrez.org/). The U.S. Eastern Interconnection States' Planning Council also includes a workgroup presently working on state energy zones modeling, for all of the states and Canadian provinces east of the Rocky Mountains (see http://communities.nrri.org/web/eispc/share-and-view-files-members/-/document_library/view/195538).

B. The nature of wind-park opposition and list of major concerns

But for public opposition, there would be little controversy about wind-park siting and zoning; technical best practices would determine siting and zoning decisions, and that would be that. Because of strongly held local concerns, though, public input frequently becomes an important or perhaps the most important factor in siting and zoning decisions. This is true for both macro- and micro-siting.[13]

It should be noted that when decisions are made by local siting and zoning authorities, the decisionmakers are most likely the neighbors of those who might be opposed. Those local decisionmakers are often elected officials, too, and there have already been experiences in some jurisdictions where voting for local officials turns on public sentiment about wind-park siting and zoning decisions. Therefore, the democratic process, with public input influencing the outcome, is of serious importance.

Wind-park siting opposition is sometimes characterized by pro-wind advocates and developers as a "not in my backyard" (NIMBY) attitude held by a small number of area residents who are most likely aggrieved because they are not going to benefit financially from land-lease payments. Although there can be a kernel of truth in this observation, academic researchers fault the NIMBY label for multiple reasons and find that anti-wind sentiments are more nuanced and complex (Devine-Wright, 2004, 2009; Devine-Wright & Howes, 2010; Eltham, Harrison, & Allen, 2008; Jegen & Audet, 2011; Jones & Eiser, 2009; Musall & Kuik, 2011; Hindmarsh, 2010; Mooney, 2010; and Wolsink, 2007a, 2007b).

Critiques of the NIMBY label are that it is overly simplistic and "pejorative" (Musall & Kuik, 2011, p. 3252). A precise definition of NIMBY "refer[s] to a situation in which someone has a positive attitude towards something in general but accompanies this with a motivation to oppose its installation locally, due to reasons of self-interest" (Wolsink, 2007, cited in Jones and Eiser, 2009, p. 4605). As Jones and Eiser (2011, p. 4605) explain, though,

> Many researchers have found that when defined strictly in these terms, NIMBYism is relatively rare and certainly is too simplistic to be used as a sole explanation for *all* local opposition to

[13] Macro-siting means the general location of a wind park. A macro-site can be thought of as the boundary that defines the overall areas that are inside and outside an area considered for wind-park construction. Micro-siting involves the detailed decisions about the placement of each wind turbine, the required access roads, and the necessary interconnections to the transmission or distribution grid. Micro-siting depends on many factors, including prevailing winds, technical features of the selected wind turbines, and the precise locations of homes and other buildings, property lines, exclusion zones, and setbacks around avoidance zones.

> proposed development [emphasis in original; references omitted]. … [A]n often incorrect and indiscriminate usage of the term has infused NIMBY with derogatory connotation and left it outdated and lacking explanatory value.

In the context of decisions about wind parks, such NIMBY self-interests most notably could include concerns about effects on property values, negative perceptions of visual impacts, and fears about noise and shadow flicker. Countervailing hypotheses about public opposition, however, identify a more complex "set of influential factors… [that] include [the] national political environment, local perception of economic impacts, social influences such as trust and institutional factors such as fairness and inclusiveness of the planning and execution of the project" (Musall & Kuik, 2011, p. 3253). In a public survey in Cardiff, Wales, Demski (2001, pp. 3-4) found that "opinions around wind farms were more complex and diverse compared to other technologies… [and] the majority of people… should not be classified as either *strong supporters* or *strong resisters* (of wind farms) and instead can be found somewhere in between these two positions." As Pasqualetti (2000, p. 385) explains, all kinds of energy facility developments can "encounter public resistance, especially where land is sacred, protected, scenic, or otherwise sensitive." In particular, he notes, siting a modern wind park changes the "out of sight, out of mind" relationship between people and energy production. Thus, researchers are finding that citizen concerns and opposition is guided by deep-seated issues involving competing land uses and attachment to place. These issues are most acute in circumstances where wind parks are proposed for areas with sufficient housing density that potential neighbors' concerns are heightened by the prospect of fairly close proximity among wind turbines and houses. These concepts and the associated lessons for public engagement and consultation are briefly explored in Part II.E of this report and revisited in the Summary and Conclusions.

When engaging in siting and zoning procedures, anti-wind groups and individuals arm themselves with information obtained from anti-wind web sites. Examples include AWEO (www.aweo.org), Industrial Wind Action Group (www.windaction.org), and National Wind Watch (www.wind-watch.org).[14]

Ubiquitous internet access among local activists facilitates the dissemination of anti-wind documents and thereby tends to focus all local anti-wind groups on the same basic issues and concerns. Table 4 summarizes many of the objections raised by opposition groups. In Table 4, *italic font* denotes recommendations for the role that each set of objections ought to play in siting and zoning decisions. Some of the concerns are not directly relevant to siting and zoning procedures, but experience with groups opposed to all kinds of locally unwanted land uses (LULUs) demonstrates that opposition groups typically raise every possible objection (Cockerill, Groothuis, & Groothuis, 2011, p. 10).

[14] Website home pages retrieved 12 Dec 2011.

Table 4: Typology of Anti-Wind-Park Arguments

Topics and Subtopics	Example of anti-wind characterization. *Siting and Zoning Relevance.*
Human Health, Nuisance, and Annoyance Factors Noise Infrasound Shadow flicker	"[W]ind farms produce a noise that's hard to comprehend and even more dangerous to live close to. The beating of the blades have not only their own throbbing sounds, but beat harmonically together to create a cacophony of audible confusion…" (Brougher, 2008). "[B]ased on our knowledge of the harmful effects of noise on children's health and the growing body of evidence to suggest the potential harmful effects of industrial wind turbine noise, it is strongly urged that further studies be conducted…before forging ahead in siting industrial wind turbines." (Bronzaft, 2011). "Dizziness (specifically, vertigo) and anxiety are neurologically linked phenomena. Hence the anxiety and depression seen in association with other symptoms near wind installations are not a neurotic response to symptoms, but rather a neurologically linked response to the balance disturbances people experience from shadow flicker or low-frequency noise... . Based on these health effects and hazards, turbines should not be placed within 1700 feet of any road or dwelling. Those living within 1/2 mile (2640 ft) should be apprised that they are likely to experience very bothersome levels of noise and flicker, which continue (though to a lesser degree) to a mile or more from the turbines." (Pierpont, 2005). *Wind parks should not be singled out for special noise criteria. Siting and zoning can apply noise criteria, but noise limits should apply equally to all sources. Separate consideration should be given to construction noise.* *It is a simple matter to calculate the precise locations and maximum annual duration of shadow-flicker effects. A siting standard can limit shadow flicker.* *Both noise and shadow-flicker complaints can be amenable to mitigation, and an escrow account subject to independent management by an objective, disinterested arbitrator can be established for this purpose.* *Neighbors should have the right to waive noise and shadow-flicker standards.*
Safety Ice-throw Blade failure Tower failure	"The bottom line is that ice, debris or anything breaking off the wind turbine blades (including the blades themselves) can impact a point almost 1,700 feet away from the base of the turbine" (Matilsky, 2011). "Especially in the mountainous sites or in the northern areas icing may occur frequently and any exposed structure – also wind turbines – will be covered by ice under special meteorological conditions. This is also true if today's Multi Megawatt turbines with heights from ground to the top rotor blade tip of more than 150 m can easily reach lower clouds with supercooled rain in the cold season, causing icing if it hits the leading edge." (Siefert, Westerhellweg, & Kroning, 2003). "[W]ind turbines are being whipsawed and hammered to pieces constantly, and the public is not being made aware of this real and present danger, for fear there will be a grass-roots uprising against it before they are saddled with [wind parks] and don't have any more say-so in the matter." (Brougher, 2008). *Tower failure for utility-scale turbines is characterized by vertical collapse (like a beverage can crushing when stepped on), rather than tipping over from the base. Tower construction standards should guide setback distances, rather than the remote possibility of tower tip-over.* *Ice throw and blade failure resulting in parts hurtling through the air are increasingly rare. Modern turbines are continuously monitored in real time and will shut themselves down if ice accumulates on blades. Ice shedding is thus almost exclusively limited to the zone directly underneath the turbine.*

Table 4 (Continued): Typology of Anti-Wind Park Arguments

Topics and Subtopics	Example of anti-wind characterization. *Siting and Zoning Relevance.*
Safety (continued) Ice-throw Blade failure Tower failure	*Setback distances of 1.5 times turbine height (tower plus blade) should be considered maximal. Neighbors should have the right to waive setback distances from "participating" buildings and property lines. Wind-park owners (and insurers) should be liable for damages caused by ice throw, blade failure, and tower failure. An escrow account should cover potential liability and decommissioning costs.*
Property Values Visual amenity Sense of place, of community Industrial appearance Tourism impacts	"The days on market was more than double for those properties inside the windmill zones. The sold price was on average $48,000 lower inside the windmill zones than those outside. The number of homes not absorbed (not sold) was 11% vs. 3%." (Luxemburger, n.d.). "There are people who can't sell their homes and are forced to rent other living accommodation and people who sell their homes to the wind energy companies at much reduced prices and then are 'gagged' from talking about any of the negative health effects" (Chevalier, n.d.). "The degradation these enormous sprawling industrial complexes bring to our cultural and visual resources is least understood. Our colleagues… describe West Texas today as an alien landscape where one can drive for miles and miles and miles (and miles) and see nothing but wind turbines. The nighttime experience is even more surreal with the blinking red lights." (Industrial Wind Action Group, 2005). *An escrow account should cover potential liability and decommissioning costs.*
Wildlife and Natural Features Avian mortality (birds and bats) Habitat destruction, fragmentation	"Where'd all the animals go? My guess is as far away from those things as they can get." (Brougher, 2008). "Save the Eagles International wishes to warn the international community about the threat that windfarms and their power lines represent for biodiversity. Unlike cars, buildings, and domestic cats, wind turbine blades and high tension lines often kill protected or endangered birds like eagles, cranes, storks, etc. Cumulatively and over the long term, 3.5 million wind turbines to be installed worldwide will cause the extinction of many bird species, some of them emblematic." (Duchamp, 2011). *Exclusion zones should be identified in concert with state and federal wildlife agencies based on the best available scientific information and pre- and post-construction monitoring. Mitigation measures should be identified and included in siting stipulations. Mitigation funds should be included in escrow accounts as necessary to ensure compliance.*
Energy Policy Capacity factor Emissions effects Integration costs Reliability	"The erratic nature of the wind means that turbines simply cannot supply the base load that other forms of generation do. Those other generators will continue to be needed to back up the wildly variable output of wind turbines, with the probability that in so doing these plants will actually emit more pollution for each kilowatt-hour they generate than if they were allowed to operate normally." (Roberson, 2004). "[S]ome reliable, dispatchable generating unit(s) must be immediately available at all times -- and operating at less than peak efficiency and capacity -- to "back up" the unreliable wind generation. The reliable, backup unit(s) must ramp up and down to balance the output from the wind turbines. … Wind turbines have virtually no 'capacity value.' Thus, electric customers pay twice: once for the wind energy and again for reliable capacity." (Schleede, 2005).

Table 4 (Continued): Typology of Anti-Wind Park Arguments

Topics and Subtopics	Example of anti-wind characterization. *Siting and Zoning Relevance.*
Energy Policy (continued) Capacity factor Emissions effects Integration costs Reliability	"Peak power… during the hottest summer months… [is] far more demanding on the power grid, yet the wind power available in the winter months… is on average greater than in the summer. That's a huge contradiction… . Nor can we store wind power… . So for the most part, winter winds and spring storms must either be wasted, or they will create surges which blow out the transformers, power equipment, and burn up their own generators, and set the grid back hundreds of millions of dollars, as has happened by wind surges in Oregon, and many times in Denmark, Germany, and other nations… ." (Brougher, 2008). "In high winds, ironically, the turbines must be stopped because they are easily damaged." (Brougher, 2008). "A nuclear plant is tens of times cheaper and thousands of times safer per [terawatt-hour] than gigantic air turbines will ever be – even if we learn someday how to prevent them from burning up, blowing the grid, and folding in half under a high wind load, and blending our birds with the landscape." (Brougher, 2008). *The only relevance to siting and zoning might be for substations and transmission facilities, which also need approvals. None of these other issues are siting and zoning issues, per se.*
Economic Development Subsidies Employment	"Tax avoidance – not environmental and energy benefits – has become the prime motivation for building 'wind farms.' … 'Wind farms' produce few local economic benefits and such benefits are overwhelmed by the higher costs imposed on electric customers through their monthly bills. … When the expected contribution of wind energy toward supplying US energy requirements is taken into account, wind energy is among the most heavily subsidized of all energy sources." (Schleede, 2005). "[I]nvestment dollars going to "renewable" energy sources would otherwise be available… for other purposes that would produce greater economic benefits. 'Wind farms' have very high capital costs and relatively low operating costs compared to generating units using traditional energy sources. They also create far fewer jobs, particularly long-term jobs, and far fewer local economic benefits. 'Wind farms' are simply a poor choice if the goals are to create jobs, add local economic benefits, or hold down electric bills." (Schleede, 2011). "[B]illions of [federal grant] dollars… – all of it exempt from federal corporate income taxes – is being used to fatten the profits of some of the world's biggest companies" (Bryce, 2011). *These are not relevant siting and zoning concerns.*

II. Best Practices for Wind Siting and Zoning Procedures

Table 5 briefly summarizes the best practices for wind siting and zoning procedures. The recommendations are influenced by practices in those states and several foreign countries where wind energy resources have been developed with what appears to be a minimum of regrets.

Of course to some extent, progress in wind energy development can reflect simply an abundance of wide-open spaces where turbines can be placed without affecting many citizens at all. As shown in Table 2, many of the states that are leading in installed wind energy capacity are in the Great Plains and West and have an abundance of rangeland and farmland, large land parcels, and sparse population density. Prominent examples include Iowa, North Dakota, Oklahoma, Texas, and Wyoming. On the other hand, there are several states that do have greater population density and more urban and suburban lands where wind development is also already substantial and growing. Prominent examples of those include Illinois, Indiana, Minnesota, and New York.

In any case, the recommendations presented here and in Part III reflect what has been gleaned from the survey of the states, a review of the literature, and the author's experience and best judgment.

Table 5: Best Practices for Procedures

Recommendation	Description
1. Develop procedures that result in clarity, predictability, and transparency	Jurisdictions with locations suitable for commercial wind development should anticipate interest and proceed to develop and publish siting and zoning procedures, principles, and guidelines.
2. Establish a one-stop, pre-submission consultation	Provide basic information for applicants in a single meeting, identifying and explaining the basics of all necessary permits and approvals.
3. Identify and map constrained and preferred wind energy development zones	Make available and accessible to the interested public GIS maps of exclusion, avoidance, and preferred development zones
4. Include preferred development zones in transmission plans	Begin modeling and planning for wind power interconnections in preferred development zones as soon as the zones are identified.
5. Prepare and make available guidelines for participants	Explain procedures and timelines for when, where, and how to participate in public hearings. Provide information about decisions already completed through rulemaking.
6. Prepare and make available for local siting and zoning officials guidelines, checklists, and model ordinances	Support local government decision makers by providing the best available technical resources.
7. Ensure the sequence for obtaining permits and approvals meets requirements to allow development of suitable projects	The sequence of events leading to approval or rejection of an application should entail a logical progression through the planning and design stages, prior to siting and zoning approval that allows construction to begin.

A. Develop procedures that result in clarity, predictability, and transparency

All involved parties benefit from procedures that are clear and predictable and lead to transparency in decision making. Procedures need to be spelled out in ample detail so that all participants can understand how to participate, and when and where participation is expected. Applicants should understand their responsibilities. This all sounds obvious, but experience shows that in too many circumstances procedures are not spelled out. Applicants and other participants often find it difficult to learn what is expected, the sequence of events and venues, and time frames needed to progress through the siting and zoning process.

At the outset, a lack of clarity can be blamed on the novelty of siting and zoning for a wind park. However, all siting and zoning officials can quickly learn about the general attractiveness of their jurisdiction for commercial wind energy development. Wind resource maps are readily available that are accurate enough for making general determinations about good, better, and best areas for commercial development (Wind Powering America, 2011). Jurisdictions with locations suitable for commercial wind development should anticipate interest and proceed to develop and publish siting and zoning procedures, principles, and guidelines.

B. Establish one-stop, pre-submission consultation for applicants

A best practice for siting and zoning is to establish a one-stop procedure for applicants, in the form of a pre-submission consultation (Rosenberg, 2008, p. 681). This means applicants will have an opportunity to meet once, with one or more of the responsible agencies. The goal is for the applicant to come away from the one meeting with a clear understanding of all the necessary permits and approvals needed. One-stop procedures can be difficult when coordination involves multiple levels of government, but good communications can still work towards this goal. If nothing else, at least the organization with lead responsibility for wind-park siting and zoning can have available for applicants a list of all permits and approvals, which specifies the criteria that trigger each requirement. For each permit or approval, the one-stop agency should be able to communicate all the basic information about each requirement, including the contact persons, procedures, sequence of approvals required, timelines, and where and how to obtain complete, detailed information.

Delaware, Florida, and Oregon have provisions for one-stop meetings with applicants. Florida and Oregon both have state level siting (although Florida's applies to other kinds of power plants, not wind parks). Delaware has primarily local siting and zoning for wind parks, but a one-stop state agency helps applicants understand all required permits.

C. Identify and map constrained and preferred wind energy development zones

Siting and zoning authorities should identify and communicate about constrained and preferred development zones; in preferred areas development would be encouraged, and in constrained areas, the opposite. Information about these zones should be available in geographic information system (GIS) format. Examples of constrained zones include areas already identified as important to the life-cycle of endangered species, areas of particular historical or archeological importance, and wetlands, and can take two forms: exclusion zones and avoidance zones. Exclusion zones are known to be off limits, and avoidance zones are places where development deserves extra caution. Many government agencies that have what is effectively veto power over siting and zoning already have maps in GIS format, showing areas that are either exclusion or avoidance zones. Basic mapping information should be available, identifying constrained zones and the relevant buffers around the constraints (Great Lakes Wind Collaborative, 2011, *Best Practice #11*).

Such maps will not be a complete substitute for ground-truth assessments of specific locations, but they can go a long way towards helping all parties to avoid wasting time and resources on the evaluation of locations that will ultimately prove to be unavailable for development. Where jurisdictions have made determinations about setback (i.e., buffer) distances, those can also be clearly communicated. All interested parties should be able to use the available maps to understand both macro- and micro-siting. As Rosenberg (2008, p. 681) explains, such maps serve to "highlight actual and potential conflicts between wind power projects and listed sensitive lands." "Hopefully," he notes, "projects could be planned to avoid these areas and if [wind power projects] were proposed for sites in the vicinity of such areas, potential adverse impacts could be mitigated through careful project planning."

Preliminary examples of this type of mapping capability are available from the Great Lakes Wind Collaborative (GLWC, http://erie.glin.net/wind/, retrieved 9 Jan 2012) and Vermont Energy Atlas (www.vtenergyatlas.org, retrieved 20 Jan 2012). The GLWC GIS system for eight states and two Canadian provinces assembles many different GIS map layers already available from various sources. It demonstrates a system that can facilitate identifying areas of concern. The Vermont atlas system does not yet include information about constrained zones, but it does demonstrate excellent ease of use and presents much practical information.

Similarly, if state or local jurisdictions have identified preferred development zones, information about those areas can be made available in map form. For example, several states are engaged in identifying renewable energy zones to receive special treatment for transmission expansion (see Table 1, Column 15). Also, some states have identified renewable energy resource development as a priority use for brownfield redevelopment (for example, New Jersey Statute § 40:55D-66.11, 31 Mar 2009, *Wind and solar facilities permitted in industrial zones*, www.dsireusa.org/documents/Incentives/NJ17R.htm). Colorado enabling legislation encourages county master plans to consider both "methods for assuring access to appropriate conditions for solar, wind, or other alternative energy sources… [and avoiding] areas containing endangered or threatened species" (Colorado Revised Statutes 30-28-106(3)(a)(VI)–(XI), www.michie.com/colorado). Similarly, Denmark directs its county governments to identify wind development zones (Danish Energy Agency, 2009, pp. 12-14).

Procedures for identifying areas for preferred development should ensure meaningful public participation and input, but once preferred development areas are selected, then information about those zones should be readily available to help guide developers.

D. Include preferred development zones in transmission plans

As discussed above, mapping preferred (and constrained) zones is recommended. With preferred zones, the mapping should, ideally, go one step further. Depending on the estimated wind power production from preferred development zones, the areas should be linked to and coordinated with transmission development plans (see Great Lakes Wind Collaborative, 2011, *Best Practices* #4 and #5). If the estimated production in a preferred development zone is substantial, wind parks will need to be interconnected to the electric transmission, rather than distribution, system. The determination of what capacity level is too big for the local distribution system needs to be done on a case-by-case basis: It depends on the design and operation of the existing distribution and transmission systems, and on nearby loads and generation.

Whatever interconnections will be required, whether to the distribution or transmission system or both, modeling and planning for interconnections in the preferred development zones should begin as soon as the zones are identified. The reason is that the entire process for transmission planning, design, and construction – including the transmission siting and zoning process – will often take much more time than the process for planning, designing, obtaining approvals, and constructing a wind park. As shown in Table 1, Column 15, 23 states are already engaged in procedures to identify wind energy resource zones, with those procedures linked to transmission planning. That includes 9 of the top 10, 16 of the top 20, and 21 of the top 30 states, in terms of wind capacity development.

E. Prepare and make readily available guidelines for participants

All participants need clearly understandable guidelines, so they can know ahead of time when to expect public hearings, what will be the substance of those hearings, and how to participate. Many participants will not be frequent participants in planning and zoning hearings. It certainly helps if they learn what is expected.

As shown in Table 4, wind-park opponents frequently raise issues that are not germane to siting and zoning hearings. It is best for everyone concerned if clear, complete information is provided, prior to public hearings, to explain which venues will be addressing which subjects. Where guidance or regulations exist, those should be made clear. For example, California legislation establishes restrictions for tower height, parcel size, setbacks, and noise level, and prescribes practices for public notice of applications and hearings (Assembly Bill 45 of 2009; see Database of State Incentives for Renewables & Efficiency, *California – County Wind Ordinance Standards,* retrieved 22 Dec 2011 from www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=CA61R&re=1&ee=1).

Maine has spelled out the sequence of procedures that apply to wind siting and zoning but does not include the expected timelines.

Ohio mandates public information meetings prior to "filing an application to build a new facility." These are not formal public hearings, which take place after an application is filed. The purpose for a public information meeting is "to inform stakeholders about plans to file an application… [and] as an opportunity to gather public input and hear the public's concerns, which the company considers in developing its application." (Ohio Power Siting Board, 2010, http://www.puco.ohio.gov/emplibrary/files/OPSB/Presentations_Manuals/OPSBbrochure2010.pdf).

There is no conclusive evidence that educational meetings will reduce public concerns or opposition. On the other hand, there is reason to believe that public opposition increases and festers if people feel, rightly or wrongly, that procedures do not provide adequate opportunities for public concerns to be aired and addressed. (See, for example, English, pp. 307-08, and Huber & Horbaty, 2010, pp. 50-51.) In fact, there is extensive literature about public engagement and participation in all kinds of land use and technology decisions, and explicitly about wind parks (see, for example: Agterbosch, Meertens, & Vermeulen, 2009; Hindmarsh, 2010; Koebel, 2011; Jones & Eiser, 2009; Mazur, 2007; Sovacool, 2009; Toke, Breukers, & Wolsink, 2008; and Wilson & Grubler, 2011).

F. Prepare and make available for local siting and zoning officials guidelines, checklists, technical resources, and model ordinances

States should consider providing technical documents to help support local government decision makers. This is important for states that have a shared or exclusive local government responsibility for wind siting and zoning, and wherever state rules do not supersede or at least constrain local authority.

It is important to recognize that local authorities might not be familiar with wind siting and zoning. It is certainly not likely that any particular local authority will come to their job with a background in wind siting and zoning. As with many issues facing local governments, specialized education is often needed to arm local governments with the tools necessary to guide decisionmaking.

As Rosenberg (2008, pp. 674-75) notes, there is a concern that "[l]ocal zoning decisions can be little more than project 'popularity contests' driven by the prevalent popular sentiment." And, he points out, the generally rural local governments that are most likely to receive proposals "often have limited resources" and can be lacking the "extensive planning resources or personnel… to evaluate wind power siting proposals." Therefore, Rosenberg (2008, pp. 675-76) prescribes "an attitude of 'shared responsibility'" between state and local governments. He recommends "provid[ing] local governments, planners and citizens with expert state-level guidance… .” This approach can include “voluntary guidelines, checklists, and technical resources… to aid [local governments] in their evaluation of siting wind projects.”

As shown in Table 1, columns 7 through 11 report on the kinds of information discussed here. Twenty-seven states have published evaluation criteria that support wind siting and zoning. Those are frequently environmental protection criteria, though, rather than explicit wind siting and zoning criteria, and apply to all construction projects. Ten states have published voluntary guidelines for wind parks, but three of those are exclusively guidelines for wildlife and habitat protection. Ten states have model ordinances and six states have model standards for setback and sound. Although many states have one or more of these documents available, only Georgia, Michigan, and New York have provided both voluntary guidelines and model ordinances. Only three states (Delaware, Rhode Island, and Virginia) have published mandatory rules about both setback and sound. Minnesota has a sound standard and Wyoming has a setback standard.

G. Ensure that the sequence for obtaining permits and approvals meets requirements to allow development of suitable projects

Procedures should allow for suitable projects to obtain all required approvals. The sequence of events leading to approval or rejection of an application should entail a logical progression through the planning and design stages, prior to siting and zoning approval that allows construction to begin.

For example, at least one state agency requires a project application to include certification that the project complies with all applicable land-use ordinances and a copy of a final interconnection agreement. At least some developers might hesitate to spend as much as sometimes can be required to obtain a final interconnection agreement, unless and until they are certain the project is approved.

Also, power purchase agreements (PPAs) could require developers to demonstrate that a project has the requisite control over the property planned for development (that is, land leases), siting and zoning approval, sufficient progress towards obtaining an interconnection agreement, and the financial wherewithal to complete construction and enter into commercial operation in a reasonable time period. If those are requirements for the sale of wind-generated electricity, then the siting and zoning approval cannot be contingent upon obtaining the PPA.

III. Guidelines for Implementing Wind-Park Siting and Zoning Criteria and Setback Distances

This part of the report reviews the many criteria that are addressed in wind-park siting and zoning, and provides guidelines based on the best available information about each criterion. As already mentioned (see p. 2), best practices are subject to refinement over time, as more knowledge is gained and as wind generator technologies change and improve. Table 6 summarizes the recommendations included in Part III.

Table 6: Wind-Park Siting and Zoning Criteria, Recommended Approaches and Setback Distances

Criterion	**Recommended approach**
Noise, sound, and infrasound	• Noise standards should allow some flexibility. • Noise standards should vary depending on the area's existing and expected land uses, taking into account the noise sensitivity of different areas (e.g., agricultural, commercial, industrial, residential). • Determine pre-construction compliance using turbine manufacturer's data and best available sound modeling practices. • Apply a planning guideline of 40 dBA as an ideal design goal and 45 dBA as an appropriate regulatory limit (following Hessler's proposed approach, 2011). • Allow participating land owners to waive noise limits. • Establish required procedures for complaint handling. • Identify circumstances that will trigger, and techniques to be used for: (a) mandatory sound monitoring; (b) arbitration; and (c) mitigation. • Do not regulate setback distance; regulate sound.
Shadow flicker	• Restrict to not more than 30 hours per year or 30 minutes per day at occupied buildings. • Allow participating land owners to waive shadow-flicker limits. • Allow the use of operational practices and mitigation options for compliance. • Do not regulate setback distance; regulate the duration of shadow flicker.
Ice throw	• Authorize demonstrated ice control measures. • Require wind park to provide insurance and escrow funds to ensure compensation for proven damages resulting from ice throw. • Do not regulate setback distance; regulate ice throw.
Wildlife and habitat exclusion zones	• Responsible wildlife protection agencies should use the best available scientific knowledge and data to determine exclusion and avoidance zones and appropriate buffers (that is, setback distances) beyond those zones. • Permits should specify required pre-, during-, and post-construction monitoring. • Permits should specify how mitigation requirements will be determined and what mitigation techniques will be considered. • Regulate setback distances as required by responsible wildlife protection agencies and do not authorize siting in exclusion and buffer zones.
Aesthetic requirements	• Require neutral paint color and minimal signage. • Require the minimum of nighttime lighting necessary to achieve FAA compliance. • Require that realistic visual impact assessments, accessible to the public, be included in wind park planning and applications. • Manage visual impact through setbacks and exclusions from critical competing land uses.

Table 6 (Continued): Wind Park Siting and Zoning Criteria, Recommended Approaches and Setback Distances

Criterion	Recommended approach
Critical competing land uses	• Map as excluded zones any special cultural, anthropological, “sacred” lands, and highly valued scenic vistas. • Apply reasonable setbacks from non-participating property lines, occupied buildings, scenic vistas, and transportation and utility rights of way. • Allow participating properties to at least partially waive setback requirements from property lines and occupied buildings, in writing.
Permit requirements for met towers, construction, and facility safety	• Predetermine requirements and simplify procedures for approving meteorological (met) towers. • Regulate heavy construction requirements the same as any other heavy construction project, using the regulatory permitting system (e.g., for stormwater, surface water, transportation, noise, and wetlands permits). • Check for all required approvals for potential interference with radio and TV reception or radar. Provide for testing and mitigation of radio and TV interference problems that do occur. • Regulate structural safety (against, e.g., tower tip-over or blade failure) through construction codes, combined with minimal setback requirements. • Regulate facility safety (e.g., preventing climbing towers, ensuring electrical safety, providing fencing around electrical gear).
Decommissioning	• Set clear requirements for what triggers and what constitutes decommissioning and restoration or reclamation. • Establish a decommissioning escrow fund, to ensure adequate resources will be available at the end of a project’s useful life or in the event the development fails.
Dispute resolution and mitigation	• Establish procedures for dispute resolution and mitigation.

A. Avoiding or mitigating public health and safety, nuisance and annoyance issues

Ellenbogen et al. (Jan 2012, p. ES-5) report, based on their independent review of the best available literature, that a “self-reported ‘annoyance’ response appears to be a function of some combination of the sound itself, the sight of the turbine, and attitude towards the wind turbine project.”

The Ellenbogen et al. study (Jan 2012, p. ES-7) concludes:

> There is no evidence for a set of health effects, from exposure to wind turbines that could be characterized as a “Wind Turbine Syndrome.” … [T]he weight of the evidence suggests no association between noise from wind turbines and measures of psychological distress or mental health problems. … None of the limited epidemiological evidence reviewed suggests an association between noise from wind turbines and pain and stiffness, diabetes, high blood pressure, tinnitus, hearing impairment, cardiovascular disease, and headache/migraine.

But the same researchers (Jan 2012, p. ES-11) recommend “an ongoing program of monitoring and evaluating the sound produced by wind turbines… [including] more comprehensive assessment of wind turbine noise in populated areas.” “Such assessments,” they report, “would be useful for refining siting guidelines and for developing best practices… .”

In any case, some people really do get upset by the idea of, or the actual fact of, wind turbines being built nearby. As opponents in a siting and zoning process, they have a tendency to raise every argument they can think of to help dissuade officials from approving projects. (See Table 4).

The following materials address the significant concerns that are raised about public health, safety, nuisance, and annoyance issues. Not included in this list are electromagnetic field (EMF) effects and stray voltage. Those subjects should be regulated by other agencies, typically the PUC, and are not germane to siting and zoning decisions.

Some research suggests that wind-park opponents are affected by a "nocebo" effect, which is essentially the opposite of a placebo effect (see the Skeptic's Dictionary, http://skepdic.com/nocebo.html, retrieved 27 Dec 2011). One widely cited study (Pedersen, Bouma, Bakker, & van den Berg, 2008) finds evidence of a nocebo reaction, among neighbors with no financial interest and an anti-wind-park predisposition. Ellenbogen et al. (Jan 2012, p. ES-8) state somewhat the reverse of this assessment. They find:

> Effective public participation in and direct benefits from wind energy projects (such as receiving electricity from the neighboring wind turbines) have been shown to result in less annoyance in general and better public acceptance overall.

The next few sections of this report: (1) address noise, sound, and infrasound; (2) shadow flicker; (3) ice throw; and (4) pre- and post-construction monitoring of noise, sound, and infrasound.

1. Noise, sound, and infrasound

As can be inferred from dictionary definitions: (a) "noise" means sound that humans perceive as generally loud, unpleasant, unexpected, or undesired; "noise" means sounds that are disturbing; (b) "sound" means simply the sensations that can be perceived by the sense of hearing; and (c) "infrasound" means "a wave phenomenon of the same physical nature as sound but with the frequencies below the range of human hearing" (*Merriam-Webster Dictionary*, retrieved 24 Jan 2012 from http://www.m-w.com/dictionary/). Sound pressure is measured in decibels (dB), using a device called a sound level meter. Decibels are measured using either an "A-weighted" scale (dBA, sometimes written "dB(A)") or "C-weighted" scale (dBC, or "dB(C)"). The A-weighted scale is intended to measure the sounds as they are subjectively perceived by the human ear. The C-weighted scale is highly sensitive to low-frequency sound and is therefore normally used to evaluate sources where the low-frequency content of the sound is prominent or dominant. The C-weighted scale was developed to assess sound levels more commonly associated with occupational exposures. Environmental noise limits are commonly expressed solely in terms of A-weighted decibels.

Ellenbogen et al. (Jan 2012, p. ES-6) reviewed the best available reports on noise, sound, and infrasound. They conclude:

> [I]t is possible that noise from some wind turbines can cause sleep disruption. … A very loud wind turbine could cause disrupted sleep, particularly in vulnerable populations, at a certain distance, while a very quiet wind turbine would not likely disrupt even the lightest of sleepers at that same distance. But there is not enough evidence to provide particular sound-pressure thresholds at which wind turbines cause sleep disruption. Further study would provide these levels. … Claims that infrasound from wind turbines directly impacts the vestibular system have not been demonstrated scientifically. Available evidence shows that the infrasound levels near wind turbines cannot impact the vestibular system.

Hessler (2011, pp. 11-12) reports:

> [A]ny noise limit on a new project must try to strike a balance that reasonably protects the public from exposure to a legitimate noise nuisance while not completely standing in the way of economic development and project viability. It is important to realize that regulatory limits for other power generation and industrial facilities never seek or demand inaudibility but rather they endeavor to limit noise from the source to a reasonably acceptable level either in terms of an absolute limit (commonly 45 dBA at night) or a relative increase over the pre-existing environmental sound level (typically 5 dBA19). … [T]he rate of adverse reaction comes down to a handful of individuals or very roughly about 4 to 6% when residences are exposed to project sound levels in the 40 to 45 dBA range. … [T]he vast majority of residents living within or close to a wind farm have no substantial objections to project noise, particularly if the mean sound level is below 40 dBA. …While the possibility of annoyance, if not serious disturbance, can almost never be completely ruled out, it appears that the total number of complaints would be fairly small as long as the mean project level does not exceed 40 dBA.

The inconsistency in reactions to wind turbine and wind-park noise makes it difficult to establish any absolute criteria that siting and zoning officials could use in all circumstances. Hessler (2011, p. 21) explains:

> [T]he exact reaction to any project can never be predicted with certainty because project noise is often audible to some extent, at least intermittently, far from the project. However, the studies of response to wind turbine noise… suggest that the threshold between a mild or acceptable impact and a fairly significant adverse reaction is a gray area centered at 40 dBA.

However, observations of neighbors' reactions to newly operational wind farms suggest that it is not necessary to rigidly impose a maximum noise level of 40 dBA in order to avoid complaints. Hessler (2011, p. 12) recommends 40 dBA as an *ideal* design goal, if it can reasonably be achieved, but 45 dBA as an appropriate regulatory limit. Adverse reactions to wind turbine noise between 40 and 45 dBA are still quite low, at roughly 2 percent of wind-park neighbors, even in rural environments with low background levels.

As with siting and zoning for other activities, the social good produced from the activity needs to be weighed against any local disturbances, including annoyances and nuisances. As with the siting and zoning of any other legal activity, the appearance of complaints, even more so the potential for complaints, is not reason enough for denial. From a legal standpoint, the preponderance of available evidence leads to the conclusion that noise requirements for wind turbines should be the same as those applied to any other legal activity that could be sited or zoned in the same jurisdiction.

Noise standards should also allow some flexibility because of the highly variable nature of both background noise and wind turbine noise. No single incursion beyond the noise standard should force abandonment of a wind park. The wide variability in wind turbine sound propagation makes it impractical to require absolute compliance with this kind of limit. Hessler (2011, pp. 35-63) provides detailed guidance for post-construction testing procedures.

The noise standard should allow micro-siting and construction based on the best available data on noise generated by the turbines planned for installation and modeling of the local conditions. It is also important to allow participating property owners to waive noise limits, in writing.

In approving wind-park construction, the siting and zoning permit should establish clear procedures to be invoked if there are complaints about noise. The wind-park owners and operators should have the opportunity to mitigate any confirmed problems, using any combination of operational and technical changes. For example, Leung & Yang (2012, p. 1037) identify opportunities to "significantly" reduce wind turbine noise "by putting obstacles in the [sound] propagation path." These researchers also report a promising experiment where an "optimized… or serrated blade" noticeably reduced wind turbine noise.

As Ellenbogen et al. (2012, p. ES-11) propose, "If noise control measures are to be considered, the wind turbine manufacturer must be able to demonstrate that such control is possible."

Ellenbogen et al. (2012, p. ES-11) also recommend "an ongoing program of monitoring and evaluating the sound produced by wind turbines… [including] more comprehensive assessment of wind turbine noise in populated areas… ." They elaborate:

> These assessments should be done with reference to the broader ongoing research in wind turbine noise production and its effects, which is taking place internationally. Such assessments would be useful for refining siting guidelines and for developing best practices… .

North Dakota Department of Transportation (NDDOT, 2011, pp. 1, 6-7), as the state's policy for "implementation of the requirements of the Federal Highway Administration (FWHA) Noise Standard at 23 Code of Federal Regulations (CFR) Part 772," identifies and categorizes lists of specific, "noise sensitive land uses." These cover everything from areas where "serenity and quiet are of extraordinary significance and serve an important public need" to "cemeteries, day-care centers, hospitals, libraries…" to areas where noise is expected and land uses are presumed to be "not sensitive to highway traffic noise" such as "agriculture, airports, … industrial, logging, … manufacturing, [and] mining… ." Similar guidelines could be produced for wind parks, or perhaps the guidelines for transportation projects could be adapted for application to wind-park siting and zoning.

2. Shadow flicker

Shadow flicker is defined as "alternating changes in light intensity that can occur at times when the rotating blades of wind turbines cast moving shadows on the ground or on structures" (Priestley, 2011, p. 2). The International Energy Agency (2010, p. 42) identifies shadow flicker as a nuisance.

The existence of shadow flicker depends on turbine micro-siting, with respect to the distance from the turbine and compass direction between the turbine and any surfaces of concern. Wind-park designers can model where shadows might fall on each day of the year (see, for example, Zephyr North, 2009).

Shadow flicker will affect any particular location only during either sunrise or sunset. The specific location is a function of the potential alignment between the sun, a wind turbine, and a receiving surface, Given the geometry of the potential alignment, and then depending on the latitude and tilt of the earth on its axis, the effect can happen for only a small number of days per year as the point in the horizon where sunrise or sunset appears changes, moving north or south by a small compass angle each day. Plus, on those several days and during the times when shadows could occur, the sky needs to be clear enough for the effect to be noticeable.

In their study, Ellenbogen et al. (2012, p. ES-7–8) determine:

> Scientific evidence suggests that shadow flicker does not pose a risk for eliciting seizures as a result of photic stimulation. … There is limited scientific evidence of an association between annoyance from prolonged shadow flicker (exceeding 30 minutes per day) and potential transitory cognitive and physical health effects.

Shadow flicker should be determined as a pre-construction activity. Reports can be provided so that the possible shadow effects on properties, buildings, and roadways can be understood. A reasonable standard can rely on micro-siting modeling to ensure that shadow flicker will not exceed 30 hours per year or 30 minutes per day at any occupied building. These are the most commonly used guidelines (Lampeter, 2011, pp. 5-14). However, the standard should also allow for property owners to waive the shadow-flicker maximum and for mitigation options, which could include changes in landscaping or window treatments to minimize concerns. It is even conceivable that a contract between a wind-park operator and property owner would provide for shadow-flicker limits through operational control, simply curtailing a particular turbine during those times when shadow flicker would otherwise constitute a nuisance in excess of the local standard or some other agreed limit.

3. Ice throw

Ellenbogen et al. (2012, p. ES-8) report:

> In most cases, ice falls within a distance from the turbine equal to the tower height, and in any case, very seldom does the distance exceed twice the total height of the turbine (tower height plus blade length). … There is sufficient evidence that falling ice is physically harmful and measures should be taken to ensure that the public is not likely to encounter such ice.

These researchers (Ellenbogen et al. 2012, p. ES-12) also advise that any ice-control measures used to comply with permit requirements should be demonstrated by the wind turbine manufacturer.
Modern wind turbines that are planned for installation in climates where icing can be expected will have both physical characteristics and operational controls designed to minimize any concern about ice throw. Turbines are designed to stop rotating if ice builds up on blades, and some designs include blade heaters to shed ice. For siting and zoning purposes, it should be sufficient to review the plans for managing operations to minimize ice throw, and to require the wind-park owners to maintain liability insurance against the unlikely event that ice throw causes any damage or injury. Explicit setback requirements for ice throw should not be necessary.

4. Pre- and post-construction monitoring for public health and safety, nuisance, and annoyance issues

Since noise is one of the most common concerns for wind-park development, both pre- and post-construction monitoring should be considered for at least some facilities. Together, developers, communities, and siting and zoning authorities can determine which areas deserve special attention for pre-construction monitoring. Post-construction monitoring could be established only as a requirement for addressing noise complaints.

Hessler (2011, p. 25) proposes the pre-construction background-sound testing protocol:

> [A] long-term, continuous monitoring approach is needed in which multiple instruments are set up at key locations and programmed to run day and night for a period of about two weeks or more. In essence, it is necessary to cast a wide net in order to capture sound levels during a variety of wind and atmospheric conditions and provide sufficient data so that the relationship between background noise and wind speed can be quantitatively evaluated. … [I]t is highly preferable to conduct this type of survey during cool season, or wintertime, conditions to eliminate or at least minimize possible contaminating noise from summertime insects, frogs and birds. In addition, it is best for deciduous trees to be leafless at sites where they are present in quantity to avoid elevated sound levels that might not be representative of the minimum annual level. Human activity, such as from farm machinery or lawn care, is also normally lower during the winter. While summertime surveys can be successful they should, as a general rule, be avoided wherever possible because nocturnal insect noise, for instance, can easily contaminate the data and make it impossible to quantify the relationship between sound levels and wind speed.

As already mentioned, Hessler (2011, pp. 35-63) provides detailed guidance for post-construction testing procedures.

All interested parties should recognize the potential role of post-construction monitoring for at least some wind parks, to produce the information necessary to inform best practices. But it is not necessary for every wind park to be monitored. Modeling and testing are reliable enough to deduce the likely noise effects from studies of similar turbines, wind conditions, terrain, and setback distances.

B. Preventing harm to flora, fauna, and habitats

Operating wind turbines in particular locations can harm ecosystems. Of special concern has been the killing of birds and bats. Thus, siting and zoning standards typically include provisions designed to protect wildlife and wildlife habitat.

The role in siting and zoning is to require the appropriate reviews before approval is granted and before construction begins. Specific wildlife and habitat concerns will require some locations to be excluded from development. Examples include habitats known to be used by threatened or endangered species or migratory birds, and wetlands. Such exclusions or related restrictions are governed by federal and state environmental protection laws and regulatory agencies. Siting and zoning authorities should also require applicants to demonstrate compliance with and approvals granted by the relevant environmental regulatory agencies, before a siting and zoning application is considered complete.

Wildlife and environmental studies are routine but critically important components of due diligence for wind-park planning. Developers know these studies are integral to obtaining the approvals that will allow construction and operation, and lenders check the studies prior to approving wind-park financing. The last thing a developer wants is to find out, post construction, that there are problems that threaten long-term operations. In fact, a developer wants to find out about such problems as early as possible, before dedicating resources to prospecting and planning for an area that can later prove to be undevelopable.

The wind industry has taken many steps to understand wind and wildlife interactions and has already changed tower and turbine designs, operating practices, and macro- and micro-siting to avoid, prevent, or mitigate problems. The American Wind Wildlife Institute (AWWI) was formed in 2008-09, as a forum for wind developers and manufacturers to work with environmental and wildlife preservation organizations and experts "to provid[e] and shar[e] scientific information and tools to advance wind energy with respect for the environment" (www.awwi.org/about/ and www.awwi.org/about/founders.aspx [web pages], retrieved 7 Jan 2012). The National Renewable Energy Laboratory (n.d.) also maintains an on-line database of literature about wind and wildlife impacts.

Efforts to understand the nature and extent of interactions between wind turbines, wind parks, and wildlife and habitat are continuing (see Wind Powering America, 2011b). But, as Ewert, Cole, & Grman (2011, p.1) report, "much remains unknown" and there are interactions that are presently "inadequately understood." Thus, wildlife and environmental experts recommend a precautionary approach, combined with pre- and post- construction monitoring efforts, to provide the best available information that can be used to establish guidelines and perhaps translate to regulatory determinations. The U.S. Department of Interior, Fish and Wildlife Service is presently developing guidelines (www.fws.gov/windenergy and www.fws.gov/habitatconservation/wind.html [web pages], retrieved 7 Jan 2012).

These concerns are best managed by a combination of three practices: (1) identifying exclusion and avoidance zones based on the best currently available information about endangered and protected species and critical habitat; (2) requiring wildlife and habitat pre- and post-construction monitoring; and (3) mitigation requirements for circumstances where disturbance of important habitats cannot be avoided.

1. Wildlife and habitat exclusion zones

Exclusion and avoidance zones for wildlife and habitat should be determined by the state's responsible wildlife protection agency. As already mentioned, to the extent practical those zones should be identified and mapped ahead of time. In addition to any areas pre-identified, wind energy developers should consult with the appropriate wildlife protection agencies to determine whether areas targeted for development include any environmentally or culturally sensitive areas that should be avoided or buffered.

It is not important for the maps to publicly specify why each area has been identified. Exclusion and avoidance zones can be identified for a wide variety of reasons, including for example "environmental, cultural, and historic sites, which may include wildlife refuges, feeding areas of protected species, and sensitive federal, state, and private lands" (Michigan Wind Energy Resource Zone Board, 2009, p. 75). It is sufficient just to identify zones being excluded and indicate they are sensitive.

2. Wildlife and habitat pre- and post-construction monitoring

When a wildlife protection agency determines that wind-park construction will encroach on or border sensitive areas, the agency should have the ability to require pre-construction monitoring and reporting. Depending on the results of pre-construction monitoring, the agency should consider its ability to enforce any conditions on construction and operation. Among reasonable conditions, depending on the concerns identified, can be monitoring and reporting during and after construction.

For example, Kansas Department of Wildlife and Parks Wind Power Position Statement (quoted in www.fishwildlife.org/files/Kansas.pdf, retrieved 11 Nov 2011) declares:

> To support the study of and establishment of standards for adequate inventory of plant and animal communities before wind development sites are selected, during construction, and after development is completed. The resultant improvement in available knowledge of wind power and wildlife interactions obtained through research and monitoring should be used to periodically update guidelines regarding the siting of wind power facilities.

3. Mitigation and operating practices to minimize negative impacts

Kansas Renewable Energy Working Group guidelines (quoted in www.fishwildlife.org/files/Kansas.pdf, retrieved 11 Nov 2011) state:

> When it is impossible to avoid significant ecological damage in the siting of a wind power facility, mitigation for habitat loss should be considered. Appropriate actions may include ecological restoration, long-term management agreements, and conservation easements to enhance or protect sites with similar or higher ecological quality to that of the developed site.

Davis, Weis, Halsey, & Patrick (2009, p. 9) advise:

> For wind projects, as with any land development, the reality is that not all impacts can be avoided. Even with full efforts at avoidance and minimization, impacts often remain including bird and bat mortality and habitat loss and fragmentation. For this reason, it is essential to understand and evaluate impacts as well as assess the need for offsets and compensatory mitigation.

Parameters for these practices are determined by the relevant wildlife protection, environmental, and natural resources authorities, and will depend on the species impacted and the potential or actual problems identified. If problems are identified after construction, then it is appropriate to consider operational changes.

For example, some operational techniques presently being tested show promise for identifying the presence of birds or bats, or even the insects that birds or bats might feed on, thus allowing operators to control wind turbines to reduce bird or bat injuries and fatalities (see: Davis, Weis, Halsey, & Patrick, 2009; Deign, 2011; and Leung & Yang, 2012).

C. Aesthetics

Siting and zoning authorities frequently include aesthetic requirements in wind-park permits. These include factors such as the appearance of the turbines themselves, nighttime lighting, and other requirements to limit visual impact. From a siting and zoning standpoint, these requirements are not very different from those authorities impose on all kinds of decisions about signage, lighting, and setbacks for commercial properties.

An apparent consensus on best practices has been achieved on paint color and nighttime lighting. Although there could be continuing progress on both issues, the gist of the consensus is that paint colors should be neutral, so that the turbines blend into the landscape to a significant extent. FAA (Patterson, 2009, p. 9) has determined that towers painted white do not need any daytime strobe lighting to warn pilots. It is most common for permits to limit any signage or advertising. For example, Delaware (Chapter 80, Title 29, § 8060, http://delcode.delaware.gov/sessionlaws/ga145/chp147.shtml) requires:

> Wind systems shall be free from signage, advertising, flags, streamers, any decorative items or any item not related to the operation of the wind turbine. Electric wiring for the turbines shall be placed underground for non-building integrated systems.

Nighttime lighting can be minimized as much as practical while still meeting FAA requirements. Patterson (2009) explains the FAA requirements and how the FAA has worked to adjust its requirements for wind turbine lighting. Since nighttime lighting can be a nuisance for neighbors and an attractant for birds, bats, and the insects birds and bats might feed on, there has been interest on the part of wind turbine manufacturers, wind park developers, and the FAA to find the best means available to reduce negative impacts while keeping sufficient lighting to alert pilots of areas to avoid. The basic results are to limit turbine lights to the machines on the perimeter of a wind park and allow spacing of up to one-half mile between lighted turbines. Since 2009, in some circumstances and on a case-by-case basis, the FAA has even been able to approve a new obstacle collision avoidance system (OCAS) that reduces the need for lighting even further (Patterson, 2009, p. 13; PRNewswire, 2009).

Although many people might think of nighttime lighting as a minor issue, the FAA's responsiveness is a positive example of the way the wind energy industry and government regulators can work together to reduce negative impacts. As Patterson (2009, pp. 1-3) reports, FAA's goal has been "to make obstructions visible to airborne aircraft, while being as sensitive as possible to the surrounding environment." He reports that the FAA worked cooperatively with DOE to "[d]etermine the most effective and efficient technique for obstruction lighting of wind turbine farms… focused on Aviation Safety, with consideration for wildlife, surrounding communities, and industry... consistent [and] easy to implement."

Molnarova et al. (2012) surveyed residents in Central Bohemia, Czech Republic and reviewed 18 earlier studies to better understand public attitudes towards the visual impacts of wind turbines. They identify special concerns for "landscapes of high aesthetic quality." But they also note, similar to findings from other research on public responses to wind turbines, "The most important characteristic of the respondents that influenced their evaluation was their attitude to wind power" (Molnarova et al., 2012, p. 269). Their conclusion is that their survey research "provides a further argument for considerate planning of renewable energy… and for the use of public participation, factors known to improve public attitudes toward wind power" (Molnarova et al., 2012, p. 277, footnotes omitted).

State guidelines often include provisions designed to ensure that realistic visual impact assessments, accessible to the public, will be included in wind park planning and applications. Examples include Kansas guidelines (Kansas Energy Council, 2005, pp. 7-8) and those of Maine, New York, Vermont, and West Virginia (Vissering, Sinclair, & Margolis, 2011, p. 6). Completing visual impact assessments and making them accessible to the public should be considered a best practice. The required level of detail can be adjustable, though, to reflect the particular landscape, population density, and proximity to especially valued scenic vistas. To some extent, the retention of high-concern scenic vistas will be managed by exclusion zones and setback criteria (discussed in Part III.D, which follows).

D. Critical competing land uses and setback distances

As previously mentioned, some areas should be excluded from consideration for wind turbine placement. Some important land uses could be so difficult or even impossible to maintain in close proximity to wind turbines or wind parks, that they should be considered off-limits. As already discussed, primary examples include important anthropological and cultural resources, significant wildlife habitats and natural resource areas, and areas with preexisting land uses that are especially noise-sensitive. Mapping such areas and making that data available to developers and the public is recommended (in Part II.C).

To some degree, impacts on residential property values can serve as a proxy for the determination of the appropriateness of a wind-parks siting, because perceived adverse impacts will likely emerge in proximate home sales prices. Wind-park opponents have claimed and frequently predict that home property values have been and will be negatively affected in the area of wind parks. Therefore, they sometimes argue, any areas near homes deserve to be excluded from wind-park development.[15]

Analyzing the possible effects of wind-park proximity on home values has been difficult due to the relatively small number of transactions near the turbines (e.g., within one mile). The most thorough available studies, however (see, e.g., Hoen, Wiser, Cappers, Thayer, & Sethi, 2011, which collected 125 transactions within one mile of existing turbines), have found no evidence of an impact on selling prices due to proximity to turbines in the period after wind-parks have been constructed and begin operation. That notwithstanding, there is some emerging evidence that the period after announcement but prior to operation might coincide with significant impacts to proximate property values (see, for example: Eltham, Harrison, & Allen, 2008, p. 29; Hinman, 2010; Hoen, Wiser, Cappers, Thayer, & Sethi, 2011, pp. 280-81; Koebel, 2011, p. 9). During this period, risks to proximate property values are highest because actual impacts are difficult to ascertain, and, therefore, to the degree that home buyers and sellers take a risk-averse stance, impacts might be present.

Moreover, as with other large industrial installations, public fears can be exacerbated by perceptions of secrecy in development plans. In an effort to reduce those fears and decrease the perceived risks, a number of steps can be taken in the development process. Those include open and transparent public planning and decision-making processes that include serious attention to public sentiments and concerns, effectively engaging all interested parties in collaborative, community-based planning, and expanded efforts to accurately explain the changes to the community due to the wind-park (see Part II.E).

Setbacks from turbines for homes and property lines are a corollary to the property value impact discussion. In part because of the nascent state of research on property value impacts, reaching consensus on setback distances has been difficult across the U.S. This has been exasperated by the myriad different land uses surrounding U.S wind parks. That notwithstanding, guidelines or mandatory requirements from a handful of states do converge on 1 to 1.5 times the turbine height (that is, tower plus blade length, or more accurately tower plus rotor and blade radius) from, for example, property lines belonging to non-participating land-owners, roads, power lines, and other rights-of-way. It is also not unusual for states to require further setbacks from residences. Examples include Delaware, Massachusetts, New York, Pennsylvania, Utah and Wyoming (see survey data for these states in Appendix A).

Pennsylvania's *Model Ordinance* recommends setbacks of 1.1 times turbine height from the nearest

[15] In many areas of the country in the recent past, it could have been difficult for casual observers to isolate the possible effects of wind-park proximity because of the pervasive backdrop of major declines in home values resulting from the so-called mortgage crisis: There could have been real, observable declines in housing values that had nothing to do with wind-park proximity.

occupied building, but adds,

> For non-participating landowners, "Wind Turbines shall be set back from the nearest Occupied Building located on a Non-participating Landowner's property a distance of not less than five (5) times the Hub Height."

Wyoming's law (*Article 5 – Wind Energy Facilities, Statute 18-5-504*) requires:

- A turbine must be sited at least 110% of its height from any property line "contiguous or adjacent" to the proposed facility, unless the property owner waives the setback distance, in writing.
- A turbine must be sited at least 110% of its height from public roads.
- A turbine must be 550% of its height and no less than 1000 feet away from "platted subdivisions."
- A turbine must be 550% of its height and no less than 1000 feet away from a residential dwelling.
- A turbine must be at least half a mile from city limits.

Two versions of setback criteria are reported as being common in Nova Scotia and Ontario, one for "on-site" and one for "off-site" (that is, for participating and non-participating) residences (Watson, Betts, & Rapaport, 2011, p. 2).

As previously mentioned, appropriate wind siting and zoning requirements, exclusion zones, and avoidance areas should depend on many factors. Setback distances tend to be used by siting and zoning authorities as an administratively simple means of addressing many concerns, including, for example, noise, shadow flicker, ice throw, wildlife and habitat, and aesthetic requirements.

Setback distances are also used to address two additional concerns, tower collapse or tip-over and blade failure. Both of these are rare occurrences, at least with respect to modern utility scale wind machines, and present evidence suggests that setbacks roughly equivalent to or modestly in excess of the turbine height offer sufficient protection against such risks. As with all other kinds of buildings and towers, to some extent construction codes and standards protect the public, which makes setback provisions for these purposes somewhat redundant.

Regulating setback distances is more convenient, in many ways, compared to directly handling the underlying issues through explicit decisions on a category by category basis. One virtue of setback distances is that once they are set they are easy to measure. But wind-park opponents frequently seek excessive setback distances, which they expect will prevent developers from trying to build a project in the area. If setback distances are based on arbitrary criteria, though, they are not likely to stand up to the scrutiny of a court challenge. It is better to establish minimal setback distances based on the few criteria where setback does appear to be justified, such as ice throw, and regulate all other determinations of distances by regulating the specific concerns as mentioned earlier, such as sound, shadow flicker, exclusion and avoidance zones for wildlife and habitat, and exclusion and avoidance zones for critical competing land uses. Given all of those restrictions, developers should be encouraged to work with host communities to establish a plan for macro- and micro-siting that will respect community desires and reduce the likelihood of post-construction problems.

E. Permit requirements for met towers, construction, and decommissioning

Siting and zoning authorities are also asked to approve requests to install temporary meteorological (met) towers. It is also common and appropriate for wind-park permits to be conditioned on meeting specific terms and conditions for construction and decommissioning.

For temporary met towers, jurisdictions with commercial-quality wind resources should predetermine the requirements and simply procedures for obtaining approvals. Criteria might include, for example, the maximum height for temporary met towers, a reasonable maximum duration (such as two years for data collection, plus reasonable set-up and take-down time), setbacks of at least tip-over distance from non-waived property lines and occupied buildings, and provisions for removal or replacement after initial data collection.

For construction, developers should enter into binding agreements with the appropriate authorities, ensuring that they will meet all requirements for minimizing negative impacts during construction. That is the same as for any other major construction project, with terms covering, for example, natural resource protection (e.g., wetlands, surface and storm water), noise, dust, and traffic.

Provisions for future site decommissioning and the restoration or reclamation of the land should also be included in permit requirements, and the decommissioning plan should be adopted as a binding contract between the developer and the relevant government authorities. The plan should describe what circumstances will trigger decommissioning, and the plan should be secured by an appropriate financial instrument (e.g., performance bonds, letters of credit or other corporate guarantees).

Rosenberg (2008, p. 684) relates:

> Of particular importance in the permitting process is the closure or decommissioning phase of the project's life cycle. At the conclusion of their useful life, wind power facilities must be disassembled and the site restored to its pre-construction conditions or other conditions specified in the permit. Wind project applicants must provide financial assurance to the state that these steps are properly funded... Having this financial assurance will prevent the unfortunate situation of localities having abandoned facilities in their midst without available resources to carry out proper decommissioning.

F. Dispute resolution and mitigation

Finally, in the interest of clarity, predictability, and transparency, a wind-park siting and zoning permit should include provisions for dispute resolution and mitigation. This is no different from any other major contract, which includes fair and foreseeable provisions for complaint or dispute resolution. It is helpful for all concerned to understand their responsibilities and the procedures to be followed in the event that disputes arise.

Summary and Conclusions

The beginning of this report observes that wind-park developers have a propensity to focus their efforts first on those areas with ample wind resources and few barriers to siting and zoning. The reverse is also true; developers will avoid areas with uneconomical or marginal wind resources and where siting and zoning barriers are difficult to overcome.

Prospective wind-park neighbors who are opposed to development are likely to cheer siting and zoning ordinances that have the effect of blocking construction in their environs. But siting and zoning authorities should recognize their responsibilities both to create ordinances that meet all legal requirements, and to consider how the costs and benefits of siting decisions will affect everyone in their jurisdiction, not only those who are most vocal. And, as Ellenbogen et al. (2012, pp. ES-11–12) observe,

> The considerations should take into account trade-offs between environmental and health impacts of different energy sources, national and state goals for energy independence, potential extent of impacts, etc.

Of course there are some areas that should be excluded and reasonable setback distances should be maintained for a variety of land use types, including occupied buildings, roadways, utility rights of way, and special wildlife habitats. Leung & Yang (2012, p. 1032) report:

> Though wind power has performed well in recent years, it also creates a strong environmental impact, such as noise, visual and climatic impact. Although these impacts seem minor when compared with fossil fuels, its effect on humans should not be overlooked, due to its potential great development in usage. It is necessary to figure these potential drawbacks out, especially their potential long-term effects, and to find solutions to them in order to retain the long-term sustainability of wind energy.

Rosenberg (2008, p. 665) acknowledges:

> Although there are many advantages to wind power, disadvantages exist as well. Every energy-producing technology contains pros and cons which must be evaluated by government policymakers, the public and private investors. With regard to wind energy, some of the associated adverse effects or disadvantages are inherent in the nature of wind power itself while others relate to the use of this technology at particular sites. In the end, judgments must be made balancing and comparing the positive features with the negative ones.

Rosenberg (2008, p. 669) also points out:

> As research and experience with wind power technology become increasingly available, it is possible to separate verifiable claims of harm from those without basis in fact.

The associated hope is that increased experience, and the wisdom derived from it, will help guide future siting and zoning decisions. In the meantime, however, siting and zoning authorities, government energy policy decision makers at every level, and competitive markets that help shape energy supply and demand all have roles to play in making decisions based on the best available information.

In any case, the energy policy issues of concern to wind energy proponents also deserve some consideration in siting and zoning decisions. Those issues include, for example: diversifying energy supply; reducing reliance on fossil fuels; conserving water; and reducing or eliminating air pollutants and greenhouse gas emissions. Some weight should also be given to the prospective economic benefits for rural landowners and rural areas and from wind energy manufacturing, construction, operations and maintenance (Rosenberg, 2008, pp. 659-665).

The precautionary principle can be a useful guide to decision makers, but wind energy opponents propose siting and zoning precautions based on one set of concerns, while proponents propose another set. Sunstein (2005, p. 93) observes:

> Much of the time… what is available and salient to some is not available and salient to all. For example, many of those who endorse the Precautionary Principle focus on cases in which the government failed to regulate some environmental harm, demanding irrefutable proof, with the consequence being widespread illness and death. To such people, the available incidents require strong precautions in the face of uncertainty. But many other people, skeptical of the Precautionary Principle, focus on cases in which the government overreacted to weak science, causing large expenditures for little gain in terms of health or safety. To such people, the available incidents justify a measure of restraint in the face of uncertainty. Which cases will be available and to whom?

As Sunstein explains, applying the precautionary principle requires decisionmakers to consider “margins of safety” and both the probability and magnitude of harm that might result from their decisions. Sunstein (2005, pp. 117-118) reasons:

> Let us suppose, too, that we will learn… over time. If so, we might elect to take certain steps now, on the basis of a principle of “Act, then learn.” The steps we now take would not be the same as those that we would take if the worst outcomes were more probable, but they should be designed so as to permit us to protect against the worst outcomes if we eventually learn that they are actually likely. On this view, an understanding of what we do not know means not that regulators should do little, but that they should act in stages over time, adopting precautions that amount to a kind of insurance against the chance that the harm will be higher than we currently project in light of our current knowledge of both probability and magnitude. (footnote omitted).

Everyone needs to recognize that each wind energy macro- and micro-siting decision has fairly long-term ramifications. Once a turbine location is pinpointed, that decision has the effect of preventing another turbine from being placed any closer than a few rotor diameters away. Specific distances between turbines in a wind park will be determined based on exclusion and avoidance zones, siting and zoning setback requirements, and data regarding prevailing winds and technical aspects of the particular turbine and its blades. This does mean that siting decisions will have long-lasting effects in the landscape.

By the same token, everyone also needs to realize that wind turbine technology and operating practices continue to improve, so that the potential negative impacts and concerns raised by future machines could be fewer and smaller than those of today. This implies, at least to some extent, that there could be multiple paths to mitigation for decisions made today that result in significant concerns or complaints. Future mitigation could include, for example, replacing various important wind turbine components (such as blades, gearboxes, controls), or even whole turbines, with machines that are some combination of more reliable, quieter, and safer.

The important questions decisionmakers and policymakers can ask are: (1) Is there a middle ground that does not require compromises where everyone loses? and (2) Are there opportunities for improvement in wind-park siting and zoning procedures that are most likely to lead to a more rapid accumulation of the information and wisdom needed to guide future decisions?

Among researchers studying wind-park siting, there is at least some optimism regarding finding answers to these questions. For example: Wolsink (2007a) suggests that better solutions will be found through collaborative, community-based planning; Upham (2009) proposes that solutions might be found through focused attention on the field of environmental psychology; Sovacool (2009) advises attention to a broader research agenda about both social and technical aspects of decision making; and Sengers, Raven, & Van Venrooij (2010) recommend a concentrated study of news media and the potential role of news media in public education regarding decisions about our energy future. Any and all of these paths might prove advantageous.

For the time being, the most sensible recommendation is for communities to work together to make decisions about future energy systems development, not only wind energy development, in their own local area. There are multiple paths to this goal, insofar as wind energy development is concerned. Some developers work extensively with host communities, prior to seeking siting and zoning approval, to create macro- and micro-siting plans that engender little, if any, public opposition. Some land owners associate and hire their own developers, so that the owners can directly guide decisions about setback distances and micro-siting. Some governments simultaneously develop specific plans that identify both areas where wind parks will be excluded or should be avoided, and also those areas where wind parks will be welcomed. Hindmarsh (2010, p. 560) holds that making good decisions about wind turbine siting requires "collaborative approaches," including "the technical mapping of wind resources… [and identifying] community qualifications and boundaries for wind farm location." He argues that community-based decision making is likely to result in "improved problem framing and decision making concerning wind farm location, and thus development." The goal, as Hindmarsh notes, is a process that will be perceived as legitimate and fair, and thus sustainable. Reaching that goal might be considered overly optimistic, but at least some communities have shown a willingness to give it a try. There is at least a good prospect that these approaches can reduce contentiousness and move towards consensus on how to guide wind-park siting and zoning.

At the outset, this report noted that wind-park siting and zoning presents serious challenges and that proposals frequently attract public opposition and are therefore contentious. History does show that public attitudes about any new technology are subject to change over time, as experience is gained. History reminds us of a similar controversy, where over 300 people vigorously protested construction of a local project which they called "useless" and a "grotesque monster." It was said that building it would be "a threat to public health, safety, and well-being." Such was part of the initial reaction to constructing the Eiffel Tower. (Gipe, 1995, pp. 252-55). Only time will tell how apt that comparison might be.

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Appendix A:
State Survey Reports

The Appendix is bound separately and is available as a PDF file at the following URL:

http://www.nrri.org/pubs/electricity/NRRI_Wind_Siting_Survey_Jan12-03A.pdf

National Regulatory
Research Institute

Put It There! –
Wind Energy & Wind-Park Siting and Zoning Best Practices and Guidance for States

Appendix A:
State Wind Siting and Zoning Survey

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January 2012
12-03

Acknowledgements

This material is based upon work supported by the Department of Energy, National Energy Technology Laboratory under Award Number(s) DE-OE0000123.

This paper results from a National Association of Regulatory Utility Commissioners (NARUC) grant for State Electricity Regulators Capacity Assistance and Training (SERCAT). Funding for the NARUC SERCAT program is provided under a cooperative agreement between NARUC and the U.S. Department of Energy (DOE) and National Energy Technology Laboratory (NETL). NRRI is grateful to NARUC, the DOE, and NETL for supporting SERCAT and this project.

The authors wish to thank these colleagues from the National Regulatory Research Institute. Without their assistance, this project would not have been possible. Four NRRI student interns worked many hours during their summer break from classes in 2011. These students completed initial surveys of the states:

- **Kai Goldynia,** from Okemos, Michigan, a sophomore studying History and Environmental Studies at Amherst College in Amherst, Massachusetts;
- **Francis Motycka**, from East Lansing, Michigan, a junior at The College of William and Mary, planning to double major in Economics and Government;
- **Lauren Teixeira**, from Silver Spring, Maryland, a sophomore at Grinnell College in Grinnell, Iowa; and
- **Marley Ward**, from St. Clair Shores, Michigan, a sophomore at the University of Michigan – Dearborn.

In addition, more than 100 individuals from all over the U.S. helped us check our survey work, including all those who helped identify the most appropriate in-state contact persons and especially those individuals listed as reviewers on the state survey reports.

The authors alone are responsible for any errors and omissions that remain.

Online Access

These survey reports can be accessed online via the National Regulatory Research Institute website at http://www.nrri.org/pubs/electricity/NRRI_Wind_Siting_Survey_Jan12-03A.pdf

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Table A-1: State Wind Siting and Zoning Survey Summary Table (26 Jan 2012)

State	NRRI Review Completed	Sent to State Contact(s)	Response from Contact(s)	Followup	Additional Edits	Complete
No. of Jurisdictions:	**51**	**51**	**39**	**6**	**5**	**39**
No. of Contacts:		**106**	**47**	**6**	**5**	**44**
Alabama	x	x	x			x
Alaska	x	x	x			x
Arizona	x	x	x	x	x	x
Arkansas	x	x	x			x
California	x	x				
Colorado	x	x				
Connecticut	x	x	x			x
Delaware	x	x	x			x
District of Columbia	x	x	x			x
Florida	x	x	x			x
Georgia	x	x	x			x
Hawaii	x	x				
Idaho	x	x	x			x
Illinois	x	x	x			x
Indiana	x	x	x			x
Iowa	x	x	x			x
Kansas	x	x	x			x
Kentucky	x	x	x			x
Louisiana	x	x	x			x
Maine	x	x	x	x	x	x
Maryland	x	x	x			x
Massachusetts	x	x	x			x
Michigan	x	x	x			x
Minnesota	x	x	x			x
Mississippi	x	x				
Missouri	x	x				
Montana	x	x	x			x
Nebraska	x	x	x	x		x
Nevada	x	x	x			x
New Hampshire	x	x	x	x	x	x
New Jersey	x	x	x			x
New Mexico	x	x	x			x
New York	x	x	x			x
North Carolina	x	x				
North Dakota	x	x	x			x
Ohio	x	x	x			x
Oklahoma	x	x	x			x
Oregon	x	x				
Pennsylvania	x	x	x			x

Table A-1: State Wind Siting and Zoning Survey Summary Table (26 Jan 2012)

State	NRRI Review Completed	Sent to State Contact(s)	Response from Contact(s)	Followup	Additional Edits	Complete
Rhode Island	x	x				
South Carolina	x	x	x			x
South Dakota	x	x	x			x
Tennessee	x	x				
Texas	x	x	x	x	x	x
Utah	x	x				
Vermont	x	x	x			x
Virginia	x	x	x	x	x	x
Washington	x	x	x			x
West Virginia	x	x	x			x
Wisconsin	x	x				
Wyoming	x	x				

The authors intend to continue efforts to update the survey reports, as needed, to keep them up to date. New information to update the survey results are welcome. Comments can be submitted to:

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State: Alabama

Wind siting basics: Investor-owned utilities providing retail electric service to the public must obtain a Certificate of Public Convenience and Necessity (CPCN) from the Alabama Public Service Commission (PSC) for construction of power generation facilities intended to serve the public. During its review, the Commission considers, among other things, the proposed facility location. However, the PSC has no specific siting authority over wind generation or generation facilities proposed by a non-regulated utility.

Other state entities that may have authority include: Alabama Department of Environmental Management; Alabama Department of Conservation and Natural Resources; local zoning authorities such as counties and cities; and circuit courts of the counties.

History of siting authority: The PSC does not have any history regarding the siting of wind turbines for the generation of power.

Approvals needed: Investor-owned utilities providing retail service to the public must obtain a Certificate of Public Convenience and Necessity (CPCN) from the Alabama Public Service Commission for construction of power generation facilities (Stemler, 2007).

Evaluation criteria: As part of its consideration of a regulated utility's request for a CPCN to construct a power generation facility intended to serve the public, the PSC reviews data rom the company, including: the type, location and cost of the proposed generation facility and related transmission facilities and upgrades; the company's existing and planned resources; the company's existing and forecasted reserve levels; and various demand and cost data germane to the request.

Public input: CPCN hearings are open to the public. In addition, any person or entity granted intervenor status may participate in the proceedings.

Relationships to other important energy policies or siting and zoning decisions: Alabama is a fully regulated market for retail electric service. Utilities under the jurisdiction of the PSC have a legal duty to maintain their facilities and proper reserve levels in order to render adequate service to the public and as necessary to meet the growth and demand of the service territory.

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Data gathered by Deborah Luyo, 3 Nov 2011
Reviewed by John Free, 25 Jan 2012.

State: Alaska

Wind siting basics: The Regulatory Commission of Alaska (RCA) issues a Certificate of Public Convenience and Necessity to any utilities and independent power producers in the state. The RCA is not involved in siting activities. Depending on site land ownership and environmental impacts, permits for turbine sites are handled through the Alaska Department of Natural Resources and Division of Wildlife, the U.S. Army Corp of Engineers, Federal Aviation Administration (FAA), and Fish and Wildlife Service, and local governments.

History of siting authority: RCA does not provide a siting review; however, generating facilities serving ten or more persons are required to receive a CPCN. (See: www.fws.gov/midwest/wind/guidance/AFWASitingSummaries.pdf.)

Approvals needed: No state-level approval is needed. Some cities and municipalities have specific wind generator siting and zoning procedures.

General permitting guidelines can be found at www.akenergyauthority.org/Reports%20and%20Presentations/2009WindBestPracticesGuide.pdf.

Evaluation criteria: No state-level criteria.

Public input: No specific procedures identified.

Relationships to other important energy policies or siting and zoning decisions: Alaska's Coastal Zone Management Program, run by the State Department of Natural Resources, used to serve as a one-stop shop for permitting issues involving the state's coastal zones. The program was discontinued by the Alaska legislature this year, though, and restarting it could take as long as two to three years.[1]

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[1] Rich Stromberg, 15 Aug 2011, personal communication. See www.alaskajournal.com/stories/060311/loc_sczm.shtml, www.adn.com/2011/06/20/1927031/alaska-house-rejects-special-session.html, and www.alaskapublic.org/2011/06/08/senators-warn-against-letting-coastal-zone-management-program-die/.

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Data gathered by Kai Goldynia, 7 Aug 2011.
Reviewed by Rich Stromberg, 15 Aug 2011.

State: Arizona

Wind siting basics: The state has no specific wind siting authority, codes, or regulations. Wind facilities must obtain siting and zoning approvals at the county level.

History of siting authority: The state has no specific wind siting authority.

Approvals needed: No state-level approval is needed for wind facilities. The Arizona Game & Fish Department provides *voluntary* guidelines for reducing wildlife endangerment during wind facility construction and operation.

The Arizona Power Plant and Transmission Line Siting Committee has the authority to approve a Certificate of Environmental Compatibility (CEC) for transmission lines 115kV or higher. The Arizona Corporation Commission (ACC) "must either confirm, deny or modify the certificate granted by the Committee or if the Committee refused to grant a certificate, the Commission may issue a certificate" (Arizona Corporation Commission).

Evaluation criteria: Voluntary guidelines issued by the AZ Game & Fish Department include:

(1) Place turbines, roads, power lines, and other infrastructure appropriately, avoiding high-quality wildlife habitats.
(2) Close, obliterate, and re-vegetate any roads constructed for the project that are not necessary for facility maintenance after tower construction.
(3) Control or prevent erosion, siltation, and air pollution by vegetating or otherwise stabilizing all exposed surfaces.
(4) Control or prevent damage to fish, wildlife, or their habitats.
(5) Prevent or control damage to public and/or private property.

Public input: ACC decisions are made during public meetings, with opportunities for public comment.

Relationships to other important energy policies or siting and zoning decisions: The Arizona Renewable Energy Standard (15% by 2025) includes wind as an eligible technology. Arizona electric utilities must file with the ACC biennial integrated resource plans, including analysis and discussion of how the utility will meet the state's renewable energy standard.

Pending issues: Major areas of concern are environmental and wildlife criteria, coupled with the development of a permitting process. Debate continues with regard to establishing comprehensive wind generator siting procedures. Currently, Arizona lacks any state regulation of wind facilities; however, with more facilities proposed, environmental groups worry about the increased impact on the physical and natural environment and habitats of vital plant and animal species. The Arizona Game & Fish Department is working with counties and the State Land Department to address wildlife concerns.

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Data gathered by Kai Goldynia, 17, 19 Jul 2011.
Reviewed by Ray Williamson, 10 Aug 2011, Ginger Ritter, 3 Nov 2011.

State: Arkansas

Wind siting basics: Wind siting is done at the local level of government.

History of siting authority: Arkansas Code A.C.A. §23-3-201 (1935) (www.offthemarble.com/arkcode/Title23/). Arkansas is a Home Rule State.

Approvals needed: All electricity generating facilities that provide "a public service" are required to obtain a Certificate of Public Convenience and Necessity (CPCN) from the Arkansas Public Service Commission.

Evaluation Criteria: None identified.

Public input: No specific procedures identified.

Relationships to other important energy policies or siting and zoning decisions: None identified.

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Citations and links:

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Data collected by Francis Motycka, 6, 11 Jul, 3 August 2011.
Reviewed by J.D. Lowery, 18 Nov 2011.

State: California

Wind siting basics: Siting authority is delegated to municipalities. Every county is required to adopt a General Plan for wind development. However, they are subject to the California Environmental Quality Act (CEQA), which requires Environmental Impact Reports (EIRs) and imposes mitigation measures to reduce significant adverse impacts.

History of siting authority: The California Planning and Zoning Law was modified in 1980 to delegate land-use decisions to municipalities (http://leginfo.ca.gov/pub/09-10/bill/sen/sb_0001-0050/sbx8_34_bill_20100322_chaptered.pdf).

The California Environmental Quality Act (CEQA), passed in 1970, requires local governments' permitting facilities to analyze wind generator environmental impacts (www.leginfo.ca.gov/cgi-bin/displaycode?section=prc&group=20001-21000&file=21000-21006).

Approvals needed: Approvals vary by municipality. It could come from the planning department, one or more planning commissions, administrative boards or hearing officers, the legislative body itself, or any combination thereof. Under CEQA, applicants are required to consult with the California Department of Fish and Game (CDFG) to meet fish and game statutes and wildlife protection laws; however, the CDFG cannot approve or disapprove of the application. If the project will occupy U.S. Bureau of Land Management (BLM) land, BLM approval is needed (www.blm.gov/ca/st/en/prog/energy/wind.html).

The applicant should first conduct an initial study of the environmental impacts of the project and prepare a document meeting the requirements of both the CEQA and the National Environmental Policy Act (NEPA). If in the initial study the county or the BLM finds potentially significant environmental impacts, the county and the BLM will hire an environmental consultant to conduct the more comprehensive Environmental Impact Report (EIR). Once this report is completed, the County Planning Commission will hold a public hearing to determine whether or not the EIR should be approved. EIR approval facilitates obtaining other necessary permits, such as a permit pursuant to the Endangered Species Act and a Conditional Use Permit (CUP), if the applicant is trying to build on certain types of land, like agricultural land. Once the applicant has acquired all the necessary permits (others include a stormwater discharge permit and a right-of-way from the BLM if the project involves BLM property), the applicant can file its application with the county.

Evaluation criteria: Required CEQA environmental impact analysis includes:

- -aesthetics
- -agricultural resources
- -air quality
- -biological resources
- -geology and soils
- -greenhouse gases
- -hazards and hazardous materials
- -hydrology and water quality
- -land use and planning
- -mineral resources
- -noise
- -population and housing
- -public services
- -recreation
- -transportation and traffic
- -utilities (meaning any required ancillary facilities, such as for wastewater or waste disposal)

For small wind generators (50kW or smaller), Assembly Bill 45 of 2009 authorizes counties to adopt siting ordinances. The Bill establishes maximum restrictions for tower height, parcel size, setbacks, public notice, and noise level (www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=CA61R&re=1&ee=1).

Public input: No specific procedures identified.

Relationships to other important energy policies or siting and zoning decisions: None identified.

Pending issues: Proposed legislation, AB 13 (www.leginfo.ca.gov/pub/11-12/bill/asm/ab_0001-0050/abx1_13_bill_20110707_amended_sen_v95.pdf), seeks to expedite the wind siting process by expanding the "SB 34" (http://leginfo.ca.gov/pub/09-10/bill/sen/sb_0001-0050/sbx8_34_bill_20100322_chaptered.pdf) process, originally conceived to facilitate solar facility siting within the state's Desert Renewable Energy Conservation Plan (DRECP). This bill would allow wind project applicants within the DRECP to pay fees to the CA Energy Commission to expedite project review and pay an in-lieu-of-mitigation fee to the state to ensure adequate wildlife and habitat protections when the project is sited.

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U.S. Bureau of Land Management [web page]. Retrieved 22 Jun 2011 from www.blm.gov/ca/st/en/prog/energy/wind.html.

Data gathered by Lauren Teixeira, 22 Jun 2011.

State: Colorado

Wind siting basics: Wind facilities must be permitted by both the local and state governments. The Colorado PUC regulates: (1) "eligible renewable energy resources;" (2) facilities larger than 2 MW capacity; and (3) facilities exceeding 50 feet in height. By state law, each county must have a Master Plan, which includes information on how to make land-use decisions with respect to siting (Stemler, 2007). State enabling legislation encourages counties to consider "methods for assuring access to appropriate conditions for solar, wind, or other alternative energy sources" and "areas containing endangered or threatened species" in their plans.

History of siting authority: Colorado Statute 40-5-101 (1963, amended 2005, 2007), www.michie.com/colorado. The Local Government Land Use Control Enabling Act (General Assembly of Colorado, 1974) delegates broad land-use decision-making authority to the municipalities.

Approvals needed: In general, applicants need one of these county government permits if the proposed facility's capacity exceeds a certain threshold established by the county: a 1041 (a.k.a. Areas and Activities of State Interest) permit, special use permit, or conditional use permit. 1041 permits are generally required for the site selection and construction of transmission lines, power plants (renewable and non-renewable), and substations with capacities exceeding the county-specified limit.

The process generally includes a pre-application meeting, public notice, submittal of the permit application, public hearing, approval of the permit, and post-approval requirements, if applicable.

For more information on these permits, see Colorado Governor's Energy Office report (p. 52; www.dora.state.co.us/puc/projects/TransmissionSiting/EnvironmentSitingLanduse_REDIProject_GEO07-20-2009.pdf).

Projects also need a Certificate of Public Convenience and Necessity (CPCN) from the PUC. The PUC is required to consult with the Colorado Division of Wildlife and the U.S. Fish and Wildlife Service. Those agencies usually determine requirements for wildlife impact studies. If the project is to be on federal land or triggers the National Environmental Policy Act (NEPA) in some way, studies must be conducted according to NEPA. The applicant must provide written documentation that consultation occurred with appropriate governmental agencies. In addition, if the project receives federal funding, involves federal land, or connects to a transmission line belonging to a federal power authority, the applicant must comply with the federal Endangered Species Act (ESA). Colorado is home to 10 endangered bird species.

The PSC checks to make sure the applicant has the consent of the relevant municipalities and will comply with the applicable zoning ordinances. An applicant can appeal a county zoning decision to the Commission and request a hearing. The PSC has the right to amend the CPCN.

Evaluation criteria: The County will either require or encourage the applicant to conduct an Environmental Impact Assessment (EIA). The Colorado Division of Wildlife requires avian and bat studies. Typically required permits include:

- County Conditional or Special use Permits
- County Building Permit
- County Septic System Permit
- State of Colorado Storm Water Permit (construction)
- State of Colorado Dust Controls Permit (construction)
- State of Colorado Highway Access and Enroachment Permit (tower and blade transportation)
- State of Colorado Water Well Permit

Public input: No specific procedures identified.

Relationships to other important energy policies or siting and zoning decisions: Colorado has a renewable portfolio standard of 30% by 2020. Transmission projects are being developed to support wind (www.eei.org/ourissues/ElectricityTransmission/Documents/Trans_Project_V-X.pdf). However, a recent report by the Governor's Energy Office found that CO might not be able to meet its RPS goal unless even more transmission lines are built (www.denverpost.com/business/ci_13913735).

Colorado Senate Bill 11-45 (June 2011) established a task force on statewide transmission siting and permitting, which will report to the governor on its recommendations for improving the state's statutory and regulatory framework (www.dora.state.co.us/puc/projects/TransmissionSiting/SB11-45/SB11-45.htm). A report by the task force, submitted on 1 Dec 2011, recommended (Colorado Public Utilities Commission, 2011):

(1) ...increased cooperation and collaboration among local governments that review transmission applications in Colorado.
(2) When local government land-use decisions on utility projects are appealed to the PUC, and the PUC's decision is subsequently appealed, cases should go directly to the Colorado Court of Appeals, rather than to a district court in order to achieve more efficient and timely review.
(3) ...establishment of processes and provision of resources to resolve transmission siting and permitting disputes between local governments and transmission operators.

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Data collected by Lauren Teixeira, 7 Jul 2011; Deborah Luyo, 20 Oct 2011.

State: Connecticut

Wind siting basics: The Connecticut Siting Council has sole jurisdiction over electric generating facilities using renewable energy sources with more than 1 MW of capacity and of PURPA non-qualifying facilities under 1 MW.

History of siting authority: Connecticut statutes Sections 16-50g, 16-50k and 16-50x(d) (1971, as amended) grant authority to the Connecticut Siting Council (www.cga.ct.gov/2011/pub/chap277a.htm#Sec16-50j.html). A new law, Connecticut Public Act 11-245 (PA 11-245), effective 1 Jul 2011, requires the Connecticut Siting Council by 1 Jul 2012, in consultation with the departments of Public Utility Control and Environmental Protection, to adopt regulations concerning the siting of wind turbines. (See **Pending Issues**.)

Approvals needed: Electric generation facilities using renewable energy sources with more than 65 MW of capacity could have a "significant adverse environmental effect" and require a certificate from the Connecticut Siting Council. Electric generation facilities using renewable energy sources with fewer than 65 MW of capacity could have a "significant adverse environmental effect" and require a declaratory ruling from the Connecticut Siting Council.

The applicant for a certificate must consult the municipality in which it wishes to build at least 60 days prior to filing the application. Within 60 days of that consultation, the municipality must issue its recommendation to the applicant. The applicant must also consult the municipal zoning and inland wetland agencies. The agencies have 65 days after the time the application is filed to issue an order restricting or regulating the proposed site. Concerned parties have 30 days after the order is issued to appeal it to the Council. The Council can affirm, revoke, or modify the zoning or wetlands order. If the Council accepts the application, it must hold a public hearing in which all parties to the proceeding may offer testimony and file evidence. The Council can reject an application if it fails to comply with certain data requirements. The Council must render a decision within 180 days of receipt of the application. The suggested form and content of the application can be found here: www.ct.gov/csc/lib/csc/guides/guidesonwebsite042010/renewableenergyfacilityapplicationguide.pdf#51365.

Only two wind facilities have been approved in the state of Connecticut: BNE filed its petition to build its Colebrook South facility on 6 Dec 2010 and its petition to build its Colebrook North facility on 13 December 2010. Their petitions were approved on 2 June 2011 and 9 June 2011, a time frame of about six months; however, including the municipal consultation beforehand, the total time was probably a few months more.

Evaluation criteria: Prior to passage of PA 11-245, criteria included:

- consultation with state agencies and municipal commissions
- Applications including reviews of:
    - hazards to air traffic;
    - health and safety;
    - justification of selection of the proposed site, including a comparison with alternative sites that are environmentally, technically, and economically practicable;
    - explanation of why this project is necessary for the reliability of electric power supply of the state or is necessary for a competitive market for electricity;
    - description of the project's proximity to certain areas (www.ct.gov/csc/lib/csc/guides/guidesonwebsite042010/renewableenergyfacilityapplicationguide.pdf#51365.)

- The applicant must include assessment of the "historic and expected availability" of necessary electric transmission infrastructure. This includes "[t]he construction type of the transmission interconnection (overhead, underground, single circuit, double circuit) and the existing and expected transmission line loadings, substation interconnection plan, and the anticipated range of dispatch based on transmission grid constraints. In addition, provide a final copy of, or a status report on, the independent system operator transmission grid interconnection study."

Public input: A public hearing will be required under Connecticut Public Act 11-245. (See **Pending issues**.)

Relationships to other important energy policies or siting and zoning decisions:

The applicant must show how its proposed facility is consistent with the approved Integrated Resource Plan. The agency in charge of IRP is the Department of Energy and Environmental Protection (DEEP).

Pending issues: Regulations promulgated under PA 11-245 must at least consider (1) setbacks, including tower height and distance from neighboring properties; (2) flicker; (3) a requirement for the developer to decommission the facility at the end of its useful life; (4) different requirements for different size projects; (5) ice throw; (6) blade shear; (7) noise; and (8) impact on natural resources. The regulations must also require a public hearing for wind turbine projects.

PA 11-245, effective date 1 Jul 2011, bars the CT Siting Council from acting on any application or petition for siting a wind turbine until the new regulations are adopted (www.cga.ct.gov/2011/SUM/2011SUM00245-R03HB-06249-SUM.htm).

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Data collected by Lauren Teixeira, 21 Jun 2011; Tom Stanton, 18 Oct 2011.
Reviewed by Melanie Bachman, 24 Oct 2011.

State: Delaware

Wind siting basics: Wind siting authority is at the local level.

History of siting authority: None identified.

Approvals needed: For an “Eligible Energy Resource,” which includes wind generators, the generation unit must be certified by the Delaware Public Service Commission. The Eligible Energy Resource can then register with PJM’s Environmental Information Services (EIS) Generation Attribute Tracking System (GATS; www.pjm-eis.com/getting-started/about-GATS.aspx), which tracks renewable energy credits (RECs) for compliance with state renewable portfolio standards (RPSs).

Developers should contact the Delaware Department of Natural Resources & Environmental Control, Regulatory Advisory Service (www.dnrec.delaware.gov/SBA/Pages/RegulatoryAdvisoryService.aspx). This Service will help identify all required state (and federal) permits, depending on the location of a proposed wind development. Examples include state-regulated wetlands, sediment and storm-water requirements for land disturbances, and federal coastal zone requirements.

Evaluation criteria: The following are criteria for wind siting on private property that may be used by county and municipal governments, as stated in Title 29, Chapter 80 of the Delaware Code:

(1) Historical: “Any wind energy system shall be buffered from any properties or structures included on the Historic Register.”
(2) Property Setback: “Wind turbines shall be setback 1.0 times the turbine height from [the] adjoining property line. Turbine height means the height of the tower plus the length of 1 blade.”
(3) Noise: “The aggregate noise or audible sound of a wind system shall not exceed 5 decibels above the existing average noise level of the surrounding area and shall be restricted to a maximum of 60 decibels measured at any location along the property line to the parcel where the wind system is located.”
(4) Visual: “Wind systems shall be free from signage, advertising, flags, streamers, any decorative items or any item not related to the operation of the wind turbine. Electric wiring for the turbines shall be placed underground for non-building integrated systems.”

Public input: No specific procedures identified.

Relationships to other important energy policies or siting and zoning decisions: Delaware has a renewable portfolio standard (RPS) requiring 25% of electricity sold by utilities to come from renewable energy sources by 2025 and imposing interim annual portfolio requirements.

Research Issues: The only current commercial wind turbine is on the University of Delaware-Lewes campus. The 2 MW wind turbine was constructed without any environmental permits. The University is completing a two-year research project to measure the impact of the school’s wind turbine on bird and bat mortality. The study is expected to be completed by December 2013.

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Data gathered by Francis Motycka, 6, 11, 12, Jul, 4 Aug 2011; Tom Stanton, 30 Aug 2011.
Reviewed by Courtney Stewart and Kimberly Chesser, 30 Aug 2011.

Jurisdiction: District of Columbia

Wind siting basics: None identified.

History of siting authority: None identified.

Approvals needed: None identified.

Evaluation criteria: None identified.

Public input: No specific procedures identified.

Relationships to other important energy policies or siting and zoning decisions: Washington, DC has a renewable energy portfolio standard of 20% by 2020 (Database of State Incentives for Renewables & Efficiency, 2011).

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Citations and links:

Database of State Incentives for Renewables & Efficiency. (29 Aug 2011). *District of Columbia Incentives/Policies for Renewables & Efficiency* [web page]. www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=DC04R&re=1&ee=1.

Data collected by Deborah Luyo, 21 Nov 2011.
Reviewed by Roger Fujihara, 29 Nov 2011.

State: Florida

Wind siting basics: Currently, all applicants proposing to build a wind farm must obtain a variety of permits from various federal and state agencies. There is one-stop permitting for power plants 75 MW and over; however, Florida has yet to extend this process to wind. If the farm is to be on state land, the applicant needs approval from the state Siting Board (the governor and the cabinet).

History of siting authority: Since Florida's Power Plant Siting Act (www.dep.state.fl.us/siting/power_plants.htm) does not apply to wind farms, applicants must obtain all of the necessary permits one by one. The necessary permits are laid out on the Florida Department of Environmental Protection (DEP) website: www.dep.state.fl.us/siting/files/renew_resource_permitting.pdf

Approvals needed: The applicant must obtain approval, either through a permit or authorization, from a variety of federal and state agencies, including: the Federal Aviation Administration, the U.S. Fish and Wildlife Service, the Florida Department of Transportation, the Florida Fish and Wildlife Conservation Commission, the Florida Department of Business and Profession Regulation, the Florida Department of Environmental Protection (sub-agencies: Bureau of Beaches; Stormwater Program; State Lands; District offices), and the Florida Office of Historic Preservation

Evaluation criteria: On the federal level, the applicant must issue a Notice of Proposed Construction concerning height restrictions to the Federal Aviation Administration. A wildlife permit from the U.S. Fish and Wildlife Service is also required.

On the state level, the following authorizations and permits are required:

- Access and roadway (Florida Department of Transportation)
- Migratory Bird Nest Removal and Relocation Permit (Florida Fish and Wildlife)
- Business incorporation (Florida Department of State)
- Business license (Florida Department of Business and Profession Regulation)
- Coastal Construction Control Line (Florida DEP Bureau of Beaches)
- Environmental resources permit (Florida DEP District Office)
- National Historical Preservation Act Compliance (Florida Office of Historic Preservation)
- National Pollutant Discharge Elimination System (NPDES) Stormwater Permit for Construction (Florida DEP Stormwater Program)
- State Lands Determination Waterways (Florida DEP State Lands)

On the county level, the following authorizations and permits are required:

- Building
- Business license
- County wetlands
- Land-use determination
- Local fire marshal
- Noise ordinance
- Zoning

Palm Beach County, which is in the process of approving Florida's first wind farm, has "Alternative Energy Development Guidelines," which the County Council voted to amend in order to accommodate the height of the proposed turbines.

Public input: Some counties include public hearings in the zoning process.

Relationships to other important energy policies or siting and zoning decisions: None identified.

Pending issues: Florida is currently in the process of siting what might be its first wind farm. A few years ago, Florida Power and Light attempted to site a 20 MW wind farm on Hutchinson Island in St. Lucie County, but the initiative failed because of widespread public opposition and because three of the turbines were to be on public land. Right now, Wind Capital Group, St. Louis, Missouri, has applied to build an 80-turbine, 150 MW wind farm in the Everglades agricultural area in Palm Beach County. The project has come into question in light of a recent U.S. Fish and Wildlife analysis that identifies concerns for avian mortality. The Fish and Wildlife Service has recommended a more comprehensive study.

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Florida Office of Historic Preservation [web page]. Retrieved 26 Jul 2011 from www.flheritage.com/preservation/compliance/index.cfm.

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Stemler, Jodi. (Apr 2007). *Wind Power Siting Regulations and Wildlife Guidelines in the United States*. U.S. Fish & Wildlife Service. www.fws.gov/midwest/wind/guidance/AFWASitingSummaries.pdf.

Data collected by Lauren Teixeira, 26 Jul 2011.
Reviewed by Cindy Mulkey, 8 Nov 2011.

State: Georgia

Wind siting basics: Georgia has no specific siting authority for wind power. Regulation is administered by local government. (Stemler, 2007).

Approvals needed: Most local governments require a land-use permit (Georgia Wind Working Group).

Evaluation criteria: Voluntary siting and land-acquisition guidelines for developers, created by the Georgia Wind Working Group, include:

- Aesthetic impacts
- Avian and bat mortality
- Noise
- Possible construction impacts
- Utility interconnection impacts

Public input: No specific procedures identified.

Relationships to other important energy policies or siting and zoning decisions: None identified.

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Georgia Wind Working Group. (Oct 2006). *Georgia Wind: A Guidebook to Wind Development in Georgia*. www.gawwg.org/images/Georgia_Wind_Guidebook_Updated_October_26th,_2006.pdf.

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Data collected by Deborah Luyo, 4 Nov 2011.
Reviewed by Rita Kilpatrick and members of the Georgia Wind Working Group, 19 Dec 2011.

State: Hawaii

Wind siting basics: Wind production in Hawaii is mainly small scale, and siting procedures are administered by local government (Stemler, 2007). Environmental reviews are conducted at the federal, state, and county levels. No guidelines specific to wind energy have been developed. Regulation is administered through general permitting guidelines (Hawaii Clean Energy Initiative, 2010).

History of siting authority: None identified.

Approvals needed: At the federal level, permits and reviews include: Environmental Impact Statement, Environmental Assessment, administered by the Council on Environmental Quality; Incidental Take Statement, Incidental Take Permit, administered by the National Oceanic and Atmospheric Administration; Incidental Take Statement, Incidental Take Permit, administered by the U.S. Fish & Wildlife Service. At the state level, most environmental permits are administered by the Hawaii Department of Health (DOH); however, depending on the project, other agencies may also issue permits. All counties in Hawaii require a Shoreline Setback Variance for structures and activities in the "Shoreline Area"; counties have their own guidelines for determining the required setback from shore. A Special Management Area Permit is also required. A utility permit, administered by the Public Utilities Commission (PUC), is required for all utility construction, reconstruction, or maintenance activities in Hawaii. (Hawaii Clean Energy Initiative, 2010).

Projects that qualify for the Renewable Energy Facility Siting Process (REFSP) can pursue a streamlined permitting process. To obtain streamlined permitting, the developer will be charged a fee to cover application processing costs.

Evaluation criteria: The most important determination is the impact of the project on the environment and wildlife.

Public input: A public comment period and public hearing are part of the process at both the state and federal levels.

Relationships to other important energy policies or siting and zoning decisions: Hawaii has a renewable portfolio standard of 40% by 2030. In 2008, a Memorandum of Understanding between the state of Hawaii and the U.S. Department of Energy established the Hawaii Clean Energy Initiative (http://apps1.eere.energy.gov/news/pdfs/hawaii_mou.pdf). Goals of this initiative include a significant increase in the use of renewable energy and a transition to the exclusive use of renewable energy on Hawaii's smaller islands. (Database of State Incentives for Renewables & Efficiency, 2011).

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Citations and links:

Advanced $H_2$0 Power. *Hawaii Renewable Energy Siting Process* [web page]. Retrieved 1 Nov 2011 from www.advancedh2opower.com/framework/Hydrokinetics%20Knowledge%20Base/Hawaii%20Renewable%20Energy%20Facility%20Siting%20Process.aspx.

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Data collected by Deborah Luyo, 1 Nov 2011.

State: Idaho

Wind siting basics: Local-government siting autonomy, with state enabling legislation.

History of siting authority: Idaho Statute Chapter 65 - Local Land Use Planning (2005) (http://lawjustia.com/codes/idaho/2005/67ftoc/670650002.html, www.legislature.idaho.gov/idstat/Title67/T67CH65SECT67-6504.htm).

Approvals needed: Developers apply for local zoning approval, for a "Conditional Use Permit." Since there is local siting autonomy, only a city council or board of county commissioners can approve wind energy projects (www.legislature.idaho.gov/idstat/Title67/T67CH64SECT67-6504.htm).

Evaluation criteria: None identified.

Public input: No specific procedures identified.

Relationships to other important energy policies or siting and zoning decisions: None identified.

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Citations and links:

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Data collected by Marley Ward, 10 Jul 2011.
Reviewed by John Chatburn 22 Nov 2011.

State: Illinois

Wind siting basics: Local government has autonomy. Each county can set standards (55 ILCS 5/5-12020). These standards include the device height and number of electricity-generating wind devices, or wind turbine generators (WTGs) (www.ilga.gov/legislation/ilcs/ilcs4.asp?DocName=005500050HArt.+5&ActID=750&ChapterID=12&SeqStart=55300000&SeqEnd=120400000).

History of siting authority: Illinois General Assembly, in 55 ILCS 5/5-12020 (2007), granted authority for counties to "establish standards for wind farms and electric-generating wind devices." Amendments were made in 2009 and 2010 (www.ilga.gov/legislation/ilcs/fulltext.asp?DocName=005500050K5-12020).

Approvals needed: County approves construction for projects in accordance with local zoning regulations. In some situations, county must consult Illinois Department of Natural Resources for approval (see Great Lakes Commission Staff, 2009, *Siting and Permitting Wind Farms in Illinois*).

Projects have to demonstrate compliance with these federal requirements:

(1) Federal Aviation Administration (FAA): (a) Determination of No Hazard to Air Navigation; (b) Notice of proposed construction (form FAA 7460-1); (c) Lighting plan; (d) Post construction form (form FAA 7460-2).

(2) US Fish and Wildlife Services (USFWS): Threatened and Endangered Species Act, Section 7 Consultation and Migratory Bird Act.

(3) US Army Corps of Engineers (COE): (a) Clean Water Act: Section 404 - Discharge of Fill Materials; (b) Rivers and Harbors Act: Section 10.

(4) Federal Communications Commission (FCC): Microwave Studies.

(5) US Environmental Protection Agency (USEPA): Spill Prevention, Control and Countermeasures Plan (SPCC Plan, 40 CFR112).

(6) U.S. Military: Determination of non-interference with flight operations and radar.

Obtain approval from municipality, National Pollutant Discharge Elimination System (NPDES) permit from Illinois Environmental Protection Agency, and road permit from Department of Transportation (*Siting and Permitting Wind Farms in Illinois*). At least one public hearing will take place not more than 30 days prior to a county board's siting decision (55 ILCS 5/5-12020).

Evaluation criteria: Standards are set at the county level.

According to the Illinois Endangered Species Act, the Illinois DNR must be consulted for approval if proposed project would take place in an area where an endangered species or its habitat might be disrupted.

Illinois Commerce Commission established interconnection standards (August 2008) for distributed generation systems up to 10 MW (Great Lakes Commission, 2009) (www.ilga.gov/commission/jcar/admincode/083/08300200sections.html).

Illinois has no model ordinance in place. However, a maximum setback limit for WTGs is established for self-service power. According to (55 ILCS 5/5-12020), "[A] county may not require a wind tower or other renewable energy system that is used exclusively by an end user to be set back more than 1.1 times the height of the renewable energy system from the end user's property line."

Public input: No specific procedures identified.

Relationships to other important energy and siting and zoning decisions: None identified.

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Data collected by Marley Ward, 1 Jul 2011; Lauren Knapp, 17 Aug 2011.
Reviewed by Jennifer Hinman, Illinois Commerce Commission, 17 Aug 2011; Jolene S. Willis, 23 Aug, 1 Sep 2011.

State: Indiana

Wind siting basics: Indiana has no state-level regulations or guidelines for wind power development. Wind power siting is administered at the local level of government. Siting and permitting requirements vary according to location. (Stemler, 2007).

History of siting authority: Article 4. (24 Apr 2007). Electric Utilities – 170 IAC 4-4.1-1 www.in.gov/legislative/iac/T01700/A00040.PDF.

Approvals needed:

- A certificate of need, granted by the Indiana Utility Regulatory Commission, is required for construction of a new power plant or for delivery of public utility service.
- An National Pollutant Discharge Elimination System (NPDES) Permit is required for discharge of stormwater runoff at construction sites having a size greater than one acre.
- A permit from the Indiana Department of Natural Resources is required for excavation, placement, modification, or repair of a permanent structure over, along, or lakeward of the shoreline or water line of a freshwater lake. (Great Lakes Commission, 2009).
- Any person who desires to erect, make, use, or maintain a structure, an obstruction, or an excavation in or on the floodway first must obtain a Construction in a Floodway permit from the Indiana Department of Natural Resources.

Evaluation criteria: All projects must comply with local and state laws governing electric generation and transmission and environmental laws related to construction (Great Lakes Commission, 2010).

Public input: No specific procedures identified.

Relationships to other important energy policies or siting and zoning decisions: Indiana's Clean Energy Portfolio Standard establishes a voluntary goal of 10% clean energy by 2025 (Database of State Incentives for Renewables & Efficiency, 2011).

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Citations and links:

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Great Lakes Commission. (Mar 2009). *Siting and Permitting Wind Farms in Indiana*. http://wiki.glin.net/download/attachments/950461/Indiana.doc.

Great Lakes Commission. (Jan 2010). *State and Provincial Land-Based Wind Farm Siting Policy in the Great Lakes Region: Summary and Analysis.* www.glc.org/energy/**wind**/pdf/GLWC-LandBased**Siting-**Jan2010.pdf.

Data collected by Deborah Luyo, 2 Nov 2011.
Reviewed by Matt Buffington, 9 Nov 2011.

State: Iowa

Wind siting basics:

Local government only: facilities with <25 MW capacity
Dual state and local siting: >25 MW capacity
State utilities board has authority at the state level.

History of siting authority: Iowa Code chapter 476A (1977) established generation-siting law. In 2001, the decision criteria for issuance of generation certification were revised. The Iowa Utilities Board can now waive certification requirements for any size facility. (www.legis.state.ia.us/IACODE/2003/476A/)

Approvals needed: A permit from the Iowa Utilities Board is required for larger facilities; otherwise, local zoning and siting regulations apply; Iowa Code 476A and Iowa Administrative Code Chapter 24 (www.legis.state.ia.us/IACODE/2003/476A/).

Cases are presented to the Iowa Utilities Board to apply for a Construction Approval Waiver; Iowa code 476A and Administrative Code Chapter 24 (199-24.15) (www.legis.state.ia.us/IACODE/2003/476A/15.html). The IUB has waived the plant certification process for several projects that would have otherwise required a full certificate proceeding.

Evaluation criteria:

"a. …consistent with the legislative intent… and the economic development policy of the state, and will not be detrimental to the provision of adequate and reliable electric service…include[ing] whether the existing transmission network has the capability to reliably support the proposed additional generation…

b. Whether the construction, maintenance, and operation…will be consistent with reasonable land use and environmental policies…considering available technology and the economics of available alternatives. Such determination shall include:
   (1) Whether all adverse impacts attendant the construction, maintenance and operation of the facility have been reduced to a reasonably acceptable level;
   (2) Whether the proposed site represents a reasonable choice among available alternatives;
   (3) Whether the proposed facility complies with applicable city, county or airport zoning requirements….

c. Whether the applicant is willing to construct, maintain, and operate the facility pursuant to the provisions of the certificate and the Act.

d. Whether the proposed facility meets the permit and licensing requirements of regulatory agencies.

e. The applicant shall use the applicable provisions in the publications listed below as standards of accepted good practice unless otherwise ordered by the board:

   I. Iowa Electrical Safety Code...
   II. National Electrical Code...
   III. Power Piping-ANSI standard B31.1-2004."

(Iowa Code 476A, www.legis.state.ia.us/IACODE/2003/476A/12.html)

Public input: Intervenors are allowed to participate in proceedings. Office of Consumer Advocate generally represents residential customers. An informational meeting and hearing (if the case has contested issues) must be held in the county where the facility is proposed to be built.

Relationships to other important energy and siting/zoning decisions: Generally, a generation certificate is issued contingent upon the applicant receiving appropriate approvals and permits from other state and local zoning authorities.

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Citations and links:

Iowa Alliance for Wind Innovation and Novel Development [web page]. Retrieved 29 Jun 2011 from www.iawind.org.

Iowa Department of Natural Resources, *Wind and Wildlife* [web page]. Retrieved 19 Oct 2011 from www.iowadnr.gov/Environment/WildlifeStewardship/NonGameWildlife/Conservation/WindandWildlife.aspx.

Iowa Energy Center, *Wind Assessment Study and Calculator* [web page]. Retrieved 19 Oct 2011 from www.energy.iastate.edu/renewable/wind/windstudy-index.htm.

Iowa Utilities Board, *Wind-powered Electricity Generation in Iowa* [web page]. Retrieved 19 Oct 2011 from www.state.ia.us/government/com/util/energy/wind_generation.html.

Iowa Wind Energy Association [web page]. Retrieved 29 Jun 2011 from www.iowawindenergy.org/.

John R. Sweet Company. (2001). *Top of Iowa Wind Farm Case Study*. http://johnrsweet.com/personal/wind/PDF/TopofIowaWindFarm.pdf.

Data gathered by Marley Ward, 29 June 2011.
Reviewed by Parveen Baig, 5 Dec 2011.

State: Kansas

Wind siting basics: Local siting autonomy (State Enabling Legislation).

History of siting authority: Kansas Statutes Annotated 12-573
http://kansasstatutes.lesterama.org/Chapter_12/Article_7/12-741.html

Approvals needed: Approval rests with the city's governing body and county commissioners.
http://kansasstatutes.lesterama.org/Chapter_12/Article_7/12-753.html

The now-defunct Kansas Energy Council compiled a wind energy siting handbook with suggested procedures that counties might use for accepting applications for wind projects. See http://kec.kansas.gov/reports/wind_siting_handbook.pdf.

KEC suggests an application process including at least the following:

-site plan
-visual impact assessment
-environmental assessment
-economic assessment
-decommissioning and reclamation plan

Evaluation Criteria: Guidelines established by the Kansas Department of Wildlife, Parks and Tourism (Available from http://kdwpt.state.ks.us/news/Services/Environmental-Reviews/Wind-Power-and-Wildlife-Issues-in-Kansas, search for "wind power position".) for consideration by local governments when making siting decisions about wind energy projects include:

(1) That wind power facilities should be sited on previously altered landscapes, such as areas of extensive cultivation or urban and industrial development, and away from extensive areas of intact native prairie, important wildlife migration corridors, and migration staging areas.
(2) To recommend adherence to the Siting Guidelines for Wind Power Projects in Kansas, produced by the Kansas Renewable Energy Working Group (www.kansasenergy.org/documents/KREWGSitingGuidelines.pdf).
(3) To support the study of and establishment of standards for adequate inventory of plant and animal communities before wind development sites are selected, during construction, and after development is completed (Manes et al., in review). The resultant improvement in available knowledge of wind power and wildlife interactions obtained through research and monitoring should be used to periodically update guidelines regarding the siting of wind power facilities.
(4) That mitigation is appropriate only if significant ecological harm from wind power facilities cannot be adequately addressed through proper siting.
(5) To support the establishment of processes to ensure a comprehensive and consistent method in addressing proposed wind power developments.
(6) To advocate the direct coupling of energy conservation and efficiency programs with any new measures aimed at increasing energy supply whether renewable or conventional."

Additionally, voluntary guidelines offered by the Kansas Energy Council's Wind Siting Handbook (http://kec.kansas.gov/reports/wind_siting_handbook.pdf) include:

Pre-construction survey recommendations: Requiring environmental assessment in siting decisions; consideration for the biological setting; use of biological and environmental experts; careful review if legally protected wildlife. Land use regulation is solely under the purview of local governments.

Design/Operation Recommendations: Perches should not be allowed on nacelles; tower design should not provide perches for avian predators; awareness of the potential for adverse effects of turbine warning lights on migrating birds.

Site Development Recommendations: Development in large, intact areas of native vegetation is discouraged; power lines should be buried if possible; turbines should not interfere with important wildlife or livestock movement corridors and staging areas.

Consultation with wildlife agency, USFWS: Contact with appropriate resource management agencies early in the planning process.

Mitigation requirements: Mitigation for habitat loss when significant ecological damage in the siting of a wind power facility cannot be avoided.

Decommissioning recommendations: Plans for future site decommissioning and restoration, including circumstances under which decommissioning and reclamation may occur and the expected end of the project life.

Public input: No specific procedures identified.

Relationships to other important energy and siting/zoning decisions: None identified.

Contacts:

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Citations and links:

Association of Fish and Wildlife Agencies. (n.d.). *Kansas*. www.fishwildlife.org/files/Kansas.pdf.

Environmental Law Institute. (May 2011). *State Enabling Legislation for Commercial-Scale Wind Power and the Local Government Role*. www.elistore.org/reports_detail.asp?ID=11410.

Kansas Energy Council. (Apr 2005). *Wind Energy Siting Handbook: Guideline Options for Kansas Cities and Counties*. http://kec.kansas.gov/reports/wind_siting_handbook.pdf.

Data gathered by Marley Ward, 11 Jul 2011.
Reviewed by Eric Johnson, 10 Nov 2011, Andy Fry, 25 Jan 2012.

State: Kentucky

Wind siting basics: Kentucky's wind energy potential is considered small. No precedent has been established for the siting and zoning of wind developments. The Kentucky State Board on Electric Generation and Transmission Siting (Siting Board) or the Public Service Commission would have authority over major wind developments. (www.fishwildlife.org/files/Kentucky.pdf.).

According to the Kentucky Integrated Resource Plan, most of the state has Class 2 (out of 7) wind speeds, making wind power generation economically impractical using currently available technology. A 2011 study by the Department of Economics at Western Kentucky University, entitled *Wind Energy Feasibility in Kentucky*, found that the wind resource in one major region of Kentucky (featuring Cumberland County) can produce affordable electricity. Statewide siting and zoning regulations could be developed as a result of this study. (www.wku.edu/jaep/html/documents/JAEPVol2708.pdf)

History of siting authority: None identified.

Approvals needed: Siting Board approval is required for merchant plants with a generating capacity of 10 MW or more. For obtaining local government approval, local zoning board rules apply.

Evaluation criteria: None identified.

Public input: No specific procedures identified.

Relationships to other important energy policies or siting and zoning: None identified.

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Citations and links:

Kentucky Economic Association. (2011). "Wind Energy Feasibility in Kentucky," *Journal of Applied Economics and Policy*, v30, pp. 1-4. http://kentuckyeconomicassociation.org/jaep/issues/JAEPVol30(1)2011.pdf.

Kentucky Utilities Company. (Mar 2011). *Analysis of Supply-side Technology Alternatives*. www.lrc.ky.gov/kar/807/005/058.htm.

Stemler, Jodi. (Oct 2007). *Wind Power Siting, Incentives, and Wildlife Guidelines in the United States*. U.S. Fish & Wildlife Service. www.fws.gov/habitatconservation/windpower/AFWA%20Wind%20Power%20Final%20Report.pdf.

Data gathered by Kai Goldynia, 2 August 2011.
Reviewed by Kate Shanks, 24 Oct 2011.

State: Louisiana

Wind siting basics: Louisiana has no specific siting authority for wind.

History of siting authority: None identified.

Approvals needed: None identified.

Evaluation criteria: None identified.

Public input: No specific procedures identified.

Relationships to other important energy policies or siting and zoning decisions: None identified.

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Citations and links:

Database of State Incentives for Renewables & Efficiency. *Louisiana Incentives/Policies for Renewables & Efficiency* [web page]. Retrieved 8 Nov 2011 from www.dsireusa.org/incentives/index.cfm?getRE=1?re=undefined&ee=1&spv=0&st=0&srp=1&state=A.

Stemler, Jodi. (Apr 2007). *Wind Power Siting Regulations and Wildlife Guidelines in the United States*. U.S. Fish & Wildlife Service. www.fws.gov/midwest/wind/guidance/AFWASitingSummaries.pdf.

Data collected by Deborah Luyo, 8 Nov 2011.
Reviewed by Beau Gregory, 9 Dec 2011.

State: Maine

Wind siting basics: In 2008, Maine implemented PL 2007 Ch 661, amending the Maine Wind Energy Act to provide for “expedited” siting and establish specific concerns regarding visual impact and community benefits (www.mainelegislature.org/legis/bills/bills_123rd/billtexts/SP090801.asp).

For projects located within the expedited permitting area for wind energy development:

- All of the organized areas of Maine are designated for expedited permitting. If a project is wholly located within organized areas, then the Maine Department of Environmental Protection (DEP) is the permitting authority at the state level. The municipality may also require a permit.
- If a project is wholly located within the unorganized areas of the state, then the Maine Land Use Regulation Commission (LURC) is the permitting authority at both the state and municipal levels.
- If a project is located within the expedited permitting area for wind energy development and is partially located within the organized areas of the state and partially located within the unorganized areas, then DEP may choose to be the permitting authority or may opt to review only the portion of the project located in the organized areas. In this case, LURC would review the portion in the unorganized areas.[2]

For projects not located in the expedited permitting area of the state, LURC is the permitting authority. In this case, a rezoning would be required first, followed by a development permit.

History of siting authority: Maine Wind Energy Act of 2003 (www.mainelegislature.org/legis/statutes/35-A/title35-Asec3402.html). The Maine Wind Energy Act includes a state goal of 3,000 MW of wind capacity by 2020.

In 2008 Maine implemented SP 980, which amended the Maine Wind Energy Act to provide for “expedited” siting and establish specific concerns about visual impact and benefits to the community (www.mainelegislature.org/legis/bills/bills_123rd/billtexts/SP090801.asp).

Approvals needed: Depending on the site plans and location, approvals may be needed from: Independent [Transmission] System Operator for New England (ISO-NE), Maine Department of Environmental Protection (DEP), Maine Public Utilities Commission (PUC) (for installations interconnecting at >100kV), the Natural Resources Council of Maine (NRCM), and the U.S. Army Corps of Engineers (COE). The Maine Department of Inland Fisheries and Wildlife (IFW) is a reviewer of permit applications for DEP and LURC.

Basic procedures:

1. Pre-application meeting(s) with the applicant and the relevant agencies – DEP and/or LURC, IFW, US Army Corps of Engineers, and others as needed – to discuss processing
2. Submit application
3. Permitting authority conducts review to determine whether application is complete for processing
4. Public meetings or hearing

[2] Unorganized areas are those having no local, incorporated municipal government; government is shared by various state agencies and county government. Organized areas are those having a local government that is incorporated.

5. Deliberation and decision
6. Appeals, if any
7. Begin construction

For more information on the LURC process:
www.maine.gov/tools/whatsnew/index.php?topic=lurcfiles&id=2642&v=tplfiles

The DEP procedure is outlined in Maine's Site Location Law:
www.maine.gov/dep/land/sitelaw/index.html

Evaluation criteria:

The Maine Wind Energy Act, section 9, provides:

- Applicants are required to submit "visual impact assessments" if the project is within three miles of scenic resources. "Scenic resources" are defined in the Act.
- The project must result in "tangible benefits" to the host community.

DEP criteria (www.maine.gov/dep/land/sitelaw/index.html):

"No adverse effect on the natural environment" standard of the Site Location Law (www.maine.gov/dep/land/sitelaw/index.html#rule)
No unreasonable adverse effect on air quality
No unreasonable alterations of climate
No unreasonable alterations of natural drainage ways
No unreasonable effects on runoff/infiltration relationships
No adverse effects on surface water quality
No unreasonable adverse effects on ground water quality or quantity
Sound-level limits
Preservation of historic sites
Preservation of natural areas
No unreasonable effect on scenic character
Protection of wildlife and fisheries

LURC criteria:

Effect on scenic character and related existing uses related to scenic character
Tangible benefits
Public safety-related setbacks

Smaller-scale developments (Other than utility scale)
(www.mainelegislature.org/legis/bills/bills_123rd/billtexts/SP090801.asp):

Projects must meet noise control requirements
Projects must be designed and sited to avoid unreasonable adverse shadow flicker effects
Setbacks must be adequate to protect public safety

Public input: Applicants, petitioners, and other interested persons may request a public hearing. Hearings may be continued and reconvened as circumstances require.

Relationships to other important energy and siting/zoning decisions: None identified.

Pending issues: Many towns in Maine have already drafted or are in the process of drafting wind-specific ordinances.

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www.maine.gov/dep/contact/index.html

Maine Land Use Regulation Commission
22 State House Station
Augusta, Maine 04333-0022
(207) 287-2631
www.maine.gov/doc/lurc/

Citations and links:

Land Use Regulation Commission. (Apr 2004). *Approval Process for Energy Generation and Transmission Projects.* www.maine.gov/tools/whatsnew/index.php?topic=lurcfiles&id=2642&v=tplfiles.

Maine State Planning Office. (7 Aug 2009). *Municipal Model Wind Energy Facility Ordinance*. http://maine.gov/spo/landuse/docs/ModelWindEnergyFacilityOrdinance.pdf.

Maine State Planning Office. (n.d.). *Municipal Role in Wind Power Regulation*. www.maine.gov/doc/mfs/windpower/pubs/pdf/wind_local_reg.pdf.

Data gathered by Lauren Teixeira. June 23, 2011.
Reviewed by Marcia Famous Spencer, 27 Dec 2011.

State: Maryland

Wind siting basics: For any electric generator 70 MW or greater, including wind-based generation, the Maryland Public Service Law requires the Maryland Public Service Commission (Commission) to issue a Certificate of Public Convenience and Necessity (CPCN) that authorizes the construction and operation of the facility. (PUC §§ 7-207 and 208 (http://law.justia.com/codes/maryland/2005/gpu/7-207.html, http://law.justia.com/codes/maryland/2005/gpu/7-208.html and www.fishwildlife.org/files/Maryland.pdf.)

History of siting authority: The current state siting law was enacted by Chapter 31 of the Laws of 1971. In 2001, by Chapter 655, the General Assembly began to exempt certain types of generation from the CPCN process if the facility does not exceed 70 MW and meets certain specified criteria. The exemption provision is codified in PUC Article § 7-207.1 (2005) (http://law.justia.com/codes/maryland/2005/gpu/7-207.1.html). In 2007, the General Assembly enacted Chapter 163 which allows land-based wind generation facilities to seek an exemption from the CPCN process if the facility will not exceed 70 MW. (PUC §7-207.1 and CPCN *Exemptions: FAQ* at http://webapp.psc.state.md.us/, and http://esm.versar.com/pprp/ceir15/Report_1_1_2.htm).

Approvals needed: For any generation facility over 70 MW, a developer must obtain a CPCN from the Maryland Public Service Commission. See PUC §§7-207 and 208 (http://law.justia.com/codes/maryland/2005/gpu/7-207.html, http://law.justia.com/codes/maryland/2005/gpu/7-208.html).

To initiate the process, a developer must file an application with the Commission that contains descriptive information as to ownership, interconnection, and specified environmental and socioeconomic information. Depending upon the type of generation being proposed as well as the location, the type of information and impact analysis required will vary. The necessary contents of the application and supporting information may be found in Chapter 79 of Title 20 of the Code of Maryland Regulations (COMAR) (www.dsd.state.md.us/comar/subtitle_chapters/20_Chapters.aspx#Subtitle79). For facilities applying for an exemption, the requirements are specified in COMAR 20.79.01.03 (www.dsd.state.md.us/comar/SubtitleSearch.aspx?search=20.79.01.*). Certain basic information, such as ownership, a facility description and location, and interconnection information, is required in either case.

For facilities required to obtain a CPCN, the Power Plant Research Program (PPRP) of the Maryland Department of Natural Resources (DNR) coordinates the state agency review and environmental evaluation. DNR is one of seven state agencies that review and comment on every application for a CPCN. The agencies include the Maryland Departments of Natural Resources, Environment, Agriculture, Business & Economic Development, Transportation, and Planning and Maryland Energy Administration. Once the review is completed, PPRP consolidates the findings of these agencies and represents them along with the state's recommended licensing conditions to the Commission as part of the Commission's hearing process. All facilities must be constructed and operated in compliance with state and federal requirements (www.dnr.state.md.us/bay/pprp/pp_brochure.html).

Regardless of whether a developer applies for a CPCN or for an exemption, the process begins with an application to the Commission. If a facility requires a CPCN, the Commission will usually delegate the application to the Commission's Hearing Office for assignment to a Public Utility Law Judge. The Law Judge sets a prehearing conference to establish a process for completing the application and developing a record to support the Commission's ultimate decision whether to grant the CPCN or not. The CPCN process will involve adjudicatory and public hearings. The time for completing the process depends upon the complexity of the proposed facility, the extent of environmental and socio-economic impacts, and public input – positive or negative. The process can take several months to a year or more. State law requires that the application be filed two years before construction is to commence, but this requirement may be, and usually is, waived upon request. If the facility is requesting an exemption, the Commission may consider the matter itself without assigning it to the Hearing Division, or it may delegate the matter to a Law Judge. The Law Judge will establish a public hearing process and ensure that the applicant meets the requirements for an exemption. The implementing regulations are set 90 days from the date of application for a decision unless otherwise directed by the Commission. COMAR 20.79.01.03 (www.dsd.state.md.us/comar/SubtitleSearch.aspx?search=20.79.01.*). In exemption proceedings, there are no compliance requirements imposed by the Commission itself beyond a requirement to ensure electrical safety and reliability. The Commission is required to hold at least one public hearing and may issue an exemption if it finds that it is in the public interest to do so. There may be local zoning requirements and state and local environmental compliance requirements outside of the CPCN process itself, such as stormwater management, non-tidal wetlands, and sediment control.

Evaluation criteria: The state of Maryland has drafted guidelines for wind power siting; however, these guidelines have yet to be implemented. Criteria in the draft guidelines include:

(1) Assess species of concern
(2) Minimize seasonal disturbance during construction
(3) Avian and bat breeding seasons
(4) Lighting issues

Public input: Both the PSC CPCN process and the related process for exempting qualifying generators include public input procedures.

Relationships to other important energy policies or siting and zoning decisions: The Maryland Renewable Energy Standard (20% by 2022) includes wind as an eligible technology.

In 2003, two commercial wind projects (one for 100 MW and one for 40 MW) each went through a licensing process and obtained a CPCN to construct and operate wind generation facilities in Garret County, Maryland. A third facility proposing to build another 40-50 MW also received a CPCN to construct a facility in Garrett County but with limitations placed on the siting of its wind turbines. Since then, all proposed commercial wind developments to date have been smaller than 70 MW.

Pending issues: The major issues are implementing the draft siting process guidelines and establishing procedures for siting offshore wind developments.

Research issues: Bird and bat activity studies in western Maryland, bat activity in the Mid-Atlantic Bight (a coastal region spanning from Cape Cod, Massachusetts to Cape Hatteras, North Carolina), bat migration and population size studies, benthic habitat studies in the Maryland Wind Energy Area, assessments of the wind resource offshore of Maryland, techniques for optimizing turbine array layouts.

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Citations and links:

Database of State Incentives for Renewables & Efficiency. (Jun 2011). *Maryland Incentives/Policies for Renewables & Efficiency* [web page]. Retrieved 4 Aug 2011 from www.dsireusa.org/incentives/index.cfm?getRE=1?re=undefined&ee=1&spv=0&st=0&srp=1&state=MD.

Maryland Energy Administration. (22 Nov 2010). *Maryland County Wind Ordinances*. http://energy.md.gov/countyOrdinance.html.

Stemler, Jodi. (Oct 2007). *Wind Power Siting, Incentives, and Wildlife Guidelines in the United States*. U.S. Fish & Wildlife Service. www.fishwildlife.org/files/Maryland.pdf.

Data collected by Kai Goldynia, 4 Aug 2011.
Reviewed by Andrew Gohn, 17 Nov 2011.

State: Massachusetts

Wind siting basics: The Energy Facilities Siting Board is the siting authority for facilities with capacities of 100 MW or larger. At this level there is a "one-stop" permitting process. Siting of < 100 MW facilities is subject to municipal or regional permitting. No on-shore wind facilities over 100 MW have been proposed or built in Massachusetts.

History of siting authority: The authority of the Massachusetts Siting Board over energy facilities with > 100 MW of capacity is established by Massachusetts General Law Chapter 164, Section 69H (www.malegislature.gov/Laws/GeneralLaws/PartI/TitleXXII/Chapter164/Section69H)

Approvals needed: On the federal level, the applicant usually needs the approval of the Environmental Protection Agency (EPA), Fish and Wildlife Agency, and the Federal Aviation Administration (FAA). On the state level, permits are generally required under the Massachusetts Environmental Policy Act (MEPA) and the Massachusetts Natural Heritage Program (MNHP). The Department of Environmental Protection (DEP) and the Endangered Species program could also regulate the project.

Since permitting in Massachusetts occurs on a local level, the procedure will vary according to the local bylaw or ordinance. Most procedures involve conducting a pre-construction survey, submitting the application, holding a public hearing, opportunity for appeals, and then a final approval granted (or denial issued) by the permitting authority.

The siting and permitting process for wind projects in Massachusetts can take an exceptionally long time. Under the Massachusetts "citizen suit statute" citizens can appeal any state or local approved permit (Chapter 21E, Section 15 www.malegislature.gov/Laws/GeneralLaws/PartI/TitleII/Chapter21E/Section15). This law allows a group of 10 or more citizens to challenge a permit. Some municipalities have recently adopted "as-of-right zoning" in designated locations, which allows wind projects in the designated zones to proceed without a special permit (Department of Energy Resources, 2011).

Evaluation criteria:

The Massachusetts Department of Energy Resources has developed two model by-laws/ordinances, one for siting projects subject to a special permit and another that allows projects to be sited without a special permit in designated locations. Generally, these bylaws include standards that address:

Design Standards, including height–.
Safety and Environmental Standards, including Setbacks, Shadow/Flicker, and Sound - must comply with DEP noise regulations (www.airandnoise.com/MA310CMR710.html)
Monitoring and Maintenance
Abandonment or Decommissioning

Public input: No specific procedures identified.

Relationships to other important energy policies or siting and zoning decisions: None identified.

Pending issues: The Wind Energy Siting Reform Act (S. 1666 – Finegold, H. 1775 – Smizik, and others[3]), currently before the Joint Committee on Telecommunications, Utilities and Energy, would:

[3] S. 1666 is the language of the conference report that made it to enactment stage in 2009-2010 session. H. 1775 is the House counterpart.

- Mandate that the Siting Board establish clear and predictable state siting standards for wind facilities; the standards must be as protective as existing state laws.

- Ensure municipalities would still establish and apply their own local standards.

- Provide for one-stop permitting at the local level and one stop at the state level for wind projects over 2 MW.

- Maintain home rule. (A municipality is free to reject any wind project, and the Siting Board has no authority to override that decision. Instead, the proponent's only remedy is to go to court – the same remedy as at present.)

- Provide for appeals. (If a municipality approves a wind project, opponents would appeal to the Siting Board. Appeal of a Siting Board ruling would go directly to the State Supreme Judicial Court.)

- Decrease the permitting process from eight years to 18 months, with an additional year if there is a judicial appeal.

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Daley, Beth. (11 Jul 2011). "Wampanoag tribe sues over sues over Cape Wind," *Boston Globe*. http://articles.boston.com/2011-07-11/lifestyle/29761941_1_cape-wind-wind-farm-horseshoe-shoal.

Department of Energy Resources, Massachusetts Executive Office of Environmental Affairs. (Jun 2011). *Model As-of-Right Zoning Ordinance or By-law: Allowing Use of Wind Energy Facilities or By-laws* www.mass.gov/eea/docs/doer/gca/as-of-right-wind-bylaw-june-2011.pdf.

_______. (1 Jan 2007). "Developing wind power projects in Massachusetts: Anticipating and avoiding litigation in the quest to harness wind." *Suffolk Journal of Trial and Appellate Advocacy*. www.thefreelibrary.com/Developing+wind+power+projects+in+Massachusetts%3a+anticipating+and+...-a0172525557.

Environmental Law Institute. (10 May 2011). *State Enabling Legislation for Commercial-Scale Wind Power Siting and the Local Government Role.* www.eli.org/pressdetail.cfm?ID=224.

Massachusetts Department of Energy Resources. *Massachusetts Wind Energy Siting Reform*. www.mass.gov/?pageID=eoeeaterminal&L=4&L0=Home&L1=Energy%2c+Utilities+%26+Clean+Technologies&L2=Renewable+Energy&L3=Wind&sid=Eoeea&b=terminalcontent&f=doer_renewables_wind_siting-reform&csid=Eoeea.

Massachusetts Department of Energy Resources. (Jun 2011). *Model Amendment to a Zoning Ordinance or By-Law: Allowing Conditional Use of Wind Energy Facilities*. www.mass.gov/eea/energy-utilities-clean-tech/renewable-energy/wind/wind-energy-model-zoning-by-law.html.

State of Massachusetts. *Massachusetts Energy Facilities Siting Board* [web page]. Retrieved 13 Jul 2011 from www.mass.gov/eea/energy-utilities-clean-tech/energy-facilities-siting-board/.

Stemler, Jodi. (Apr 2007). *Wind Power Siting Regulations and Wildlife Guidelines in the United States*. U.S. Fish & Wildlife Service. www.fws.gov/midwest/wind/guidance/AFWASitingSummaries.pdf.

Data collected by Lauren Teixeira, 13 Jul 2011.
Reviewed by Meg Lusardi, 12 Dec 2011.

State: Michigan

Wind siting basics: Michigan is a home-rule state. Local townships, villages, cities, and counties are responsible for wind siting and zoning. The state government has responsibility for identifying one or more Wind Energy Resource Zones, where transmission construction will be facilitated (see www.michigan.gov/windboard and http://www.michigan.gov/mpsc/0,1607,7-159-16393_52375---,00.html).

History of siting authority: None identified.

Approvals needed: No state permit process exists for construction of wind farms. Local land use and zoning regulations apply.

All construction projects can trigger the need for permits:

(1) Soil Erosion and Sedimentation Control – obtained from the appointed county or municipal enforcing agency
(2) National Pollutant Discharge Elimination System (NPDES) – Construction activities of 1 acre or more with a point-source discharge to waters of the state are required to submit a Notice of Coverage (NOC) to obtain coverage under Permit by Rule from the Michigan Department of Environmental Quality.
(3) Shoreline Construction from the State of Michigan Department of Environmental Quality
(4) Wetland Construction from the State of Michigan Department of Environmental Quality
(5) Sand Dune Construction from the State of Michigan Department of Environmental Quality

These processes are expected to take no more than a few months. A Soil Erosion and Sedimentation Control permit is required for all construction projects. Other permits are required, depending on location.

In addition, developers apply to the local township(s) or municipalities, and sometimes county(ies), for land-use permits (see http://expeng.anr.msu.edu/miwind/zoning_siting).

Like many other states, Michigan faces the challenge of implementing wind technology on the local, community scale. If zoning exists in a city, village, township, or county with its own existing zoning, the provisions adopted must be pursuant to the Michigan Zoning Enabling Act (2006 PA 110; http://legislature.mi.gov/doc.aspx?mcl-Act-110-of-2006). Some Michigan townships rely on county zoning, in which case the township must work with county planning commissions so that wind generator provisions are included in the county's zoning ordinance pursuant to the Michigan Zoning Enabling Act. Where zoning does not already exist, regardless of city, village, or township, it is not possible to adopt regulations without first adopting zoning (Michigan Department of Labor and Economic Growth, 2008).

Evaluation criteria: Some local governments have passed wind energy ordinances. Common evaluation criteria include:

(1) Property Setback
(2) Sound Pressure Level
(3) Safety
(4) Visual Impact
(5) Electromagnetic Interference

Public input: No specific procedures identified.

Relationships to other important energy policies or siting and zoning decisions:

The Wind Energy Resource Zone Board (WERZ Board) was created by the Michigan Public Service Commission (MPSC) in Dec 2008 for the purpose of identifying regions in the state with the greatest potential for harvest of wind energy. In its final report, the WERZ Board determined two geographical zones with the highest estimated generating capacity.

In one of those zones, a transmission construction project has been approved to accommodate future wind generation (http://efile.mpsc.state.mi.us/efile/viewcase.php?casenum=16200&submit.x=21&submit.y=6, www.midwestiso.org/Planning/TransmissionExpansionPlanning/Pages/TransmissionExpansionPlanning.aspx). The Michigan Public Service Commission granted an expedited siting certificate to ITC Transmission for construction of a transmission line and four substations in Michigan's Thumb region, considered the state's highest wind energy resource zone. Appeals to this decision were filed by the Association of Businesses Advocating Tariff Equity (ABATE) and the Michigan Public Power Agency (MPPA) and Michigan Municipal Electrical Association (MMEA).

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Citations and links:

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Michigan Department of Energy, Labor and Economic Growth, Bureau of Energy Systems. (16 Apr 2008). *Sample Zoning for Wind Energy Systems*. http://miwind.msue.msu.edu/uploads/files/michigan_department_of_energy_growth.pdf.

Michigan Economic Development Corporation, Energy Systems. *Michigan Wind Working Group* [webpage]. Retrieved 9 Aug 2011 from www.michigan.gov/mdcd/0,1607,7-122-25676_25774-75767--,00.html.

Michigan Public Service Commission. *Wind* [webpage]. Retrieved 9 Aug 2011 from www.michigan.gov/mpsc/0,1607,7-159-16393_55246-136909--,00.html.

Michigan Public Service Commission, *Wind Energy Resource Zones* [web page]. Retrieved 19 Oct 2011 from www.michigan.gov/mpsc/0,4639,7-159-16393_52375---,00.html.

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U.S. Department of Energy. *Wind Powering America—Michigan* [web page]. Retrieved 28 Jun 2011 from www.windpoweringamerica.gov/astate_template.asp?stateab=mi.

Data collected by Kai Goldynia, 28 June 2011; Deborah Luyo, 19 Oct 2011.
Reviewed by Julie Baldwin, 20 Oct 2011, John Sarver, 20 Oct 2

State: Minnesota

Wind siting basics: In 2005, the Minnesota Legislature transferred to Minnesota Public Utilities Commission (PUC or Commission) from the Minnesota Environmental Quality Board (MEQB) the permitting authority for wind facilities greater than or equal to 5 MW in capacity (Minnesota statute, Chapter 216F [Wind Energy Conversion Systems] (www.revisor.mn.gov/statutes/?id=216F). Siting authority for facilities < 5 MW is reserved for local jurisdictions.

Section 216F.08 allows counties to assume authority for permitting of facilities with capacities of up to 25 MW if they, as a minimum, adopt the Commissions' General Permit Standards (www.revisor.mn.gov/statutes/?id=216F.08).

History of siting authority: In 1995, the Minnesota legislature enacted legislation that excluded wind energy facilities from the requirements of the Power Plant Siting Act, established a review process specific to wind energy facilities and authorized the MEQB to adopt rules specific to large wind energy conversion systems. (www.revisor.mn.gov/laws/?doctype=Chapter&year=1995&type=0&id=203). Minnesota statute 216F.02 gives local governments authority over wind farms less than 5 MW: www.revisor.mn.gov/statutes/?id=216f.02.

Approvals needed: The Commission, in making its determination on whether to issue a final site permit, relies on standards, criteria, and factors in Minnesota Rules parts 7850.4000 and 7850.4100 (https://www.revisor.mn.gov/rules/?id=7850) and the record developed in the review process governed by Minnesota Rules, Chapter 7854 (https://www.revisor.mn.gov/rules/?id=7854). Commission site permit requirements address site designation, setbacks and site layout restriction, compliance procedures, surveys and reporting, construction and operation practices, final as built documents, decommissioning, restoration and abandonment, and special conditions as warranted. The Commission's website at www.puc.state.mn.us/PUC/energyfacilities/siting-routing/index.html provides access to each project docket, which contains the primary documents associated with a project, and eDockets, which contains all of the documents associated with an individual project.

Other permits required for LWECS construction may also include:

Minnesota Public Utilities Commission

Certificate of Need (for facilities generating 50 MW or more).
www.puc.state.mn.us/portal/groups/public/documents/pdf_files/001075.pdf

Minnesota Department of Transportation

Utility Permit (Long Form) - www.dot.state.mn.us/utility/files/pdf/permits/long-form-complete.pdf

Utility Permit (Short Form) www.dot.state.mn.us/utility/files/pdf/permits/short-form-complete.pdf

Access Driveway Permit - www.dot.state.mn.us/utility/files/pdf/permits/access-form-complete.pdf

Oversize/Overweight Permits Page - www.dot.state.mn.us/cvo/oversize/forms_and_applications.html

County and Township Road permits

In Minnesota, it is common practice for wind developers and counties to enter into development agreements that provide for designation of haul roads, assessment of road and infrastructure conditions prior to construction, damages, restoration, and ditch requirements. The following link (www.lrrb.org/trafcalc.aspx) provides a downloadable interactive document that provides web links, sample ordinances, reports, traffic calculators to quantify the traffic impact on roads, public policy options to recapture roadway maintenance costs, experience from current projects, and research information. This site will provide updates when available.

Tall Structure Permits

Wind energy conversion systems near airports may require a permit from the Minnesota Department of Transportation. Additional information is available on the Department's Aeronautics and Aviation website.

Minnesota Pollution Control Agency

NPDES Permit www.pca.state.mn.us/index.php/water/water-types-and-programs/stormwater/construction-stormwater/construction-stormwater.html?menuid=&redirect=1). This may also include and/or satisfy the Soil Erosion and Sediment Control Plan.

Noise Standards. The project must comply with Minnesota Rules Chapter 7030 (www.revisor.leg.state.mn.us/rules/?id=7030) for setbacks from defined facilities.

Minnesota Department of Natural Resources

Permits to cross public lands and waters (www.dnr.state.mn.us/waters/watermgmt_section/pwpermits/applications.html)

Native Prairie: turbines and associated facilities shall not be place in native prairie unless approved in a native prairie protection plan (www.dnr.state.mn.us/prairierestoration).

Minnesota Board of Water and Soil Resources

Wetland Conservation Act (WCA) (www.bwsr.state.mn.us/wetlands/forms/form03_B.PDF)

Other PUC Site Permit and or Study Requirements

Archaeological Resource Survey and Consultation (through State Historic Preservation Office (www.mnhs.org/shpo/).

Avian and Bat Protection Plan: Avian and Bat Assessments, Survey and Monitoring Requirements

Shadow Flicker Modeling, Analysis and Mapping

Noise Modeling, Analysis and Mapping and Post Construction Noise Surveys

Demonstrate Control of Wind Rights

Wind Access Buffer: Turbine towers must be placed a minimum of 5 rotor diameters (RD) from all boundaries of site on the prevailing wind directions and 3 RD on the non-prevailing directions, unless otherwise approved by the Commission.

Internal Turbine Spacing Requirements: Turbine towers must be placed a minimum of 5 rotor diameters apart on the prevailing winds directions and a minimum of 3 RD on the non-prevailing winds within the permitted site boundaries, unless otherwise approved by the Commission

Off-Air TV Analysis

AM and FM Radio Reports

Licensed Microwave Report

Land Mobile Report

Freestanding permanent MET Towers

For projects under the authority of the local jurisdiction, the applicant must obtain the appropriate land use and zoning permits, depending on the ordinance.

Model ordinance: www.cleanenergyresourceteams.org/files/2005_model_wind_ordinance.pdf.

Public input: Commission rules include provisions for application distribution requirements, public notice, public meetings, public hearings, and other procedural requirements (https://www.revisor.mn.gov/rules/?id=7854).

The Commission makes a final decision within 180 days of the acceptance of the application. If the project is approved, a permit is issued with any conditions the Commission considers necessary to protect the environment, enhance sustainable development, and promote the efficient use of resources. Minn. Rules 7854 | LWECS Permitting Flowchart.

Relationships to other important energy policies or siting and zoning decisions:
Minnesota law provides for the creation of wind and solar easements for solar and wind-energy systems. The Commission's site permit wind access buffer requirements protect the wind rights of both project participants and non-participants (See Minn. Stat. 500.30).

Pending issues: Health effects and Avian and bat issues.

Research issues: Avian and bat issues.

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(651) 297-2375 or 1-800-657-379
http://mn.gov/commerce/energy/utilities/Energy-Facility-Permits.jsp
www.energyfacilities.puc.state.mn.us/contact.html

Citations and links:

Great Lakes Wind Commission. (Mar 2009). *Siting and Permitting Wind Farms in Minnesota*. http://wiki.glin.net/download/attachments/950461/Minnesota.doc.

Minnesota Public Utilities Commission. *Energy Facilities* [web page]. www.puc.state.mn.us/PUC/energyfacilities/index.html.

Minnesota Statutes. (2011). *Chapter 216F. Wind Energy Conversion Systems*. https://www.revisor.mn.gov/statutes/?id=216F.

Data collected by Marley Ward, 1 July 2011, Deborah Luyo 27 Oct 2011.
Reviewed by Tricia DeBleeckere, 22 Dec 2011, Larry Hartman 9 Jan 2012.

State: Mississippi

Wind siting basics: Mississippi has no specific siting authority for wind.

History of siting authority: None identified.

Approvals needed: None identified.

Evaluation criteria: None identified.

Public input: No specific procedures identified.

Relationships to other important energy policies or siting and zoning decisions: None identified.

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Citations and links:

Database of State Incentives for Renewables & Efficiency. *Mississippi Incentives/Policies for Renewables & Efficiency* [web page]. Retrieved 6 Nov 2011 from www.dsireusa.org/incentives/index.cfm?getRE=1?re=undefined&ee=1&spv=0&st=0&srp=1&state=MS.

Stemler, Jodi. (Apr 2007). *Wind Power Siting Regulations and Wildlife Guidelines in the United States*. U.S. Fish & Wildlife Service. www.fws.gov/midwest/wind/guidance/AFWASitingSummaries.pdf.

Data collected by Deborah Luyo, 6 Nov 2011.

State: Missouri

Wind siting basics: Local siting autonomy (Environmental Law Institute, 2011).

History of siting authority: None identified.

Approvals needed: There is no specific approval process; however, the Public Service Commission and Department of Natural Resources can have input and provide oversight, depending on the location and facilities planned. Otherwise, wind energy facilities are subject only to existing local government zoning regulations (Association of Fish and Wildlife Agencies).

Local government grants permit for construction if project is in compliance with zoning laws. (Association of Fish and Wildlife Agencies).

Evaluation criteria: None identified.

Public input: No specific procedures identified.

Relationships to other important energy policies or siting and zoning decisions: None identified.

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Citations and links:

Association of Fish and Wildlife Agencies. *Missouri*. www.fishwildlife.org/files/Missouri.pdf.

Environmental Law Institute. (10 May 2011). *State Enabling Legislation for Commercial-Scale Wind Power Siting and the Local Government Role*. www.eli.org/pressdetail.cfm?ID=224.

Missouri Department of Natural Resources, *Wind Energy Resources* [web page]. Retrieved 20 Oct 2011 from www.dnr.mo.gov/energy/renewables/wind-energy.htm.

Data collected by Marley Ward, 1 Jul 2011.

State Name: Montana

Wind siting basics: Wind power development on private land is generally not government regulated, but under a statewide permit, persons disturbing more than one acre of land are required to file a Storm Water Pollution Prevention Plan with the Montana Department of Environmental Quality. The Montana Department of Environmental Quality can regulate projects impinging on wetlands, water quality, and the like (www.fishwildlife.org/files/Montana.pdf*)*. Each county controls zoning for commercial and industrial development. *The Montana Department of Natural Resources and Conservation must approve projects on state owned land.*

History of siting authority: None identified.

Approvals needed: No specific wind energy siting or zoning approvals are needed from state or local agencies. If the project encroaches on wildlife, or impacts the human environment, environmental reviews may be necessary.

Only projects requiring a state permit or approval are subject to review under the Montana Environmental Policy Act (MEPA). If a wind project is determined to require MEPA review, an Environmental Assessment (EA) and/or Environmental Impact Statement (EIS) is required. One of the functions of an EA is to document whether there is potential for a significant impact. If there is a potential significant impact, an EIS must be prepared by the permitting agency. An EIS details the purpose of the project, describes the areas and resources affected, and reviews alternatives including the no action alternative and possible measures to reduce adverse impacts. Public participation is discretionary during EA review, but mandatory for EIS review.

Evaluation criteria: No specific criteria identified. Permits may be required from the Department of Environmental Quality depending on circumstances involving:

(1) Electric Transmission
(2) Open-cut Mining
(3) Wastewater
(4) Water Quality

Public Input: Public participation is a vital tool during the Environmental Impact Statement review and may be required during a state agency during preparation of an Environmental Assessment. The agency must provide at least a 30-day period for comments on the draft EIS and must not make a decision for a 15-day period following publication of a final EIS. The 30-day comment period may be extended for up to an additional 30 days unless the state agency is doing a joint review with a federal agency. In addition, the state agency must inform the public of its decision and its justification for that decision.

Relationships to other important energy policies or siting and zoning decisions: Montana's RPS requires that all public utilities obtain 15% of their electricity supply from qualified renewable energy resources by 2015.

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Citations and Links:

Association of Fish and Wildlife Agencies. *Montana*. www.fishwildlife.org/files/Montana.pdf.

Gaelectric. (13 Apr 2011). "Study confirms unique features of Montana wind in providing solutions for Pacific NW power market." www.gaelectric.ie/news-detail.asp?nid=79&id=5.

Montana Wind Group [web page]. Retrieved 13 Jul 2011 from http://montanawindgroup.org/index.html.

Montana Dept. of Environmental Quality. *Wind Energy Permit Requirements* [web page]. Retrieved 13 Jul 2011 from www.deq.mt.gov/energy/renewable/windweb/WindPermits.mcpx.

National Wind, *Montana Wind Facts* [web page]. Retrieved 13 Jul 2011 from www.nationalwind.com/montana_wind_facts.

Data collected by Kai Goldynia, 12 Jul 2011.
Reviewed by Tom Kaiserski, 12 Jan 2012, Tom Ring, 18 Jan 2012.

State: Nebraska

Wind siting basics: Nebraska is the only state where all electric power is publicly owned. As such, all power is regulated by the legislature, a local utility, or the Nebraska Power Review Board (NPRB).

Under 80 MW: Applicants connecting to the electric grid must obtain a power purchase agreement with a local utility and comply with local ordinances. Applicants must receive approval prior to construction either from the Federal Energy Regulatory Commission using the PURPA certification process, or from the NPRB. Customer generators (net metering) with a generator under 25 kilowatts rated capacity are exempt from the NPRB approval requirement.

Over 80 MW: Applicants must obtain NPRB approval prior to construction. The approval criteria the NPRB must use is set out in Neb. Rev. Stat. § 70-1014 (1996) (www.nprb.state.ne.us/prbmanual/4.html). A special generation application process is available under Neb. Rev. Stat. § 70-1014.01(2) if filed by a Nebraska utility for a renewable energy project and the total production from all such facilities does not exceed 10 percent of the utility's total energy sales. Approval of special generation applications is allowed if the applicant conducts a public hearing on the proposed project.

Wind-for-export project: Private developers wishing to construct renewable generation facilities can file an application using special NPRB approval criteria if at least 90 percent of the power will be exported outside Nebraska. The developer must offer certain public power utilities 10 percent of the renewable-generated electricity. The utilities can negotiate – the utilities do not have to purchase 10 percent. This process is set out in Neb. Rev. Stat. § 70-1014.02.

The Nebraska Power Review Board's approval criteria in Neb. Rev. Stat. § 70-1014 for generation and transmission facilities are based on public convenience and necessity, cost-effectiveness, and feasibility, as well as whether the proposed facility will duplicate existing facilities. The Board also determines issues relating to territorial disputes between utilities and is the repository for all Nebraska electric power suppliers' certified service areas.

History of siting authority: The authority of the Nebraska Power Review Board is statutory law: www.powerreview.nebraska.gov/powerlaws.htm

Terms for wind-for-export projects are defined in Section 70-1014.02, which was added in 2010. http://uniweb.legislature.ne.gov/laws/laws-index/chap70-full.html

Community-Based (C-BED) legislation was added in 2007, Sections 70-1901 to 70-1907: http://nebraskalegislature.gov/laws/laws-index/chap70-full.html

Approvals needed: Approval is also needed from: the Federal Aviation Administration, the Department of Defense, and the Nebraska Game and Parks Commission. The developer must notify either the Nebraska Game and Parks Commission or the U.S. Wildlife Agency. The project will receive a thumbs up/thumbs down from federal and state wildlife agencies as a unit. The NPRB is required to consult with the Nebraska Game and Parks Commission on all applications to ensure that approval will not cause harm to threatened or endangered species or their critical habitat. The Game and Parks Commission will notify the NPRB of its determination. The NPRB will also coordinate with the Nebraska Department of Aeronautics, the State Historical Society and the Nebraska Commission on Indian Affairs.

Omaha Public Power District, the Municipal Energy Agency of Nebraska, and NPPD have all solicited wind resources through requests for proposals (RFPs). NPPD expects to need 533MW of wind generation in order to meet its goal of 10% renewables by 2020. The NPPD RFP process is as follows:

(1) The NPPD submits an RFP, specifying a capacity and general location for the facility. Developers can propose projects on NPPD land or privately owned land.
(2) Developers submit their proposals during the RFP time period. (The second most recent RFP, which closed 15 Apr 2009, yielded 22 proposals.)
(3) The NPPD evaluates the proposals and develops a short list.
(4) From this shortlist the NPPD Board of Directors must approve a power purchase agreement.

Evaluation criteria: Energy cost to NPPD, cost of transmission, developers' experience, and environmental impact.

Counties drafting ordinances usually consult the NPPD. Setback distances are recommended by the U.S. Bureau of Land Management.

Public input: No specific procedures identified.

Relationships to other important energy policies or siting and zoning decisions: C-BED legislation gives landowners first right to wind energy development and provides a sales and use tax exemption on the gross receipts from the sale, lease, or rental of personal property for use in a C-BED project (http://uniweb.legislature.ne.gov/laws/statutes.php?statute=s7727004057).

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Citations and links:

Environmental Law Institute. (10 May 2011). *State Enabling Legislation for Commercial-Scale Wind Power Siting and the Local Government Role*. www.eli.org/pressdetail.cfm?ID=224.

Stemler, Jodi. (11 Apr 2007). *Wind Power Siting Regulations and Wildlife Guidelines in the United States*. U.S. Fish and Wildlife Service. www.fws.gov/midwest/wind/guidance/AFWASitingSummaries.pdf.

WOWT. "NPPD Receives 18 Wind Energy Proposals," *WOWT.com*. www.wowt.com/news/headlines/43127912.html?storySection=story.

Data collected by Lauren Teixeira, 11 Jul 2011.
Reviewed by Jerry Loos, 5 Jan 2012; David Ried, 5 Jan 2012; Tim Texel, 9 Jan 2012.

State: Nevada

Wind siting basics: Wind siting is done at the local level. The Public Utilities Commission of Nevada issues a permit for construction of renewable electric generating plants, including wind, with a nameplate capacity of 70 MW or more.

History of siting authority: Utility Environmental Protection Act; Nevada Revised Statutes § 704.820 through 704.900 (1971) (www.leg.state.nv.us/nrs/nrs-704.html). Nevada is a Dillon's Rule state.

Approvals needed: Approval at the county level is needed. Applicants are required to file with the Nevada PUC, including a summary of environmental impact and need. The applicant must also submit a copy to the Division of Environmental Protection, Nevada Department of Conservation and Natural Resources, and Nevada State Clearinghouse. Within 150 days, the PUC will grant or deny the application.

Approximately 85% of Nevada land is federal property, where environmental studies are required by the federal Bureau of Land Management. Such studies are thorough and usually take up to two years (for an environmental assessment; EA) or three years (for an environmental impact statement; EIS).

Evaluation criteria: A community does not have authority to deny approval of a wind energy system if the owner has written consent from all owners of properties within 300 feet of the system and meets all of the local jurisdiction's ordinances for wind energy systems if in effect (Database of State Incentives for Renewables & Efficiency, *Nevada Solar and Wind Easements & Rights Laws*).

Public input: No specific procedures identified.

Relationships to other important energy policies or siting and zoning decisions: Nevada's most recent renewable portfolio standard (RPS) mandates that 25% of energy must come from renewable sources by 2025. Portfolio energy credits (PECs) are used to facilitate the buying and selling of renewable energy to meet portfolio standards. One PEC is equal to one kilowatt-hour (kWh) produced from a non-solar renewable source.

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Citations and links:

Database of State Incentives for Renewables & Efficiency. (2 Jun 2011). *Nevada Incentives/Policies for Renewables & Efficiency* [web page]. Retrieved 6 Jul 2011 from www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=NV01R&re=1&ee=1.

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Robison, Jennifer. (22 Jun 2011). "In Wind Farms, Nevada Decidedly Calm," *The Las Vegas Review-Journal*. www.lvrj.com/business/in-wind-farms-nevada-decidedly-calm-124337909.html.

United States Court of Appeals for the Ninth Circuit. *Western Watersheds Project and Center for Biological Diversity v. Bureau of Land Management*, Docket 11-15799. www.sustainabilityclimatechangereporter.com/uploads/file/11-15799%5b2%5d.pdf.

Data collected by Francis Motycka, 6, 11 Jul 2011, 4 Aug 2011.
Reviewed by Mark Harris, 31 Oct 2011.

State: New Hampshire

Wind siting basics:

Small Wind: Wind siting is done at the local level of government. However, developers of facilities larger than 5 MW and smaller than 30 MW can petition the New Hampshire Site Evaluation Committee (SEC) for a Certificate for Site and Facility, which would preempt local jurisdiction (www.nhsec.nh.gov/rules/index.htm).

Large Wind: The NH SEC has overall siting authority for energy facilities 30 MW or over, as demonstrated by its decision-making authority in RSA 162-H:16, II (www.gencourt.state.nh.us/rsa/html/XII/162-H/162-H-16.htm). The committee works closely with the host community(ies) to ensure orderly development of the region and incorporates local interests as much as possible in a decision as long as the preamble to RSA 162-H is not compromised. Local ordinances, etc. are not binding on the NH SEC. The NH SEC possesses the authority to supersede the local host community(ies) if its requirements conflict with the preamble of the law (RSA 162-H:1, www.gencourt.state.nh.us/rsa/html/XII/162-H/162-H-1.htm) in favor of the greater good.

History of siting authority: New Hampshire Revised Statute: RSA 162-H:2, XI (1991, 1998, 2009) (www.gencourt.state.nh.us/rsa/html/XII/162-H/162-H-mrg.htm). New Hampshire is a Home Rule state.

Approvals needed: For Large Wind, the New Hampshire Energy Facility Siting Evaluation Committee (SEC) provides a Certificate of Site and Facility.

Within 60 days of submitting an application to the SEC, a decision will be made to either accept or deny the application. If an application is deemed incomplete, the applicant has 10 days to make corrections or choose to begin anew. Within five months, all state agencies involved are to submit to the SEC reports of progress and list any additional information required for permits. Within eight months, the state agencies are to report their final decisions regarding their respective jurisdictions. Within nine months of the application's acceptance date, the SEC makes a decision to either issue or deny the certificate.

Evaluation criteria: The SEC must determine that the project:

- Applicant has adequate financial, technical, and managerial capability to assure construction and operation of the facility in continuing compliance with the terms and conditions of the certificate.
- Will not unduly interfere with the orderly development of the region, with due consideration having been given to the views of municipal and regional planning commissions and municipal governing bodies.
- Will not have an unreasonable adverse effect on aesthetics, historic sites, air and water quality, the natural environment, and public health and safety.

(1) Environmental impact: The New Hampshire Fish & Game Department reviews potential impacts to wildlife. The New Hampshire Natural Heritage Bureau focuses on the potential impact to endangered species and plants.
(2) Historic sites: The New Hampshire State Historic Preservation Office is responsible for historic and cultural resource issues.
(3) Stormwater and wetlands: New Hampshire Department of Environmental Services is responsible for storm water runoff, wetlands, and alteration of terrain.

Public input: The SEC subcommittee must hold at least one public hearing after acceptance of the application, and another after submission of final decisions from participating state agencies (www.nhsec.nh.gov/rules/index.htm).

Relationships to other important energy policies or siting and zoning decisions: New Hampshire's Renewable Energy Portfolio mandates that 23.8% of electric generation must come from renewable sources by 2025. Wind energy, among others, is listed as a Class I energy source. Class I energy sources must increase by 1% every year from 2011 through 2025, reaching 16% by 2025.

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Citations and links:

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Data collected by Francis Motycka, 3, 6 Jul 2011, 4 Aug 2011.
Reviewed by Tim Drew, 4 Nov 2011, Kate Epsen, 26 Jan 2012.

State Name: New Jersey

Wind Siting Basics: New Jersey has no specific wind siting authority.

History of Siting Authority: New Jersey Statute § 40:55D-66.11, 31 Mar 2009. *Wind and solar facilities permitted in industrial zones* ftp://www.njleg.state.nj.us/20082009/AL09/35_.PDF.

New Jersey Statute § 40:55D-66.12, 16 Jan 2010. *Municipal ordinances relative to small wind energy systems* www.njleg.state.nj.us/2008/Bills/AL09/244_.PDF.

New Jersey Statutes §13:19-10.1, Jan 2010. *Wind as a Permitted Use on Piers*. www.njleg.state.nj.us/2010/Bills/S0500/212_R3.PDF.

New Jersey Statutes § 48:3-51, 29 Mar 2010. *The Offshore Wind Economic Development Act* http://law.onecle.com/new-jersey/48-public-utilities/3-51.html.

Approvals needed: Approval is needed from the Department of Environment Protection and from local governments through the planning and zoning commission. Offshore wind power, considered the greatest source of wind power potential in New Jersey, is subject to state coastal zone management rules.

There are two general types of wind energy generation projects in New Jersey; net metered systems interconnected behind an electric customer's meter and merchant wholesale power generators. Developers of net metered generation facilities must file an interconnection application with the Electric Distribution Company serving the potential "customer-generator". The state's Board of Public Utilities (NJBPU) promulgates regulations governing how the state's franchise Electric Distribution Companies interconnect and net meter NJ Class I renewable resources, including wind energy.

Developers of new wholesale merchant power generation facilities must file an application with the PJM Interconnection. The PJM will conduct a review, which includes preliminary feasibility, impact and cost allocation studies.

Evaluation criteria: Pre-construction requirements for projects located in the coastal zone (Four distinct regions are included in New Jersey's coastal zone. Standards for determination of boundaries differ among regions.) include:

- Visual and Audio Bird Surveys
- Migratory Bat surveys
- Radar Surveys

Post construction monitoring is also required (NJ Department of Environmental Protection, 2010).

Public Input: No specific procedures identified.

Relationships to other important energy policies or siting and zoning decisions: New Jersey's renewable portfolio standard requires that each electricity supplier or provider serving retail electric customers in the state's competitive generation marketplace procure 22.5% of electricity sold from renewable sources by 2021 (Database of State Incentives for Renewables & Efficiency, 2010).

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Data collected by Deborah Luyo, 1 Nov 2011.
Reviewed by B. Scott Hunter, 20 Jan 2012.

State: New Mexico

Wind siting basics: Local siting with local autonomy for projects up to 300 MW (Environmental Law Institute, 2011). The New Mexico Public Regulation Commission has authority for projects greater than 300 MW. State agencies have the authority to override local decisions, if they are not within the guidelines of Section 62-9-3 of the 2009 New Mexico Code (http://law.justia.com/codes/new-mexico/2009/chapter-62/article-9/section-62-9-3/).

History of siting authority: 2009 New Mexico Code (http://law.justia.com/codes/new-mexico/2009/chapter-3/article-21/section-3-21-1).

Approvals needed: Approval of projects by county government is based on zoning laws.

New Mexico's Public Regulation Commission has no process for review of potential wind projects.

Evaluation criteria: Guidelines from the New Mexico Department of Game & Fish include:

- Turbines should not be place in documented locations of any species of wildlife, fish or plant protected under the Federal Endangered Species Act.
- Turbines should not be located in known local bird migration pathways or in areas where birds are highly concentrated, unless mortality risk is low.
- Turbines should not be placed near known bat hibernation, breeding, and maternity/nursery colonies, in migration corridors, or in flight paths between colonies and feeding areas.
- Configure turbine locations to avoid areas or features of the landscape known to attract raptors (hawks, falcons, eagles, owls).
- Configure turbine arrays to avoid potential avian mortality where feasible.
- Avoid fragmenting large, contiguous tracts of wildlife habitat.
- Avoid placing turbines in habitat known to be occupied by Lesser Prairie Chickens or other species that exhibit extreme avoidance of vertical features and/or structural habitat fragmentation.
- Minimize roads, fences, and other infrastructure.
- Develop a habitat restoration plan for proposed sites that avoids or minimizes negative impacts on vulnerable wildlife while maintaining or enhancing habitat values for other species.
- Post-development mortality studies should be a part of any site development plan.

Public input: No specific procedures identified.

Relationships to other important energy policies or siting and zoning decisions: None identified.

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Data collected by Marley Ward, 13 Jul 2011.
Reviewed by Rachel Jankowitz, 8 Nov 2011.

State: New York

Wind siting basics: Projects with a nameplate capacity of 25 MW or more require a Certificate of Public Convenience and Necessity from the Public Service Commission. Wind energy projects may require specific approvals from state or federal agencies, for example wetland or stream disturbance permits from the Department of Environmental Conservation (DEC) or U.S. Army Corps of Engineers (USACE). Before local and State agencies can issue these approvals, an environmental review must be conducted according to the State Environmental Quality Review Act (SEQRA).

History of siting authority: Public Service Law (PSL) § 617, 1996**.** Co-generation, Small Hydro and Alternate Energy Production Facilities**;** New York Code: Energy Law Article 21 - § 21-106, 2010. State Environmental Quality Review Act (SEQRA), 2011**.** New York is a Home Rule State.

Approvals needed: The pre-application process involves submission of an application to the siting board, which includes five state agency officials and two ad hoc members from the community. Depending on location and environmental impact, required permits could include:

(1) Construction stormwater permit
(2) Coastal erosion control permit
(3) Freshwater wetland permit
(4) Protection of waters permit
(5) Tidal wetlands permit
(6) Endangered and threatened species take permit

The first step in the approval process is initiating the SEQRA review, where a local agency is typically the Lead Agency. If at least one potential adverse environmental impact is identified, depending on the type and amount of impact, an Environmental Impact Statement (EIS) could be required. After completion of the SEQRA process, which sometimes includes a public comment period, all involved agencies make decisions, based on each agency's jurisdiction, to approve or deny the project. SEQRA publishes its procedures (www.riverkeeper.org/wp-content/uploads/2009/06/A_Citizens_Guid-1.pdf).

The Department of Environmental Conservation has issued guidelines for pre- and post-construction bird and bat monitoring (www.dec.ny.gov/energy/40966.html). Prior to construction, at least one year of monitoring is encouraged, longer if findings indicate that more study is needed. Post-construction monitoring is typically done for a minimum of two years at each project, longer if findings indicate that more study is needed or if site-specific situations warrant further observation.

Evaluation criteria: The following criteria are from the *Model Ordinance* developed by the New York State Research and Development Authority (NYSERDA; http://nyserda.ny.gov/):

- Controls and brakes: "All wind turbines shall have an automatic braking, governing or feathering system."
- Climb prevention and locks: "…a fence six feet high with a locking portal shall be placed around the facility's tower base or the tower climbing apparatus shall be limited to no lower than 12 feet from the ground, or the facility's tower may be mounted on a roof top."
- Decommissioning: "Any wind energy system found to be unsafe… shall be repaired…or removed within six months. If any wind energy system is not operated for a continuous period of 12 months, the Town will notify the landowner."
- Environmental: "Wind turbines shall be set back at least 2,500 feet from Important Bird Areas… and at least 1,500 feet from State-identified wetlands."

- Interference with communications devices: “The applicant shall minimize or mitigate any interference with electromagnetic communications.”
- Liability insurance: “Prior to issuance of a building permit, the applicant shall provide the town proof of… insurance.”
- Lighting: “Towers shall be equipped with air traffic warning lights and shall have prominent markings on the rotor blade tips of an international orange color where the total height of the tower exceeds 175 feet.”
- Minimum property setbacks: “The minimum setback distance… shall be equal to no less than 1.5 times the sum of proposed structure height plus the rotor radius.”
- Power lines: “All wiring between wind turbines and the wind energy facility substation shall be underground.”
- Protection of public roads: “…if new roads are needed, minimize the amount of land used for new roads and locate them so as to minimize adverse environmental impacts.”
- Sound levels: “Individual wind turbine towers shall be located so that the level of noise produced by wind turbine operation shall not exceed 55 dBA.”
- Substation: “…if new substations are needed, minimize the number of new substations.”
- Visual appearance of wind turbines and related infrastructure: “Brand names or advertising… shall not be visible from any public access” and “colors and surface treatment… shall minimize visual disruption. … Where wind characteristics permit, wind towers shall be set back from the tops of visually prominent ridgelines.”

Public input: No specific procedures identified.

Relationships to other important energy policies or siting and zoning decisions: The state of New York has a renewable portfolio standard (RPS) of 24% percent by 2013. “Main tier” sources, including wind power, must provide at least 93% of this standard.

Pending issues: On 22 Jun 2011, the New York State Assembly passed the State Power Act of 2011, which will create a centralized and streamlined process for wind facility siting for projects over 25 MW. The new siting board will be composed of executives at various state agencies. http://public.leginfo.state.ny.us/LAWSSEAF.cgi?QUERYTYPE=LAWS+&QUERYDATA=$$PBS18-A$$@TXPBS018-A+&LIST=LAW+&BROWSER=EXPLORER+&TOKEN=21386711+&TARGET=VIEW.

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Reviewed by Brianna Gary, 10 Nov 2011.

State: North Carolina

Wind siting basics: Wind siting is done at the local level of government.

History of siting authority: North Carolina General Statutes, Chapter 62 (1963) (www.ncga.state.nc.us/enactedlegislation/statutes/html/bychapter/chapter_62.html)

Rule R8-61regarding certificates of public convenience and necessity for construction of electric generation and related transmission facilities in North Carolina (Feb 2008) (http://ncrules.state.nc.us/ncac/title%2004%20-%20commerce/chapter%2011%20-%20utilities%20commission/04%20ncac%2011%20r08-61.pdf)

North Carolina Environmental Policy Act (SEPA) (1971, 1991) (www.ncleg.net/EnactedLegislation/Statutes/HTML/ByChapter/Chapter_113A.html)

North Carolina is a Home Rule state.

Approvals needed: The following agencies should be contacted:

(1) North Carolina Department of Environment
(2) North Carolina Department of Natural Resources
(3) U.S. Army Corps of Engineers for projects in or around streams, wetlands, or other waters
(4) County government

The developer must obtain a Certificate of Public Convenience and Necessity from the NCUC. If the project is 300 MW or more, the applicant must submit a summary at least 120 days before filing an application.

Evaluation criteria: Criteria from the Watuaga County ordinance (2006) include:

(1) Decommissioning
(2) Demographics of surrounding area
(3) Location, topography and wetland assessments
(4) Maintenance
(5) Noise
(6) Public health and safety
(7) Tourism and community benefits
(8) Visual impacts, with a special emphasis on the Blue Ridge Parkway viewshed.

Public input: Within ten days of filing an application, the applicant must provide at least three public notifications through the local newspaper to all residents in the county and municipality that will be affected by the facility. A project summary must also be forwarded to the North Carolina State Environmental Review Clearinghouse (www.doa.state.nc.us/clearing/).

Relationships to other important energy policies or siting and zoning decisions: North Carolina's renewable portfolio standard (RPS) requires 12.5% of 2020 electricity sales to come from renewable sources. Each utility shall file compliance reports in 2012, 2013, 2014, 2015, 2018, and 2021, detailing the previous year's electricity sales. (Database of State Incentives for Renewables & Efficiency, 2011).

Pending issues: The Desert Wind Energy Project, North Carolina's first utility-scale wind facility, a 300 MW wind facility in the counties of Pasquotank and Perquimans, has received approval from the North Carolina Utilities Commission. Electricity generation is anticipated to begin by the end of 2012.

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Data collected by Francis Motycka 6, 11, 12 Jul , 3 Aug 2011.

State: North Dakota

Wind siting basics: The North Dakota Public Service Commission (PSC) regulates the siting of wind facilities greater than 0.5 MW (www.legis.nd.gov/cencode/t49c22.pdf). Smaller facilities are regulated at the local level (by either county or township board).

History of siting authority: The Energy Conversion and Transmission Facility Siting General Provisions were amended in 1979, and again in 1982, 2008, and most recently in 2011.[4] Passage of Senate Bill 2196 (Sixty Second Legislative Assembly of North Dakota, 2011) closed what one state senator referred to as a "loophole" that allowed wind developers to avoid the state siting provisions by breaking up larger wind projects into smaller ones simply to keep under the minimum capacity threshold ("ND PSC may get broader wind farm siting authority," 2011). Prior to this amendment, North Dakota PSC had authority to review energy conversion facilities for projects over 60 MW. The 2011 amendments lower the limit for wind generators to 0.5 MW and all other generators to 50 MW.

Approvals needed: For any wind project greater than 0.5 MW, applicants must obtain a Certificate of Site Compatibility from the North Dakota Public Service Commission. The Commission works in concert with as many as 21 state agencies in determining whether to issue a Certificate.[5]

The North Dakota PSC outlines a comprehensive list of procedures and required certificates and permits. These include:

(1) General Provisions
- Advisory Committees
- Public Hearings

(2) Utility Reporting Requirements
(3) Letter of Intent
(4) Certificate of Site or Corridor Compatibility
(5) Transmission Facility Permit
(6) Waiver of Procedures and Time Schedules
(7) Criteria
(8) Continuing Suitability of Certificate or Permit

The timetable for application review is undetermined, dependent upon completion of all requirements.

Evaluation criteria: Criteria for evaluating energy conversion facility siting decisions include:

(1) Exclusion zones
- national parks, forests, etc.
- state parks, forests, etc.
- irrigated lands

[4] North Dakota Administrative Code, Title 69-06, www.legis.nd.gov/information/acdata/html/69-06.html.
[5] The list of 21 state agencies required to receive notice of applications for Energy Conversion Facilities and Transmission Facilities is included in § 69-06-01-05. These include the North Dakota Departments of Agriculture, Health, Human Services, Labor, Career and Technical Education, and the Aeronautics Commission, Attorney General, Economic Development Commission Energy Development Impact Office, Game and Fish Department, Geological Survey, Governor, Highway Department, State Historical Society of North Dakota, Indian Affairs Commission, Job Service of North Dakota, Land Development, Parks and Recreation Department, Division of Community Services-Department of Commerce, Soil Conservation Committee, and State Water Commission.

- areas important to the life-cycle of endangered species

(2) Avoidance areas
- geologically unstable areas
- historically significant areas
- woodlands and wetlands

(3) Selection criterion – evaluation of impacts on:
- Agriculture
- Law enforcement
- School systems and educational programs
- Governmental services and education programs
- General and mental health care facilities
- Recreational programs and facilities
- Transportation facilities and networks
- Retail service facilities
- Utility services
- Local institutions
- Noise-sensitive land uses
- Rural residences and businesses
- Aquifers
- Human health and safety
- Animal health and safety
- Plant life
- Temporary and permanent housing
- Temporary and permanent skilled and unskilled labor

Public input: General hearings are held prior to adopting or modifying the criteria, or suspending a certificate or permit. Application hearings are held for a certificate or permit.

Relationships to other important energy policies or siting and zoning decisions: North Dakota has a Renewable Portfolio Standard of 10% by 2015. North Dakota already has over 1,400 MW of installed wind capacity (Wind Powering America, 2011).

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Citations and links:

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Data gathered by Kai Goldynia, 23 Jul 2011.
Reviewed by Christopher Marohl, 31 Oct 2011.

State: Ohio

Wind siting basics: The Ohio Power Siting Board (OPSB) has regulatory jurisdiction for the siting of all wind projects in Ohio with a generating capacity of at least 5 megawatts (MWs). For wind projects less than 5 MW, the local zoning requirements would apply.

History of siting authority: Previously, the OPSB had jurisdiction for wind farms with a capacity of at least 50 megawatts; however, as of 2008, the legislature extended the Board's jurisdiction to also include economically significant wind farms, defined as having generating capacities between 5 and 50 MWs (http://codes.ohio.gov/orc/4906.20).

Approvals needed: Developers who wish to site wind facilities designed for or capable of generating five or more megawatts must first apply for and obtain a certificate of environmental compatibility and public need from the OPSB.

Permits required for construction could include at least:

- National Pollutant Discharge Elimination System (NPDES) Permit – Construction that disturbs 1 acre or more requires a stormwater-discharge permit from the Ohio Environmental Protection Agency (EPA).
- Water Quality Certificate – Construction that disturbs lakes, rivers, streams, and wetlands requires a water-quality certificate from the Ohio EPA.
- Shoreline – Shore structure construction requires a permit from the Ohio Department of Natural Resources. (Great Lakes Commission, 2009).

Evaluation criteria: For the complete *Basis for Decision Granting or Denying Certificate* (Ohio Revised Code 4906.10), see http://codes.ohio.gov/orc/4906.10. The OPSB criteria include:

- The need for the facility if the facility is an electric transmission line…;
- The probable environmental impact of the proposed facility;
- Whether the facility represents the minimum adverse environmental impact…;
- In the case of electric transmission lines, that the facility is consistent with regional plans for expansion of the electric power grid of the electric systems serving Ohio…
- That the facility will comply with all air and water pollution control and solid waste disposal laws and regulations;
- That the facility will serve the public interest, convenience, and necessity;
- The facility's impact on the viability as agricultural land of any land in an existing agricultural district; and
- That the facility incorporates maximum feasible water conservation practices as determined by the Board…. (Ohio Power Siting Board, 2010).

Public input: The Ohio power siting process includes several opportunities for public input, including mandatory public information meetings prior to the filing of an application and public hearings. Members of the public can seek to intervene in the siting proceeding, testify at public hearings without intervening, and submit letters that are considered by the Board in making its decisions. (www.puco.ohio.gov/emplibrary/files/OPSB/Presentations_Manuals/OPSBbrochure2010.pdf).

Relationships to other important energy policies or siting and zoning decisions: Ohio has an alternative energy resource standard of 25 percent by 2025; at least half must come from renewable sources, including a specific in-state requirement (Database of State Incentives for Renewables & Efficiency).

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Data collected by Kai Goldynia, 23 June 2011.
Reviewed by Stuart Siegfried, 8 Nov 2011.

State: Oklahoma

Wind siting basics: Responsibility for wind siting is entirely at the local level of government. Wind power projects can go through a voluntary review by the Oklahoma Corporation Commission.

History of siting authority: *The Oklahoma Wind Energy Development Act* (Jun 2010) – Oklahoma Statutes Title 17, §160.11 – § 160.19 (www.occeweb.com/GC/OKLaw.html). Oklahoma is a Dillon Rule state (National League of Cities).

Approvals needed: Applicants must adhere to the requirements mandated by the local jurisdiction.

The Oklahoma Wind Energy Development Act regulates decommissioning, requires wind farm operators to provide prompt statements regarding royalty payments to land-owners, and requires commercial liability insurance with the landowner insured (Oklahoma Statutes Title 17, §160.14 et seq.) .

Evaluation criteria: None identified.

Public input: No specific procedures identified.

Relationships to other important energy policies or siting and zoning decisions: Oklahoma has a renewable energy portfolio standard (RPS) mandating that 15% of energy capacity will come from renewable sources, including wind, by 2015. Each utility files an annual report to the Oklahoma Corporation Commission, including total kilowatt-hours (kWh) and the sources for generation. Oklahoma has no specific provisions for using or trading renewable energy credits (RECs) (Database of State Incentives for Renewables & Efficiency).

Pending issues: The Oklahoma Exploration Rights of 2011 (§52-801 – §52-805 www.oklegislature.gov/osstatuestitle.html) mandates that the exploratory rights of oil and natural gas companies "not be diminished, abrogated or interfered with in any respect by a wind or solar energy agreement except with the prior written consent of the owner of exploration rights, which consent may be granted or withheld for any reason or for no reason."

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Data collected by Francis Motycka, 8, 10, 11 Jul 2011.
Reviewed by George Kiser, 16 Dec 2011.

State: Oregon

Wind siting basics: Wind projects smaller than 105 MW are regulated by cities and counties. The Oregon Energy Facility Siting Council (EFSC) regulates larger projects.

History of siting authority: The Energy Facility Siting Council and the Oregon Department of Energy were created in 1975 (Oregon Statutes – Chapter 469, www.leg.state.or.us/ors/469.html).

Approvals needed: For small wind applications, applicants must obtain local land-use permits and electrical (building) permits. For large wind, developers must apply to the EFSC for a site certificate.

Evaluation criteria:

Small Wind

- Turbines must be mounted on towers between 60-100 feet tall, at least 30 feet above obstructions
- Residential wind turbines must range from 500 watts to 10 kilowatts

Large Wind

General Standards
- Noise
- Wetlands
- Water Pollution Control Facility
- Water Rights

Specific Standards
- Organizational Expertise: helps ensure that the applicant has the abilities and resources to successfully build and operate the facility.
- Structural Standard: protects public health and safety, including the safety of
- facility workers, from seismic hazards.
- Soil Protection
- Protected Areas
- Fish and Wildlife Habitat
- Threatened and Endangered Species
- Scenic Resources
- Historical, Cultural, and Archaeological Resources
- Recreation
- Public Services
- Waste Minimization
- Carbon Dioxide Emissions
- A "one-stop" process in which the Council determines compliance with specific standards of the Council and other state and local permitting agencies.
- Appeals requiring judicial review go directly to the Oregon Supreme Court.

Public input: For large wind, public comment periods take place during the early phase of the process and are followed by formal contested case proceedings.

Relationship to other important energy policies or siting and zoning decisions: Oregon's Renewable Portfolio Standard directs utilities to reach 25% of retail electricity needs with qualified renewable resources by 2025.

Pending issues: A major issue for Oregon large wind generation arises due to competition with hydroelectric power for limited transmission capacity. The Bonneville Power Authority (BPA) has sometimes issued curtailment orders for wind farms along the Columbia River (Laskow, 2011). On 7 Dec 2011, the Federal Energy Regulatory Commission (FERC) ruled that curtailment of wind power is discriminatory (Ranken, 2011).

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Data collected by Kai Goldynia, 10 Jul 2011.

State: Pennsylvania

Wind siting basics: Siting responsibility lies at the municipal level of government. A model ordinance was created in 2006; however, many local municipalities have developed their own guidelines and ordinances (Pennsylvania Department of Environmental Protection, 2006).

History of siting authority: Pennsylvania Municipalites Planning Code (MPC) Act of 1968, P.L.805, No.247. http://mpc.landuselawinpa.com/mpc_full.html

Approvals needed: Within 30 days of a permit application, the municipality will determine whether or not the application is complete. Once the application is determined to be complete, the municipality will schedule a public hearing, and, within 120 days or 45 days after any hearing is completed, whichever is later, the municipality will decide to issue or deny the permit application (Pennsylvania Department of Environmental Protection, 2006).

A cooperative agreement with the Pennsylvania Game Commission addressing bat, bird, and wildlife issues is voluntary. Specific wildlife surveys can be required, depending on projected impacts. According to the *Wind Energy Voluntary Cooperation Agreement* with the Pennsylvania Game Commission, the developer must notify the PGC 14 months prior to construction. Within 45 days of the notification, the PGC will communicate its findings on the potential impact of the wind development site on wildlife and habitat.

For erosion and sediment control, the Pennsylvania Department of Environmental Protection (DEP) requires a general or individual NPDES *Permit for Storm Water Discharges Associated with Construction Activities*. For water obstruction and encroachment and wetlands, developers must obtain a separate DEP permit (Commonwealth of Pennsylvania). In addition, before submitting to the DEP, the applicant must complete an online Pennsylvania Natural Diversity Inventory (PNDI) Environmental Review (Commonwealth of Pennsylvania Office of Energy and Technology Development, Department of Environmental Protection).

Evaluation criteria: No firm criteria identified. The *Model Ordinance* includes:

- Controls and brakes: “All Wind Energy Facilities shall be equipped with a redundant braking system.”

- Climb prevention and locks: “Wind Turbines shall not be climbable up to fifteen (15) feet above ground surface,” and “All access doors to Wind Turbines and electrical equipment shall be locked or fenced, as appropriate.”

- Decommissioning: “The Facility Owner and Operator shall… complete decommissioning of the Wind Energy Facility, or individual Wind Turbines, within (12) twelve months after the end of the useful life of the Facility or individual Wind Turbines”

- Dispute resolution: “The Facility Owner and Operator shall maintain a phone number and identify a responsible person for the public to contact with inquiries and complaints.”

- Interference with communications devices: “The Applicant shall make reasonable efforts to avoid any disruption or loss of radio, telephone, television or similar signals, and shall mitigate any harm caused by the Wind Energy Facility.”

- Liability insurance: “There shall be maintained a current general liability policy. ”

- Minimum property setbacks: “Wind Turbines shall be set back from the nearest Occupied Building a distance…1.1 times the Turbine Height. For non-participating landowners, “Wind Turbines shall be set back from the nearest Occupied Building located on a Non-participating Landowner’s property a distance of not less than five (5) times the Hub Height.”

- Power lines: “On-site transmission and power lines between Wind Turbines shall… be placed underground.”

- Protection of public roads: “Any road damage caused by the applicant or its contractors shall be promptly repaired at the Applicant’s expense.”

- Shadow flicker: There are no specific standards in the *Model Ordinance*.

- Sound levels: “Audible sound from a Wind Energy Facility shall not exceed fifty (55) dBA.”

- Visual appearance of wind turbines and related infrastructure: “Wind Turbines shall be a non-obtrusive color…” and “Wind Turbines shall not display advertising.”

Public input: No specific procedures identified.

Relationships to other important energy policies or siting and zoning decisions: Pennsylvania’s Advanced Energy Portfolio Standard (AEPS) mandates that 18% of electricity sold by each electric distribution company (EDC) and electric generation supplier (EGS) within Pennsylvania must be generated from alternative energy sources by the year 2020. The standard includes a mandate for 8% of the energy sources to come from “Tier 1” sources, which includes wind, among other sources.

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Data collected by Francis Motycka, 5, 8 Jul 2011.
Reviewed by Scott Gebhardt and Kerry Campbell, 11 Nov 2011.

State: Rhode Island

Wind siting basics: For projects 40 MW and over, the Rhode Island Energy Facilities Siting Board is in charge. For projects under 40 MW, local governments have siting authority.

History of siting authority: The Energy Facility Siting Act, most recently updated in 2001 (www.rilin.state.ri.us/Statutes/TITLE42/42-98/INDEX.HTM).

The Comprehensive Energy Conservation Efficiency and Affordability Act of 2006 gives the Rhode Island Division of Planning the authority to establish standards and guidelines for locating renewable energy facilities (www.rilin.state.ri.us/BillText/BillText06/SenateText06/S2903Baa.pdf).

Approvals needed: For facilities over 40 MW, the Siting Board collaborates with various state and local agencies to ensure that the applicant is complying with state and local regulations and then issues a one-stop permit. The only on-shore wind facilities in Rhode Island, as well as any that have been proposed to date, are far under 40 MWs (Gonsalves, Paul, Rhode Island Division of Planning, personal communication, 8 Aug 2011). Therefore, applicants are permitted by the local government. In this case, the applicant would at least need approval from the local Planning Commission and a special use permit from the zoning board.

Evaluation Criteria:

A report by the Rhode Island Department of Environmental Management (DEM) proposed the following guidelines for siting wind turbines on *state* lands:

-Distance from nearest property line: 1.5 times hub height + rotor radius
-Distance from nearest structure: 1.5 times hub height + rotor radius
-Distance from roads: 1.5 times hub height + rotor radius
-Distance to protect from icing: 820 feet
-Public safety distance: 1.5 times hub height + rotor radius
-Noise: Project must not exceed 35 DBA in the evening, 45 DBA in the daytime in residential areas. Cannot increase background tonal sound by more than 3 DB.

The Rhode Island Division of Planning is currently in the process of developing wind siting guidelines for the municipalities, and possibly a model ordinance. The guidelines should be released next month.

Rhode Island Energy Plan (includes discussion of wind guidelines):
www.planning.ri.gov/landuse/Energy%20plan311.pdf

Public input: None identified. Municipalities can hold public hearings.

Relationships to other important energy policies or siting and zoning decisions: Rhode Island has an RPS of 16% by 2019. A separate and distinct standard enacted in June 2009 (Long-Term Contracting Standard for Renewable Energy) requires electric distribution companies to solicit proposals and enter into long-term contracts for capacity, energy and attributes from new renewable energy facilities. (DSIRE, 10 Aug 2011).

Pending issues: Over 95% of wind energy potential in Rhode Island is located offshore. As such, the Rhode Island Coastal Resources Management Council has developed the Ocean Special Area Management Plan (Ocean SAMP), in an effort to encourage renewable energy development offshore. Link to the Ocean SAMP:
http://seagrant.gso.uri.edu/oceansamp/pdf/samp_approved/800_renewable_OCRMchanges_5.4_Clean.pdf

Several towns currently in the process of permitting a wind turbine have placed a moratorium on permitting until the RI Division of Planning releases its new wind siting guidelines.

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Citations and links:

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Data collected by Lauren Teixeira, 28 Jul 2011.

State Name: South Carolina

Wind siting basics: The Utility Facility Siting and Environmental Protection Act (S.C. Code Ann. § 58-33-10, www.scstatehouse.gov/code/t58c033.php) governs siting of major utility facilities. Currently, wind power projects less than 75 MW are not regulated at either the state or local level of government. Electric suppliers regulated by the Public Service Commission (PSC) seeking to build an electric generating plant of 75 MW or greater must obtain a Certificate of Public Convenience and Necessity (CPCN), issued by the PSC. The application includes a description of the facility, its location, a statement explaining the need for the facility, and environmental impact studies.

The South Carolina Office of Regulatory Staff (ORS) has sole responsibility for the inspection, auditing, and examination of public utilities, and represents the public interest in regulation of the major utility industries (Act 175 of 2004, www.scstatehouse.gov/code/t58c003.php).

History of siting authority: None identified.

Approvals needed: No state level approval is needed, unless the facility is covered under the Utility Facility Siting and Environmental Protection Act or involves lands otherwise subject to regulation, such as wetlands.

Evaluation criteria: None identified.

Public input: No specific procedures identified.

Relationships to other important energy policies or siting and zoning decisions: South Carolina currently has no Renewable Portfolio Standard. The potential for use of offshore wind as a key renewable technology is currently a subject of discussion in South Carolina.

Pending issues: South Carolina Act 318 of 2008 (www.scstatehouse.gov/code/t48c052.php) established the Wind Production Farms Feasibility Study Committee to evaluate wind power feasibility. The study results were issued in a 1 Jan 2010 report to the Governor and South Carolina General Assembly (http://energy.sc.gov/index.aspx?m=6&t=123).

The Regulatory Task Force for Coastal Clean Energy was established as an objective of a 2008 grant from the U.S. Department of Energy, which has the goal of identifying and overcoming existing barriers for coastal clean energy development for wind, wave and tidal energy projects in South Carolina (http://energy.sc.gov/index.aspx?m=6&t=85&h=904).

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Citations and Links:

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Data gathered by Kai Goldynia, 4 August 2011, Deborah Luyo 27 Oct 2011.
Reviewed by Allyn Powell, 20 Jan 2012.

State: South Dakota

Wind siting basics: A permit from the South Dakota Public Utilities Commission (PUC) is required for electric generating facilities with a capacity over 100 MW.
http://legis.state.sd.us/statutes/DisplayStatute.aspx?Type=Statute&Statute=49-41B-35

History of siting authority: Siting authority created by SD Legislature in SDCL 49-41B (1977) (http://legis.state.sd.us/statutes/DisplayStatute.aspx?Type=Statute&Statute=49-41B-1).

SDCL 43-13-21 through 24 (2009) established setbacks for wind turbines (http://legis.statse.sd.us/statutes/DisplayStatute.aspx?Type=Statute&Statute=43-13).

Draft Model Ordinance for Siting of Wind Energy Systems (2008) (http://puc.sd.gov/commission/twg/WindEnergyOrdinance.pdf).

Approvals needed: In addition to the permit from the PUC, approvals are required from the following agencies:

South Dakota Game, Fish & Parks, concerning grasslands, wetlands and wildlife, http://gfp.sd.gov/.

South Dakota State Historic Preservation Office, concerning historically important sites, http://history.sd.gov/Preservation/.

South Dakota Department of Environment and Natural Resources, concerning air and water protection, http://denr.sd.gov/.

South Dakota Department of Transportation, www.sddot.com/ – Need is dependent on whether the site will utilize state right-of-way.

Local Government (County/City Commission) – Building permits typically required regardless of project size.

The time frame for obtaining a permit from the PUC is (Binder, 2009):

- Notice of intent filed six months prior to Application for Permit. (Notice of intent process only applies to non-wind energy conversion facilities over 100 MW.)
- Application for Permit filed.
- Public Hearing within 60 Days.
- Decision within six months of receipt of Application (one year for non-wind energy conversion facilities).

Evaluation criteria: Evaluation criteria are laid out in SDCL 49-41B (http://legis.state.sd.us/statutes/DisplayStatute.aspx?Type=Statute&Statute=49-41B) and ARSD 20:10:22 (http://legis.state.sd.us/rules/DisplayRule.aspx?Rule=20:10:22).

“The Public Utilities Commission shall also hear and receive evidence presented by any state department, agency, or units of local government relative to the environmental, social, and economic conditions and projected changes therein” (http://legis.state.sd.us/statutes/DisplayStatute.aspx?Type=Statute&Statute=49-41B-19).

Public input: Per SDCL 49-41B-16, a public hearing shall be held as close as practicable to the proposed facility's location. Timing requirements usually schedule this about 60 days after the application is filed (http://legis.state.sd.us/statutes/DisplayStatute.aspx?Type=Statute&Statute=49-41B-16).

Relationships to other important energy policies or siting and zoning decisions: None identified.

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Data collected by Marley Ward, 1 Jul 2011, Deborah Luyo, 24 Oct 2011.
Reviewed by Brian Rounds, 1 Dec 2011.

State: Tennessee

Wind siting basics: Wind siting is done at the local level of government. The applicant could apply to the Tennessee Department of Economic and Community Development (TECD) for energy facilities that will produce over 50 MW.

History of siting authority: None identified.

Approvals needed: TECD will find information regarding economic need and transmission. If the application meets TECD approval, it is then forwarded to the Tennessee Department of Environment & Conservation for environmental permitting. Tennessee is a Home Rule state.

Evaluation criteria: None identified.

Public input: No specific procedures identified.

Relationships to other important energy policies or siting and zoning decisions: None identified.

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Tennessee Valley Authority. *Wind Turbine Energy* [web page]. Retrieved 6 Jul 2011 from www.tva.gov/greenpowerswitch/wind_faq.htm.

Data collected by Francis Motycka, 6, 11 Jul 2011.

State: Texas

Wind siting basics: All siting authority is delegated to the local governments. If asked, the Texas Parks and Wildlife Department will review projects for compliance with wildlife protection guidelines. The Texas PUC has some indirect authority (see discussion of transmission below).

History of siting authority: 2007 Statute regarding Competitive Renewable Energy Zones: www.statutes.legis.state.tx.us/Docs/UT/htm/UT.39.htm#39.904.

Title 7. Regulation Of Land Use, Structures, Business, and Related Activities (1987) (www.statutes.legis.state.tx.us/Docs/LG/htm/LG.231.htm)

Approvals needed: No approval is needed from anyone, except leases with landowners; however, wind developments are subject to federal and state laws protecting endangered species. Applicants can request a review from the Texas Parks and Wildlife Department. The Department's findings are not binding (Boydston, 2011). Applicants can ask the county comptroller for a property tax abatement, based on the jobs and general economic benefits expected. The county board can deny the property tax abatement if there is public opposition.

Most projects take about 18 months to begin commercial operation, and few projects take longer than two years (Boydston, Kathy, Texas Parks and Wildlife Department, personal communication, 24 Jun 2011).

Evaluation criteria: Although there are no officially required criteria, developers often conduct pre-construction wildlife surveys.

Public input: No specific procedures identified.

Relationships to other important energy policies or siting and zoning decisions: Competitive Renewable Energy Zone (CREZ) legislation passed in 2007. The Texas PUC designates CREZs, which allow construction of transmission lines to serve the zone, prior to the commercial operation of new renewable energy generators. In this way, the Texas PUC has indirect siting authority.

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Data collected by Lauren Teixeira, 24 Jun 2011, Deborah Luyo, 29 Oct 2011.
Reviewed by Brian Almon, 8 Nov 2011.

State: Utah

Wind siting basics: Wind siting is done at the local level of government. Utah does not have a state agency with sole authority over electric plant siting. The developer must contact the various agencies that could have responsibility. Those agencies will determine what approvals are required (Stemler, 2007). Utah is a Home Rule state.

History of siting authority: UTAH CODE – TITLE 541-1 – PUBLIC SERVICE COMMISSION – Establishment of Commission – Functions (1983), http://le.utah.gov/~code/TITLE54/htm/54_01_000100.htm.

UTAH CODE – TITLE 54-4a-1 – DIVISION OF PUBLIC UTILITIES – Establishment of Division – Functions (1989), http://le.utah.gov/~code/TITLE54/htm/54_04a000100.htm.

UTAH CODE – TITLE 79-2-201 – DEPARTMENT OF NATURAL RESOURCES – Department of Natural Resources Created, http://le.utah.gov/~code/TITLE79/htm/79_02_020100.htm.

UTAH CODE – TITLE 23-14-1 – DIVISION OF WILDLIFE RESOURCES AND WILDLIFE BOARD – Division of Wildlife Resources – Creation – General Powers and Duties – Limits on Authority of Political Subdivisions (1995), http://le.utah.gov/~code/TITLE23/htm/23_14_000100.htm.

Approvals needed: A Certificate of Public Convenience and Necessity from the Utah Public Service Commission is required for new generation facilities. Developers should also contact the Utah Division of Public Utilities, the Utah Department of Natural Resources, and the Utah Division of Wildlife.

If the project includes facilities on or near lands that are under the jurisdiction of the federal Bureau of Land Management (BLM), an application must be submitted to the BLM. (United States Department of the Interior, Bureau of Land Management, 2008).

Evaluation criteria: Utah's *Model Wind Ordinance* (2009) lists:

- Climb prevention and locks
- Decommissioning
- Height and blade height (clearance above the ground)
- Lighting
- Maintenance
- Minimum property setbacks (110% of the height of the system from all inhabited structures, overhead utility lines, and public roads or public right-of-ways; § 4.1.2)
- Sound levels (compliance with the existing noise or sound ordinance; § 4.1.9)
- Visual appearance of wind turbines and related infrastructure

Public input: No specific procedures identified.

Relationships to other important energy policies or siting and zoning decisions: *The Energy Resource and Carbon Emissions Reduction Initiative* was passed into law in 2008, with a goal of 20% electricity generated from renewable sources by 2025. The first compliance year will be 2025.

Pending issues: On 23 Mar 2011 the Utah Association of Counties and the Uintah County Commission filed a lawsuit (United States Department of the Interior) against Ken Salazar, Secretary of the Interior, et al., in response to Secretarial Order 3310, declaring 385,000 acres of Uintah County land wild lands territory (The Secretary of the Interior, 2010). The declaration will expand the power of the Bureau of Land Management in control of public land and would place additional restrictions on the potential for wind development.

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Utah State Energy Program. (2009*). Utah Model Wind Ordinance*. http://geology.utah.gov/sep/wind/pdf/model_wind_ordinance.pdf.

Data collected by Francis Motycka, 6, 11 Jul 2011; Deborah Luyo, 21 Oct 2011.

State Name: Vermont

Wind siting basics: The Vermont Public Service Board (PSB) issues a Certificate of Public Good (CPG) for all wind facilities, with the exception of those operated solely for the customer's on-site consumption. Net metering systems do require a CPG. The Vermont Department of Public Service (DPS), which represents ratepayers in PSB proceedings, and the Vermont Agency of Natural Resources (ANR) are automatic parties to any proceeding.

History of siting authority:
30 V.S.A. § 248 www.leg.state.vt.us/statutes/fullsection.cfm?Title=30&Chapter=005&Section=00248
PSB Rule 5.400
http://psb.vermont.gov/sites/psb/files/rules/OfficialAdoptedRules/5400_248_Requirements.pdf

Approvals needed: The PSB regulates all grid-connected wind developments and must find that the facility will promote the general good of the state before it can issue a CPG. In addition, the Vermont Agency of Natural Resources (ANR) has independent jurisdiction over certain permits that may be required by the facility; these may include permits involving the facility's impact on wetlands and water quality.

Local permits are not required; however, the PSB is required to give "due consideration" to the recommendations of municipal and regional planning organizations as well as the recommendations of municipal legislative bodies.

Evaluation criteria: Pursuant to statute, the PSB must find that the facility meets certain criteria. These include whether the project will:

1. adversely affect system stability and reliability;
2. provide an economic benefit to the state; and
3. have an undue adverse impact on natural resources and aesthetics.

In analyzing the project's impacts on natural resources, developers often provide information regarding:

(1) Radar and acoustical surveys to develop an understanding of bird and bat activity and migration characteristics
(2) Evaluation of the presence of rare, threatened, and endangered species and associated habitat(s)
(3) Analysis of suitable habitat for endangered bat species
(4) Resident avian and breeding survey
(5) Necessary wildlife habitat surveys
(6) Delineation of habitats that may be especially vulnerable

ANR requests that developers follow specific voluntary procedures in accordance with ANR guidelines, including:

(1) Completion of pre-construction survey
(2) Site development recommendations
(3) Consultation with wildlife agency, USFWS
(4) Mitigation requirements
(5) Post-construction/operational surveys
(6) Decommissioning procedures

Public Input: With the exception of net metered projects, and projects of limited size and scope, all PSB siting proceedings involve a public hearing in the county in which the facility is located. In addition, the deadline for intervention requests is typically after the public hearing in order to allow members of the public that meet the PSB's standards for intervention to participate in the proceeding.

Relationships to other important energy policies or siting and zoning decisions: Vermont has a state-wide voluntary renewable goal of 20% by 2017. *30 V.S.A. § 8005(d)(2).* http://www.leg.state.vt.us/statutes/fullsection.cfm?Title=30&Chapter=089&Section=08005

Pending issues*: On 3 Oct 2011 the PSB recommended an RPS of 75% by 2034 (*http://psb.vermont.gov/sites/psb/files/publications/Reports%20to%20legislature/RPSreport2011/Study%20on%20Renewable%20Electricity%20Requirements%20-%20Final.pdf*).*

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Vermont Agency of Natural Resources. (Dec 2004). *Wind Energy and Other Renewable Energy Development on ANR Lands*. www.vtfpr.org/lands/documents/windpower.pdf/.

Data collected by Kai Goldynia, 6 Aug 2011.
Reviewed by Ed McNamara, 24 Jan 2012.

State: Virginia

Wind siting basics: Siting for renewable energy projects is conducted under the authority of local government. The permitting program for construction and operation of renewable energy projects is administered at the state level by the Virginia Department of Environment Quality (DEQ), which explicitly considers the impacts of the project on natural resources (in particular, on wildlife and historical resources).

The Virginia Department of Environmental Quality permits "small renewable energy projects" up to 100 MW (https://leg1.state.va.us/cgi-bin/legp504.exe?091+ful+CHAP0808). The State Corporation Commission (SCC) has siting authority for energy facilities over 100 MW, constructed by rate-regulated utilities (1999, as amended) (https://leg1.state.va.us/cgi-bin/legp504.exe?000+cod+56-580).

History of siting authority: Code of Virginia: Chapter 11.1 of Title 10.1, Article 5, sections 10.1-1197.5 through 10.1-1197.11 (https://leg1.state.va.us/cgi-bin/legp504.exe?091+ful+CHAP0808). Previously, authority over wildlife and historic resources resided with the SCC. This authority was transferred to the DEQ in 2009 for "small renewable energy projects."

Approvals needed: A special use permit or zoning approval comes from the local government. Virginia is a Dillon's Rule state.

Among the Virginia counties that have enacted wind ordinances are Pulaski County and Rockingham County, which are inland, and Northampton, located on the coast.

> Article 26, the Pulaski County Draft Wind Ordinance, www.pulaskicounty.org/planning/minutes%20and%20agendas/2010/08-10-10%20minutes.pdf
>
> Ordinance Repealing and Re-enacting Certain Designated Definitions Section 17-6 and 17-6.2 of the Code of Ordinances of Rockingham County Virginia, www.preserverockingham.org/images/Wind_Energy_Conversion_System_Draft_Oct_8_2010_Changes_Accepted.pdf
>
> Draft revised to incorporate Planning Commission Recommendations of August 2, 2011 & Board of Supervisors' Intended Recommendations of August 18, 2011, www.co.northampton.va.us/departments/pdf/Wind%20Tower%20draft%20%20incl%20PC%20recs%208-2-11%20and%20BOS%208-18-11%20edits%20_2_.pdf.

Code of Virginia: Title 10.1, Chapter 11.1, Article 5 (2009), vests authority in the Virginia Department of Environmental Quality for permitting a "small renewable energy project," defined as having "a rated capacity not exceeding 100 megawatts… ."

Mitigation authority, under the DEQ process, is limited to wildlife and historic resources. Specific wildlife considerations include the effects of wind development on threatened and endangered species, bats, coastal avian protection zones, and sea turtle nesting beaches.

Evaluation criteria: As prerequisites to the renewable energy permit-by-rule application to the DEQ, 14 statutory requirements (from https://leg1.state.va.us/cgi-bin/legp504.exe?091+ful+CHAP0808) must be met:

1. A notice of intent…to submit the necessary documentation for a permit by rule for a small renewable energy project;
2. A certification by the [local] governing body[ies] … that the project complies with all applicable land-use ordinances;

3. Copies of all [electric grid] interconnection studies…;
4. A copy of the final interconnection agreement …;
5. A certification… that the maximum generation capacity… does not exceed 100 megawatts;
6. An analysis of potential environmental impacts… on attainment of national ambient air quality standards;
7. Where relevant, an analysis of the beneficial and adverse impacts… on natural resources;
8. If the Department determines that… significant adverse impacts to wildlife or historic resources are likely, the submission of a mitigation plan…including plans to measure the efficacy of mitigation actions;
9. A certification [that the design is] in accordance with all of the standards that are established in the regulations applicable…;
10. An operating plan describing how any standards… will be achieved;
11. A detailed site plan with project location maps…;
12. …all necessary environmental permits;
13. A requirement that the applicant hold a public meeting; and
14. A 30-day public review and comment period….

The process by which DEQ's wind permit-by-rule regulations were developed involved 22 Regulatory Advisory Panel meetings, 2 public comment periods, 1 public hearing, and 1 public meeting. (http://vwec.cisat.jmu.edu/workshop/Presentations/Wampler%20-%20Navigating%20Wind%20PBR.pdf)

Criteria common to the three county ordinances cited above include:

- Wind turbines must be of a non-obtrusive color
- Wind energy systems cannot display advertising
- Wind energy systems cannot be artificially lit unless required by the FAA
- Audible sound cannot exceed 55-60 decibels
- Setback requirements
- Height restrictions

P**ublic input:** No specific procedures identified.

Relationships to other important energy policies or siting and zoning decisions: Virginia has a voluntary Renewable Portfolio goal for 15% of electricity to come from renewable energy sources by 2025. Yearly percentage goals are formulated with 2007 as the base year upon which future years are calculated. To help facilitate these goals, the SCC provides an increased rate of return for participating utilities that meet the requirements. Onshore wind production credits are doubled for compliance purposes (www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=VA10R&re=1&ee=1).

Pending issues: A model wind ordinance is under consideration by an informal Local Government Outreach Stakeholder Group, which includes professionals from state and local government, academia, environmental groups, and industry. A suggested model ordinance is expected by year end 2011. (Contact Carol Wampler, Department of Environmental Quality.)

Research issues: The DEQ would like to know more about the impact of wind turbines on bats, avian species, other wildlife, and historic resources. Research is ongoing.

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Data collected by Francis Motycka, 6 Jun, 3, 12 Jul 2011; Deborah Luyo, 14 Oct 2011.
Reviewed by Carol Wampler, 18 Nov 2011.

State: Washington

Wind siting basics: Review by the Energy Facility Site Evaluation Council (EFSEC) is available for proposed wind power projects, but applicants must "opt in" to EFSEC's process. Most existing wind projects have been permitted through counties.

History of siting authority: Revised Code of Washington (RCW) 80.50. 040 (1970, 2001) (http://apps.leg.wa.gov/rcw/default.aspx?cite=80.50.040)

Approvals needed: From the EFSEC website:

"The EFSEC certification process was designed to give applicants an opportunity to present their proposals, allow interested parties to express their concerns to the Council, and have the Council to [sic] address issues related to the application.

There are six major steps in the certification process:

I. Application Submittal
II. Application Review
III. Initial public hearings
IV. Environmental impact statement
V. Adjudicative proceedings and permits review
VI. Recommendation to the Governor

Each step has specific requirements the applicant and the Council must follow to ensure a comprehensive and balanced review of the project. Many of the steps take place at the same time." (www.efsec.wa.gov/cert.shtml#Certification2).

Applicants who qualify, as determined by the Council, can undergo an expedited process. The Council has four months to evaluate the application to determine whether to grant expedited processing. The Council has an additional two months to forward a recommendation of approval to the governor. This schedule may be modified as mutually agreed to by the applicant and the Council.

Evaluation criteria: Criteria used by the Department of Fish and Wildlife include:

(1) Baseline and Monitoring Studies: Calls for pre-project assessments of wind power sites with the goal of avoiding and minimizing bird and bat impacts related to wind turbines; information review; habitat mapping; bird and bat surveys, and threatened and endangered species surveys.
(2) Minimization of Wildlife Impacts: Outlines the path for avoiding and minimizing potential impacts related to construction methods and sensitive habitat areas.
(3) Operational Monitoring: Details the post-construction monitoring recommendations and the role of the Technical Advisory Committee (TAC), which is recommended for the purpose of providing advice to the project owner and the permitting authority. Members of the TAC can include wind project owners and developers, landowners, and representatives from environmental groups, counties, tribes, and state and federal resources agencies.
(4) Research-oriented Studies: Offers recommendations and examples for research needs related to wind power development as it relates to wildlife habitats and species.
(5) Habitat Types and Mitigation: Provides statewide ecoregional definitions of habitat types throughout Washington State; encourages development into previously disturbed and developed areas and away from undeveloped fish and wildlife habitat; provides ratios for replacement habitat as mitigation for temporary and permanent wind project impacts; adheres to the principle of no loss of habitat functions and values. (http://wdfw.wa.gov/conservation/habitat/planning/energy/wind.html)

Public input: State regulations provide opportunities for public input at several points during the licensing process.

Relationships to other important energy and siting/zoning decisions: EFSEC is statutorily authorized to preempt local land-use/zoning ordinances for the siting of energy projects.

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Data collected by Marley Ward, 10 Jul 2011.
Reviewed by Meg O'Leary, 14 Dec 2011.

State: West Virginia

Wind siting basics: The Public Service Commission (PSC) has sole authority of all public utility siting.

History of siting authority: West Virginia Code §24-2-1 (1991) (www.legis.state.wv.us/WVCODE/Code.cfm?chap=24&art=2#02).

Approvals needed: Developers of wind generation that will produce electricity for sale in wholesale markets need a certificate of public convenience and necessity from the PSC (West Virginia Code §24-2-11, www.legis.state.wv.us/WVCODE/ChapterEntire.cfm?chap=24&art=2&section=11#02). West Virginia is a Dillon's Rule state.

An applicant must give the PSC a 30-day notice before filing an application for the certificate of public convenience and necessity. After an application is filed, the PSC will either issue or deny the certificate within 270 days. If the projected cost is over $50 million, the PSC will issue or deny the certificate within 400 days.

Evaluation criteria: None identified.

Public input: No specific procedures identified.

Relationships to other important energy policies or siting and zoning decisions: West Virginia's Renewable Portfolio Standard (RPS) mandates that utility companies with more than 30,000 residential consumers must have at least 25% of their energy from alternative and renewable sources by 2025, with no minimum requirement from renewable sources. Alternative energy credits (AEPs) are used for compliance. Each megawatt-hour of renewable energy (wind) is equal to two AEP credits. Utility companies must have submitted their compliance strategies to the West Virginia PSC by 1 Jan 2011, followed by annual compliance reports. The PSC will impose penalties for utilities not in compliance on 1 Jan 2015 (www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=WV05R&re=1&ee=1).

Pending issues: The Cow Knob Wind Farm is a proposed project in Pendleton County. Solaya Energy LLC has requested that Pendleton County create an ordinance to help facilitate wind facility construction (Adams, 2011).

Research issues: The Beech Ridge Wind Farm in Greenbrier County is currently shutting down its turbines at night, from 1 Apr to 15 Nov, because of concerns over potential harm to the Indiana bat, an endangered species. The developer faces a lawsuit on claims that it did not obtain a permit from the U.S. Fish and Wildlife Service when siting this facility (Hammack, 2011).

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Mountain Communities for Responsible Energy [web page]. Retrieved 12 Jul 2011 from www.wvmcre.org/.

West Virginia Division of Natural Resources [web page]. Retrieved 12 Jul 2011 from www.wvdnr.gov/.

West Virginia Public Service Commission (PSC) [web page]. Retrieved 12 Jul 2011 from www.psc.state.wv.us/.

Data collected by Francis Motycka, 6, 11, 12 Jul 2011.
Reviewed by Earl Melton, 10 Oct 2011.

State: Wisconsin

Wind siting basics: Power plants with a capacity of 100 MW or more must have a Certificate of Public Convenience and Necessity (CPCN) from the Public Service Commission of Wisconsin (PSCW) prior to construction. Projects having less than 100 MW capacity may require a Certificate of Authority (CA) from the PSCW.

History of siting authority: In 2009, Wisconsin Act 40 (Wisc. Stat. § 196.378(4g)(b)) directed the PSCW to establish statewide wind energy siting rules (http://psc.wi.gov/renewables/windSitingRules.htm). The new law required the PSCW to appoint a Wind Siting Council, to advise the PSCW in developing its standards (http://psc.wi.gov/renewables/windSitingCouncil.htm). The Act also provided that local government wind siting ordinances could not be more restrictive than the PSCW rules. The Act dictated that the rules were to include:

> setback requirements that provide reasonable protection from any health effects, including health effects from noise and shadow flicker … decommissioning and may include visual appearance, lighting, electrical connections to the power grid, setback distances, maximum audible sound levels, shadow flicker, proper means of measuring noise, interference with radio, telephone, or television signals, or other matters.

(See https://docs.legis.wisconsin.gov/statutes/statutes/196/378/4g/b and https://docs.legis.wisconsin.gov/statutes/statutes/66/IV/0401).

In March 2011, before the Council's proposed rules could take effect, the state legislature's Joint Committee for the Review of Administrative Rules suspended the rules indefinitely. (See http://psc.wi.gov/apps35/ERF_view/viewdoc.aspx?docid=145834).

Approvals needed: The PSCW and the Wisconsin Environmental Policy Act require that applicants provide information on at least two sites. The PSCW then prepares an environmental impact statement, in conjunction with the Wisconsin Department of Natural Resources (WDNR), or an environmental assessment.

Developers must submit an engineering plan to the Wisconsin Department of Natural Resources (DNR) at least 60 days prior to filing an application for a CPCN.

Evaluation criteria: None identified.

Pending issues: How and when the legislature will act on the WPSC proposed rules.

Relationships to other important energy and siting and zoning policies: Wisconsin has a wind (and solar) access law, which protects a right to wind access, via local land-use easement, if the land owner installs a wind generator.

To assist counties, towns, and municipalities in interpreting Wisconsin's wind access laws, chiefly Wis. Stat. § 66.0401, the state developed a Model Small Wind Ordinance which suggests appropriate zoning language for wind energy systems of 100 kilowatts (kW) or less. (http://dsireusa.org/incentives/incentive.cfm?Incentive_Code=WI16R&re=1&ee=1).

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Data gathered by Kai Goldynia, 24 Jun 2011; Tom Stanton, 20 Oct 2011.

State: Wyoming

Wind siting basics: Under Wyoming law, all wind energy facilities with a capacity greater than 0.5 MW (500 kW) must obtain county permits. Facilities with 30 or more turbines must, in addition, obtain a permit from the Wyoming Industrial Siting Council (part of the state Department of Environmental Quality). Any application for a project that does not meet the statutory definition of a facility can be referred to the Industrial Siting Council, consistent with the requirements of the Industrial Development Information and Siting Act. No county may adopt wind siting laws less stringent than those of the state. If any part of the proposed project is to occupy federal lands, the applicant must also obtain a permit from the federal Bureau of Land Management (BLM).

History of siting authority: Wyoming Statutes 18-5-501 to 18-5-509 are the most relevant (Wyoming Legislature).

Approvals needed: A permit from the Industrial Siting Council may be required for proposed facilities with less than 30 turbines if the county authority finds that a proposed facility poses certain significant environmental or societal risks that the county does not feel qualified to assess.

Procedures for application include:

(1) Developer must submit application to the County Board of Commissioners
Notifications
   - Applicant must have made "reasonable efforts" to provide notice to all owners of land within one mile of the facility and to all cities and towns located within 20 miles of the facility.
   - Applicant must publish a notice of application in a widely circulated newspaper at least 20 days prior to a public hearing.

(2) The board will conduct a review to determine whether the application is complete.
(3) Within 45 days after completion of the hearing period, the Board shall "make complete findings" and issue its decision granting or denying the application.
(4) Any party can file an appeal in district court. The decision issued in the appeal is considered final.
(5) If the facility does not automatically fall under the Industrial Siting Council, the County Board may refer the applicant to the Industrial Siting Council for further permitting.

Evaluation Criteria: Environmental approval is part of a collaborative review process in which the Industrial Siting Council asks for input on environmental standards from the Wyoming Fish and Game Department. The Council has the authority to require wildlife mitigation measures.

Various other standards must be met and certified in the application:

Setbacks

- A turbine must be sited at least 110% of its height from any property line "contiguous or adjacent" to the proposed facility, unless the property owner waives the setback distance in writing.
- A turbine must be sited at least 110% of its height from public roads.
- A turbine must be 550% of its height and no fewer than 1000 feet away from "platted subdivisions."
- A turbine must be 550% of its height and no fewer than 1000 feet away from a residential dwelling.
- A turbine must be at least a half mile from city limits.

Other criteria:

- Must have an emergency management plan.
- Must have a waste management plan (including decommissioning).
- Must conduct a traffic study of any public roadways leading to and away from the proposed facility. (Applicant can be required to enter into "reasonable road use" agreements.)
- There can be no advertising on the facility, with the exception of the applicant's logo on the nacelle.
- Must have a reclamation and decommissioning plan that indicates the planned life of the wind energy facility.
- Must certify that the landowners have been consulted.
- The decommissioning/reclamation plan must be updated every five years.

Public input: Once the application is determined to be complete, the Board must provide notice of the date and time of completion of the hearing period. The public hearing period is no fewer than 45 days and no more than 60 days after the application has been determined to be complete.

Relationships to other important energy policies or siting and zoning decisions: Wyoming statutory law requires that applicants proposing to build a wind energy facility include in their application a "project plan" indicating proposed roadways, tower locations and substation locations, transmission, collector and gathering and lines, and other "ancillary facility components" (http://legisweb.state.wy.us/statutes/statutes.aspx?file=titles/Title18/T18CH5AR5.htm)

Research issues: Wyoming is home to over half of all sage grouse, an endangered species, in the United States. Conservationists have expressed concern that wind development and the building of ancillary transmission lines will harm the sage grouse. Horizon Wind, a developer, has called for peer-reviewed study to establish the impact of turbines on the sage grouse. The United States Bureau of Land Management (BLM) has announced its intention to include sage grouse conservation measures in land management plans in Wyoming and nine other western states, including Colorado, North Dakota, South Dakota, Utah, Montana, California, Idaho, Nevada, and Oregon (www.blm.gov/wo/st/en/info/newsroom/2011/december/NR_12_08_2011.html).

In an effort to protect the sage grouse, there has been a movement by conservationists, supported by the governor, to draw up "core areas" in Wyoming where no energy development, agriculture, or recreation will be allowed. According to state government estimates, the proposed areas include only 14% of Wyoming's windy land. (Stoddard, 2009).

In an effort by the Federal Bureau of Land Management to facilitate development of renewable energy sources on public lands, the Wyoming Wind and Transmission Study is being conducted to analyze Wyoming's wind resources in order to identify potential sites for wind power development. The study is expected to be completed within approximately three years.

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Case 70076, Columbus Gas Transmission Corporation, Order Granting a Certificate of Environmental Compatibility and Public Need (issued September 5, 1979), p. 9;

Case 70157, Lenape Resources Corporation, Order Granting Certificate of Environmental Compatibility and Public Need (approved at a Session held on November 22, 1983), p. 4;

Case 10-T-0019, Fortuna Energy, Inc. and Corning Natural Gas Corporation, Order Approving Transfer and Amendment of Certificate (issued July 26, 2010), p. 28;

Case 10-T- 0350, DMP New York, Inc. and Laser Northeast Gathering Company, LLC, Order Granting Certificate of Compatibility and Public Need (issued February 22, 2011), p. 88;

Case 11-T- 0401, Bluestone Gas Corporation of New York, Inc., Order Adopting the Terms of a Joint Proposal and Granting Certificate of Environmental Compatibility and Public Need and Certificate of Public Convenience and Necessity (issued September 21, 2012), pp.;

Case 11- T-0534, Rochester Gas and Electric Corporation, Order Adopting the Terms of a Joint Proposal and Granting Certificate of Environmental Compatibility and Public Need, With Conditions (issued April 23, 2013), Attachment 1, Appendix D, pp. 10-11.

Case 10-T- 0350, DMP New York, Inc. and Laser Northeast Gathering Company, LLC, Order Regarding Certificates of Environmental Compatibility and Public Need (issued October 16, 2015), p. 78;

WIND TURBINE AM REVIEW

PHASE 2 REPORT

CONFIDENTIAL

AUGUST 2016

WSP | PARSONS BRINCKERHOFF

WIND TURBINE AM REVIEW

PHASE 2 REPORT

Department of Energy & Climate Change

Issue 3 – Issued

Project no: 3514482A
Date: August 2016

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QUALITY MANAGEMENT

ISSUE/REVISION	DRAFT ISSUE	FIRST ISSUE	SECOND ISSUE	THIRD ISSUE
Remarks	Issued for external peer review	Issued for DECC review	Second Issue	Third Issue
Date	27.01.16	14.03.16	31.03.16	10.08.16
Prepared by	M. Lotinga	M. Lotinga	M. Lotinga	M. Lotinga
Signature				
Checked by	R. Perkins	R. Perkins	R. Perkins	R. Perkins
Signature				
Authorised by	R. Perkins	R. Perkins	R. Perkins	R. Perkins
Signature				
Project number	3514482A	3514482A	3514482A	3514482A
Report number	2	2	2	2
File reference	3514482A	3514482A	3514482A	3514482A

PRODUCTION TEAM

DEPARTMENT OF ENERGY AND CLIMATE CHANGE (DECC)

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Project Manager	Richard Perkins
Researcher	Michael Lotinga

INDEPENDENT EXTERNAL REVIEWERS

Reviewer	Bernard Berry
Reviewer	Colin Grimwood
Reviewer	Stephen Stansfeld

PREAMBLE

The project has been undertaken by a research team lead by WSP | Parsons Brinckerhoff (the Internal Research Team), who are responsible for the overall editorial content of the report. During the project, help was sought from three Independent External Reviewers (IER), who undertook a number of paper reviews, providing commentary on the robustness and conclusions for those papers. They also provided a review of the entire document. Comments attributed to the IER are clearly signposted in the report.

An OAM Review Steering Group, chaired by DECC, was set up to agree the detail of the proposed approach to this work and to monitor progress. The Group provided a scrutiny and challenge function but it did not seek to influence the conclusions or recommendations, in order to maintain the independence of the research. The other Steering Group members were Public Health England (PHE); Department for Environment, Food and Rural Affairs (Defra); Department for Communities and Local Government (DCLG); Welsh Government; Scottish Government and Northern Ireland Executive. The [WSP | Parsons Brinckerhoff] project team were also invited to attend the Steering Group meetings.

A draft report was provided to three peer reviewers commissioned separately by DECC. This final report addresses the comments raised by the peer reviewers, and a spreadsheet detailing their comments and how they have been addressed in the report has been produced.

The authors would like to take this opportunity to thank all those who have assisted in gathering data, making papers available, and raising awareness with Stakeholders of this research.

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NON TECHNICAL SUMMARY

BACKGROUND

Current planning policy for the assessment and rating of wind turbine noise in England, Scotland, Wales and Northern Ireland refers to the ETSU-R-97[1] document. Wind turbines are known for their distinctive acoustic character often described as a 'swish', which is also referred to as amplitude modulation (AM). Recent evidence suggests that at times this 'swish' can become more of a pronounced 'thump', leading to complaints from wind farm neighbours.

In response to growing concerns about the impact of excessive AM on residents, WSP | Parsons Brinckerhoff was commissioned by the Department of Energy and Climate Change to undertake a review of research into the effects of and response to AM and, if considered necessary, to recommend a control method suitable for use as part of the planning regime.

AIMS

The aims of the study are to review the evidence on the effects of AM in relation to wind turbines, the robustness of relevant research into AM, and to recommend how excessive AM might be controlled through the use of a planning condition, taking into account the current policy context of wind turbine noise. The work included working closely with the Institute of Acoustics' AM Working Group, who have proposed a robust metric and methodology for quantifying and assessing the level of AM in a sample of wind turbine noise data.

METHOD

The study has involved the collation and critical review of relevant literature on the subject of AM, which included published papers on dose response studies, case studies, existing planning conditions, and current planning guidance. Key points from the reviewed evidence have been extracted and summarised upon which to draw the reports' conclusions.

CONCLUSIONS

The review has concluded that there is sufficient robust evidence that excessive AM leads to increased annoyance from wind turbine noise, and that it should be controlled using suitable planning conditions. Key elements required to formulate such a condition have been recommended.

RECOMMENDATION

It is recommended that excessive AM is controlled through a suitably worded planning condition which will control it during periods of complaint. Those periods should be identified by measurement using the metric proposed by work undertaken by the Institute of Acoustics, and enforcement action judged by Local Authority Environmental Health Officers based on the duration and frequency of occurrence.

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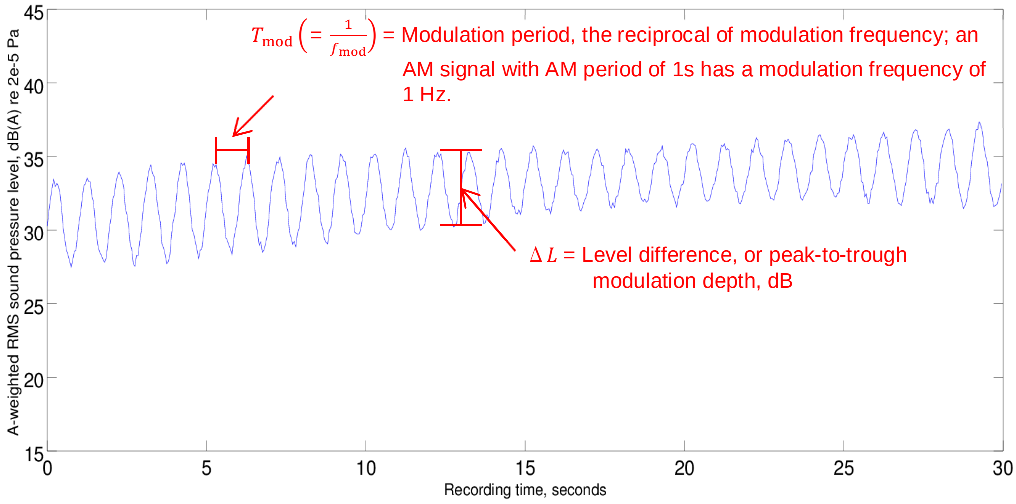
[1] *ETSU-R-97 The assessment and rating of noise from wind farms,* The Working Group on Noise from Wind Turbines Final Report September 1996

EXECUTIVE SUMMARY

WSP | Parsons Brinckerhoff has been commissioned by the Department of Energy and Climate Change (DECC) to undertake a review of research into the effects of and response to the acoustic character of wind turbine noise (WTN) known as Amplitude Modulation (AM).

The diagram below illustrates an example of a signal exhibiting amplitude modulation, and how the terms of modulation frequency and depth are defined.



In WTN, these fluctuating AM characteristics are commonly perceived as sounds that could be described as ‘swish’, or less frequently as ‘thump’. Further definitions of amplitude modulation, fluctuation sensation and relevant acoustical concepts are described in an Appendix to this report.

At the time of writing, planning policy in England, Scotland, Wales and Northern Ireland refers to the ETSU-R-97[2] document for the assessment and rating of wind turbine noise. This planning guidance document is supplemented by a Good Practice Guide[3] (GPG) which is currently endorsed by all four Governments.

The ETSU-R-97 and GPG documents set out how noise assessments should be undertaken at the planning stage in the United Kingdom. It should be noted that the acoustic descriptor $L_{A90,\ 10min}$ is used for both the background noise and the wind turbine noise, and that the noise levels recommended in ETSU-R-97 *“take into account the character of noise described as blade swish.”* That is to say that a certain level of amplitude modulation is included within the recommended noise limits.

The objective of this project has been to review the current evidence on the human response to WTN AM, evaluate the factors that contribute to human response (such as level, intermittency, frequency of occurrence, time of day, etc.), and recommend how excessive AM might be controlled through the use of a planning condition. The work has been undertaken in two Phases. This report relates to Phase 2, and should be read in conjunction with the Phase 1 report.

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[2] *ETSU-R-97 The assessment and rating of noise from wind farms,* The Working Group on Noise from Wind Turbines Final Report September 1996

[3] *A good practice guide to the application of ETSU-R-97 for the assessment and rating of wind turbine noise*, Institute of Acoustics, May 2013

The project work for Phase 2 has involved the collation and critical review of relevant papers, existing planning conditions, and existing planning policies where they relate to AM from wind turbines. Based on a combination of the evidence found and professional experience, a recommendation has been made on the potential make up of a planning condition to control AM. It should be noted that the condition has been designed only for new planning applications, and applicability for use in Statutory Nuisance investigations (where methodologies and acceptability criteria are different to those used for planning enforcement) on existing wind turbine sites has not been considered as part of this review.

The collated research was split into two categories. 'Category 1' papers comprised only those studies specifically investigating a scaled response to quantified AM WTN exposure, while 'Category 2' papers covered any other papers considered relevant to AM, such as complaints-triggered case-studies, broader epidemiological studies, and research into the psychoacoustics of WTN sound characteristics.

The main conclusions from the Category 1 studies reviewed in Section 3.2 can be summarised as follows:

- Within both laboratory and field test environments there is a strong association between increasing overall time-average levels of AM WTN-like sounds with increasing ratings of annoyance.
- Within a laboratory test environment:
  - subjects rated noticeable modulating WTN-like sounds as more annoying than similar noise without significant modulation;
  - the onset of fluctuation sensation for a modulating WTN-like sound appeared to be in the region of around 2 dB modulation depth;
  - increasing modulation depth above the onset of fluctuation sensation showed a broadly increasing trend in mean ratings of annoyance, but changes in mean annoyance rating tended to be relatively small and in some cases inconsistent;
  - equivalent annoyance ratings of AM and steady WTN-like sounds derived by level adjustment did not show a strong increasing trend with increasing depth of modulation; and
  - equivalent 'noisiness perception' of WTN-like AM sounds compared with a steady sound showed a gradually increasing trend with modulation depth.

It was also concluded that the results from both the laboratory and field studies should be approached with caution, since they may not readily translate to how people respond to WTN exposure in their homes[4].

The Category 2 papers reviewed in section 3.3 provide supporting evidence that:

- Perception of amplitude modulation in WTN and other environmental sounds affects subjective annoyance;
- There is a potential association between WTN-related annoyance and increased risks of sleep disturbance and stress;
- There are non-acoustic factors that play an important role in influencing the subjective annoyance attributed to noise from wind turbines, including sensitivity, attitude, situation,

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[4] The field studies typically quantify noise exposure externally to the properties, but exposure (especially at night) could often be indoors.

aesthetic perception and economic benefits (this is common to many other industrial noise sources as well); and

- Annoyance due to AM WTN seems to be increased during normal resting periods, i.e. late evening / night-time / early morning. This could be due to increased sensitivity, greater AM prevalence or magnitude (e.g. due to diurnal variations in atmospheric conditions) or a combination of these factors.

It is noted that none of the Category 1 or 2 papers have been designed to answer the main aim of the current review in its entirety. The Category 1 studies have limited representativeness due to sample constraints and the artificiality of laboratory environments, whereas the Category 2 studies generally do not directly address the issue of AM WTN exposure-response. A meta-analysis of the identified studies was not possible due to the incompatibility of the various methodologies employed. Notwithstanding the limitations in the evidence, it was agreed with DECC that the factors to be included in a planning condition should be recommended based on the available evidence, and supplemented with professional experience.

The prevalence of unacceptable AM has not been evaluated as part of this study, and current state of the art is that the likely occurrence cannot be predicted at the planning stage. That does not preclude future research to determine the likelihood of AM occurring coming forward, and the development of a risk based evaluation, or similar. Due to the lack of ability to predict AM occurring on a site, and the reported difficulties in applying Statutory Nuisance provisions to control AM on existing sites, it is likely that the default position for a decision maker would be to apply the condition on all sites unless evidence is presented to the contrary.

The review concludes that where there are high levels of AM[5], the adverse effects could be significant. On this basis a control for AM is required, and this could be achieved via a suitably-worded planning condition imposing action on the operator of the turbine(s) to reduce the impacts identified. The condition must accord with existing planning guidance, and should be subject to legal advice on a case by case basis.

The few existing planning conditions or suggested methods in existence to control AM have been reviewed as part of the project. The methods include the well documented condition for the Den Brook[6] wind farm, a sample condition from Renewable UK[7] and proposals to use the method in British Standard BS 4142:2014.

Following the review, the elements required for a suitable planning condition to control AM have been recommended. It is noted that the AM control has only been designed for use with new planning applications; applicability for use in Statutory Nuisance investigations on existing wind turbine sites, where the legal regime is different (and outside the project scope), has not been considered as part of this review.

Any condition developed using the elements proposed in this study should be subject to a period of testing and review. The period should cover a number of sites where the condition has been implemented, and would be typically in the order of 2-5 years from planning approval being granted.

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5 At present it is not possible to predict whether AM will or will not be prevalent on a site.
6 http://www.den-brook.co.uk/
7 http://www.renewableuk.com/en/publications/index.cfm/template-planning-condition-am-guidance-notes

PROPOSAL FOR PENALTY SCHEME

The review found that the planning condition should include the following elements:

- ✓ The AM condition should cover periods of complaints (due to unacceptable AM);
- ✓ The IOA-recommended metric[8] should be used to quantify AM (being the most robust available objective metric);
- ✓ Analysis should be made using individual 10-minute periods, applying the appropriate decibel 'penalty' to each period (using Figure 12), with subsequent bin- analysis;
- ✓ The AM decibel penalty should be additional to any decibel penalty for tonality;
- ✓ An additional decibel penalty is proposed during the night time period to account for the current difference between the night and day limits on many sites to ensure the control method works during the most sensitive period of the day, i.e. the night-time period (this addition would not apply to situations in which other planning conditions dictate the limits to be set as lower for night-time than for daytime).;
- ✓ Professional judgement should be used for planning enforcement of the AM condition in terms of frequency and duration of breaches identified; and
- ✓ The condition is only designed for upwind, 3-bladed turbines with rotational speeds up to approximately 32 RPM[9]. Further research is needed for turbines with higher rotational speeds or greater numbers of blades[10].

Further research has been recommended to supplement the limitations of the available research which underpins the above recommendation, although if the proposed penalty system, when implemented in a suitable planning condition, achieves the aim of reducing the impact from AM, then this research may not be required.

[8] *A Method Rating Amplitude Modulation in Wind Turbine Noise,* Institute of Acoustics Noise Working Group (Wind Turbine Noise), 2016

[9] Specifically, the IOA metric is limited to a working upper modulation frequency of around 1.6 Hz, and the exposure-response research underpinning the proposed penalty system addresses modulation frequencies within the 0-1.5 Hz range.

[10] Both of these factors affect the AM character due to the 'blade passing frequency', as explained in Appendix A Glossary & Concepts.

1 INTRODUCTION

1.1 GENERAL

1.1.1 WSP | Parsons Brinckerhoff has been commissioned by the Department of Energy and Climate Change (DECC) to undertake a review of research into the effects of and response to the acoustic character of wind turbine noise (WTN) known as Amplitude Modulation (AM), or more specifically an increased level of modulation of aerodynamic noise as perceived at neighbouring residential dwellings. A glossary of acoustical terminology and concepts relevant to WTN and AM is included in Appendix A.

1.1.2 At the time of writing, planning policy in England, Scotland, Wales and Northern Ireland refers to the ETSU-R-97 (Energy Technology Support Unit Working Group on Noise from Wind Turbines, 1996) document for the assessment and rating of wind turbine noise. This planning guidance document is supplemented by a Good Practice Guide (GPG) which is currently endorsed by all four Governments, published by the Institute of Acoustics (IOA, 2013).

1.1.3 The ETSU-R-97 and GPG documents set out how noise assessments should be undertaken at the planning stage in the United Kingdom, The following aspects of the assessment process are particularly drawn out for later reference:

- The acoustic descriptor $L_{A90,\ 10min}$ is used for both the background noise and the wind turbine noise. In the case of wind turbine noise, the $L_{A90,\ 10min}$ is expected to be about 1.5-2.5dB(A) less than the L_{Aeq} measured over the same period. The reason stated for the use of the $L_{A90,\ 10min}$ descriptor for wind turbine noise is *"to allow reliable measurements to be made without corruption from relatively loud, transitory noise events from other sources."*
- The noise levels recommended in ETSU-R-97 *"take into account the character of noise described as blade swish."* That is to say that amplitude modulation is included within the recommended noise limits.
- ETSU-R-97 contains a separate assessment method for the identification of tonality in wind turbine noise, and a prescribed 'penalty'[11] system is stated which adds a decibel penalty to the overall noise level to be compared to the noise limits.

1.1.4 Concern about AM has been growing over recent years. The issue is routinely brought up at planning meetings and Public Inquiries for new wind turbine schemes, and it is alleged that complaints to Local Authorities relating to AM from wind turbines are increasing[12]. The extent of the problem is unclear, due in part to a lack of agreement on the definition of the type and degree of AM in wind turbine noise that could lead to complaints, and suggestions from residents groups that some complaints are not being reported through Local Authorities. While a national survey of noise attitudes (SoNA) and annoyance has recently been published (AECOM, 2015), wind turbine noise does not feature in the key findings, a fact that may reflect the relatively small proportion of the UK population exposed to WTN.

1.1.5 A recent study of wind farm impacts in Scotland indicated that AM could be perceived by residents in around two thirds of the ten case study sites, however specifics about the AM (such

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[11] Throughout this report, unless otherwise stated, 'penalty' refers to a numerical decibel penalty, as contrast with other forms, for example financial or legal penalties.

[12] See later reviews in Section 3 for more details.

as the magnitude affecting the descriptions) were less clear (SLR & Hoare Lea, 2015). The study also noted that a large majority of the surveyed residents were not affected by noise from the wind farms.

1.1.6 The Institute of Acoustics (IOA) formed an AM working group (AMWG) in the summer of 2014. The work of the group has been to undertake a review of the current knowledge of AM, to agree a definition of AM which is consistent with the likelihood of complaints, and to define a robust metric and methodology to quantify AM when it is present within wind turbine noise. A proposal for three metrics was consulted upon in 2015, and a preferred metric has been proposed as providing the most robust method to quantify AM in field measurements of wind turbine noise.

1.1.7 The objective of this project is to review the current evidence on the human response to AM, evaluate the factors that contribute to human response (such as level, intermittency, frequency of occurrence, time of day, etc.), and recommend how excessive AM might be controlled through the use of a planning condition. Where possible, a method to assess the likely impacts of the decision on the level of AM control in relation to current Government planning policy, and potential health effects will be set out.

1.1.8 The work has been undertaken in two Phases. This report relates to Phase 2, and should be read in conjunction with the Phase 1 report.

1.2 STUDY AIMS

In order to achieve the project objectives, the aims of this study are:

- To review the evidence on the effects of, and response to, AM in relation to wind turbines, focussing on any peer reviewed literature, and including but not limited to the research commissioned and published by RenewableUK (RUK) in December 2013;
- To work closely with the Institute of Acoustics' AM Working Group, who are expected to recommend a preferred metric and methodology for quantifying and assessing the level of AM in a sample of wind turbine noise data;
- To review the robustness of relevant dose-response relationships, including the one developed by the University of Salford as part of the RUK study;
- To consider how, in a policy context, the level(s) of AM in a sample of noise data should be interpreted;
- To recommend how excessive AM might be controlled through the use of an appropriate planning condition; and
- To consider the engineering/cost trade-offs of possible mitigation measures.

2 METHODOLOGY

2.1 APPROACH

2.1.1 The project work for Phase 2 has involved the following steps:

Phase 2

1. Undertake the search for relevant papers; Obtain copies of all relevant evidence, including the RUK work
2. Critically review the robustness of the relevant studies into the subjective response to AM, and any penalty schemes
3. Critically review the RUK proposed planning condition in the context of ETSU-R-97[13] and the “six tests” for a planning condition. These tests are listed in the NPPF[14] and other Devolved Authority Planning Guidance
4. Summarise (for a non-technical audience) main findings of the review
5. Recommend an appropriate penalty scheme (or alternative) for use in a planning condition, compatible with the IOA AM Working Group’s preferred metric
6. Prepare a draft report summarising the main findings and setting out clear recommendations, in a form suitable for publication by DECC.
7. Amend the report in light of peer review comments, and produce a final report.
8. Present the main findings and recommendations to the IOA’s AM Working Group and, separately, to DECC’s Steering Group.

2.1.2 This report includes the output from steps 1 to 6 inclusive.

2.2 STAKEHOLDER CONTACT

2.2.1 A number of Stakeholders were contacted to raise awareness of the research, and secondly solicit responses on research work in hand, or papers about to be released. These Stakeholders represent a wide range of Local Authorities, Trade Bodies, Residents Groups and Universities

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[13] Energy Technology Support Unit Working Group on Noise from Wind Turbines (1996)
[14] National Planning Policy Framework in England (DCLG, 2012), or equivalent documents in Wales, Scotland and Northern Ireland

involved in research in the field. The list of Stakeholders was drawn up in consultation with the OAM Review Steering Group, and the final list of those consulted is shown in Table 1.

Table 1: Stakeholder List

No.	Body
1	Anglesey / Ynys Mon Council
2	Armagh, Banbridge and Craigavon Council
3	Cardiff University Psychology Dept
4	Carmarthenshire County Council
5	Chartered Institute of Environmental Health
6	Friends of the Earth / (Cymru)
7	Harrogate Borough Council
8	Highland Council
9	Huntingdonshire District Council
10	Institute of Acoustics AM Working Group
11	Institute of Acoustics Scottish Branch
12	Local Government Association
13	Midlothian Council
14	Montgomeryshire Against Pylons
15 & 16	Planning Scotland
17	Powys District Council
18	Powys Wind Farm Supporters
19	RenewableUK
20	Scotland Against Spin
21	Scottish Borders Council
22	Scottish Government Inquiry Reports Unit
23	Scottish Industry Policy
24	South Cambridgeshire District Council
25	The Independent Noise Working Group
26	The Planning Inspectorate
27	Waveney District Council
28	Welsh Local Government Association
29	West Lothian Council
	Research Institutions:
30	The University of Salford
31	The University of Tokyo
32	Seoul National University
33	Ghent University

2.2.2 A summary of the responses is included in Section 3.1.

2.3 EVIDENCE REVIEW METHODOLOGY

OVERVIEW

2.3.1 The purpose of the literature review was to establish the current level of knowledge of AM, and the extent to which the human response to AM is understood. In order to undertake the reviews, the papers were initially categorised as follows:

1. Research directly addressing a scaled response to a quantified human exposure to amplitude-modulated wind turbine noise (real or simulated)
2. Other papers (e.g. self-reported complaints, anecdotal evidence, etc.)

2.3.2 Category 1 papers were each reviewed by two of the independent external reviewers. Category 2 papers have been catalogued, reviewed by the internal research team, and where deemed to be important, also reviewed by an independent external reviewer. A summary of the review outcomes for Category 1 and 2 papers are contained in sections 3.2 and 3.3 respectively.

PROCESS

2.3.3 The following databases were searched for ‘black’ literature (i.e. independently peer-reviewed and published in recognised and reputable journals, and searchable in research databases):

- Web of Science
- PubMed

2.3.4 The search terms used were those identified and agreed at Phase 1, as summarised in Table 2.

Table 2: Keywords for Literature Search

a)	**Wind Turbine Noise**	
	NOISE	QUALITY OF LIFE
	WT	SOUND QUALITY
	WIND TURBINE	JUDGEMENT
	AMPLITUDE	FLUCTUATION
	MODULATION	FLUCTUATING
	WIND FARM	FLUCTUATE
	WTG	WIND TURBINE GENERATOR
	DOSE	NUISANCE
	RESPONSE	COMPLAINTS
	DOSE-RESPONSE	EXPOSURE
	ANNOYANCE	ACCEPTABILITY RATING
	ANNOYING	THRESHOLD
	SLEEP	PENALTY
	HEALTH	SWISH
	WELLBEING	THUMP
	AM	MENTAL HEALTH
	RHYTHMIC	NOISE SENSITIVITY
	FLUTTER	EXPERIENCE
	SWOOSH	EXPERIENTIAL
	WHOOSH	LOW FREQUENCY

Table 2: Keywords for Literature Search	
b) Other Areas	
NOISE	QUALITY OF LIFE
AMPLITUDE	SOUND QUALITY
MODULATION	PRODUCT SOUND QUALITY
AM	JUDGEMENT
DOSE	FLUCTUATION
RESPONSE	FLUCTUATING
DOSE-RESPONSE	FLUCTUATE
ANNOYANCE	NUISANCE
ANNOYING	COMPLAINTS
SLEEP	EXPOSURE
HEALTH	ACCEPTABILITY RATING
WELLBEING	HELICOPTER BLADE SLAP
THRESHOLD	HELICOPTER NOISE
PENALTY	SWISH
FLUTTER	MENTAL HEALTH
RHYTHMIC	NOISE SENSITIVITY
THUMP	LOW FREQUENCY

2.3.5 These terms were combined where possible using Boolean operators to narrow the results. The date range was generally limited to 2000-present. Example combinations are given in Table 3 (other combinations were also employed):

Table 3: Example Combinations of Keywords for Literature Search

Database	Search terms	Results
Web of Science	TS=((nois* OR sound) AND ((wind NEAR (farm* OR turbine* OR generator)) OR WTG OR WT) AND (AM OR amplitude OR modulation OR rhythmic OR flutter OR swoosh OR whoosh OR fluctuat* OR swish OR thump OR "low frequency") AND (dose OR response OR dose-response OR exposure OR exposure-response OR annoy* OR sleep OR health OR (well NEAR/5 being) OR "quality of life" OR "sound quality" OR judgement OR nuisance OR complaints OR "acceptability rating" OR threshold OR penalty OR (mental NEAR health) OR sensitiv* OR experien*))	146 results on 30/10/2015
PubMed	((((((((nois*[Title/Abstract] OR sound[Title/Abstract])) AND ("wind farm"[Title/Abstract] OR "wind turbine"[Title/Abstract] OR "wind farms"[Title/Abstract] OR "wind turbines"[Title/Abstract] OR WTG[Title/Abstract] OR WT[Title/Abstract]))) AND (amplitude[Title/Abstract] OR modulation[Title/Abstract] OR AM[Title/Abstract] OR exposure[Title/Abstract] OR dose[Title/Abstract] OR response[Title/Abstract])))))	115 results on 03/11/2015

2.3.6 The titles and abstracts of the search results were examined to identify relevant literature. In addition to the searchable databases, conference proceedings were searched for further 'grey' literature (i.e. non-independently peer reviewed, or where peer review status is uncertain), including from the following sources:

- International Commission on the Biological Effects of Noise (ICBEN) Congress
- International Meeting/Conference on Wind Turbine Noise
- International Meeting on Low Frequency Noise and Vibration
- International Congress on Sound and Vibration (ICSV)
- International/European Congress and Exposition on Noise Control Engineering (Inter-noise/EuroNoise)

2.3.7 Finally, any other additional literature made known to the research group or identified from reference lists was added to the database. A total of 134 publications were identified using this process. The full list of identified papers is included in Appendix B.

2.3.8 The titles and abstracts of the list were reviewed to classify the papers in terms of relevance to the study aims. On this basis, papers addressing only physical source mechanisms and measurement techniques for AM WTN were specifically excluded. At the end of this process, 69 separate publications were shortlisted for more detailed review.

2.3.9 The detailed reviews were carried out using a standard process framework to extract specific details about each paper, including the quality, conclusions and risks of bias (see Appendix C for included categories). At the inception of the review process it was hoped that a recognised research quality rating scale could be applied to allow direct comparison, and the Newcastle-Ottawa Scale (Wells, et al.) was initially considered as a potentially useful candidate (Zeng, et al., 2014). It swiftly became clear that the design of the most relevant studies, which were primarily laboratory-based, uncontrolled and cross-sectional in nature, did not lend themselves well to this type of rating scale and the results would therefore not yield useful comparative information. As a result it was decided that weighted consideration would be determined by reviewers based on their judgement of the importance of the study relative to the aims of this research. For the key publications, i.e. those within the first category described above, two external reviewers independently reviewed each paper, and the results were compared. Conclusions and applications to be drawn from the studies were agreed by discussion.

2.3.10 Prior to the first draft of this review report, a final check was made (16th March 2016) in the database sources referred to above, to ensure no relevant new research had been published in the interim.

STUDY LIMITATIONS

2.3.11 It is noted that applying the search terms and filtering the papers as stated could introduce selection and publication bias into the process. The risk of bias in any review cannot be eliminated, but steps were taken to minimise this risk as described above, i.e. by searching more than one database, including searches of grey literature, by defining the categorisation criteria and by defining a protocol for reviewers to complete the reviews.

2.3.12 For studies falling into Category 1, the risks of selection bias are extremely low, given the relatively small body of existing literature.

2.3.13 Selection bias in Category 2 is more probable due to the wider range and volume of studies identified, and it has been acknowledged in section 3.3 that some studies have been specifically excluded. This is most relevant to the epidemiological papers addressing the potential health effects relating to general WTN exposure, in which the AM component has not been specifically quantified or rated. This body of literature is relatively large, and represents a wide range of different theories, results, views and opinions. The current review of this work has focussed on recent, existing systematic reviews, and recent large-scale field studies only. The conclusions drawn from this work may therefore be questioned on the basis of selection bias, but it should be noted that these conclusions do not impose significant practical influence on the outputs of this research, i.e. a recommendation for an AM planning control.

2.3.14 Wind turbine acoustics is a swiftly-developing field of knowledge, and new research is published on a regular basis. The drafting and review process of this report took place over a period of months, and consequently new study material inevitably came to light after the review period had been completed. In particular, two papers appeared in the peer-reviewed literature prior to the final draft that would have met the Category 1 criteria in the review. These papers have not been reviewed by the independent external reviewers, but the main findings and possible implications have been briefly outlined by the internal research team in the Annexes to this report (Annex 1 and Annex 2). To summarise the findings, both studies are believed to broadly support the recommendations made for a proposed planning control.

3 REVIEW SUMMARY

3.1 STAKEHOLDER RESPONSES

3.1.1 A number of Stakeholders identified during the Phase 1 work were contacted by email firstly to raise awareness of the research, and secondly solicit responses on research work in hand, or papers about to be released. A number of the Stakeholders responded to the email, the key points of which are summarised below:

- ✓ No new WTN AM research was identified that the team were not able to find through the searches undertaken, or from previous knowledge that was considered to be relevant to the study. Other non-AM research was noted by two Stakeholders, but was also not relevant to the study;
- ✓ Some of the Local Authorities contacted are currently investigating noise complaints from wind farms sites with suspected AM aspects. None of these investigations had been concluded at the time of writing (Jan 2016); and
- ✓ The papers produced by the Independent Noise Working Group (INWG)[15] were referenced a number of times. These have been included in the Category 2 review in section 3.3.

3.1.2 There was also general feedback that there is a need for an AM control through the planning system.

3.2 CATEGORY 1 PAPERS

INTRODUCTION

3.2.1 The literature search yielded five studies directly investigating a scaled response to quantified AM WTN exposure: 3 laboratory-based and 3 field-based (one study was composed of both field and laboratory components).

3.2.2 The identification details of these studies are summarised below, including the nature of the publication (in square brackets; black = independently peer-reviewed paper; grey = not independently peer-reviewed, or peer review status uncertain).

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[15] http://www.heatonharris.com/reports-publications

Table 4: Category 1 Research Papers

Study	Lead research group	Relevant key publications	Study type
A	Seoul National University, Korea	*An estimation method of the amplitude modulation in wind turbine noise for community response assessment* (Lee, Kim, Lee, Kim, & Lee, 2009) [grey] *Annoyance caused by amplitude modulation of wind turbine noise* (Lee, Kim, Choi, & Lee, 2011) [black] *An experimental study on annoyance scale for assessment of wind turbine noise* (Seong, Lee, Gwak, Cho, Hong, & Lee, 2013a) [black] *An experimental study on rating scale for annoyance due to wind turbine noise* (Seong, Lee, Gwak, Cho, Hong, & Lee, 2013b) [grey]	Lab
B	The University of Tokyo, Japan	*Study on the amplitude modulation of wind turbine noise: part 2 – auditory experiments* (Yokoyama, Sakamoto, & Tachibana, 2013) [grey] *Audibility of low frequency components in wind turbine noise* (Yokoyama, Sakamoto, & Tachibana, 2014a) [grey] *Perception of low frequency components in wind turbine noise* (Yokoyama, Sakamoto, & Tachibana, 2014b) [black] *Subjective experiments on the auditory impression of the amplitude modulation sound contained in wind turbine noise* (Yokoyama, Koboyashi, Sakamoto, & Tachibana, 2015) [grey] *Nationwide field measurements of wind turbine noise in Japan* (Tachibana, Yano, Fukushima, & Sueoka, 2014) [black] *Outcome of systematic research on wind turbine noise in Japan* (Tachibana, 2014) [grey]	Lab/field
C	The University of Salford, UK	*Wind turbine amplitude modulation: research to improve understanding as to its cause & effect. Work package B(2): development of an AM dose-response relationship* (von Hünerbein, King, Piper, & Cand, 2013) [grey] *Affective response to amplitude modulated wind turbine noise* (von Hünerbein & Piper, 2015) [grey]	Lab
D	Ghent University, Belgium	*Wind turbine noise: annoyance and alternative exposure indicators* (Bockstael, Dekoninck, de Coensel, Oldoni, Can, & Botteldooren, 2011) [grey] *Reduction of wind turbine noise annoyance: an operational approach* (Bockstael, Dekoninck, Can, Oldoni, de Coensel, & Botteldooren, 2012) [black]	Field
E	The University of Adelaide, Australia	*Characterisation of noise in homes affected by wind turbine noise* (Nobbs, Doolan, & and Moreau, 2012) [grey]	Field

REVIEW

3.2.3 The research papers discussed in this section were reviewed by the independent external reviewers.

STUDY A

SUMMARY I

3.2.4 A group at Seoul National University conducted a state-funded laboratory study aimed at developing a scale for rating annoyance from AM WTN.

3.2.5 There were two distinct stages to this work: the first (I) is described by Lee et al. (2009), (2011). This experiment used modified turbine sound recordings as stimuli and subjects rated 'annoyance' on an 11-point scale according to ISO 15666:2003 (ISO, 2003). The results indicated a strong and statistically significant association between the annoyance and the overall A-weighted time-averaged level of the noise, as shown in the reproduced Figure 1. The direct relationship between the modulation and the mean annoyance ratings was not presented graphically, but reanalysis of the results produces the charts shown in Figure 2, with overall average level as a parameter. This indicates a broadly increasing trend, but with relatively small changes in mean annoyance over the range of modulation depths[16]; almost all of the samples showed a change in the mean annoyance of less than 1 scale interval across the entire range of modulation depths (compared with 4-5 intervals for changes in level).

3.2.6 The spread in the data was also not presented and the statistical analysis produced a range of results: analysis of variance (ANOVA) indicated a significant relationship between annoyance and modulation depth at the 5% level, but statistically significant differences were not consistent across the stimuli set; only the samples featuring the two maximum and the minimum AM depths[16] could be distinguished in paired comparisons (also at the 5% level).

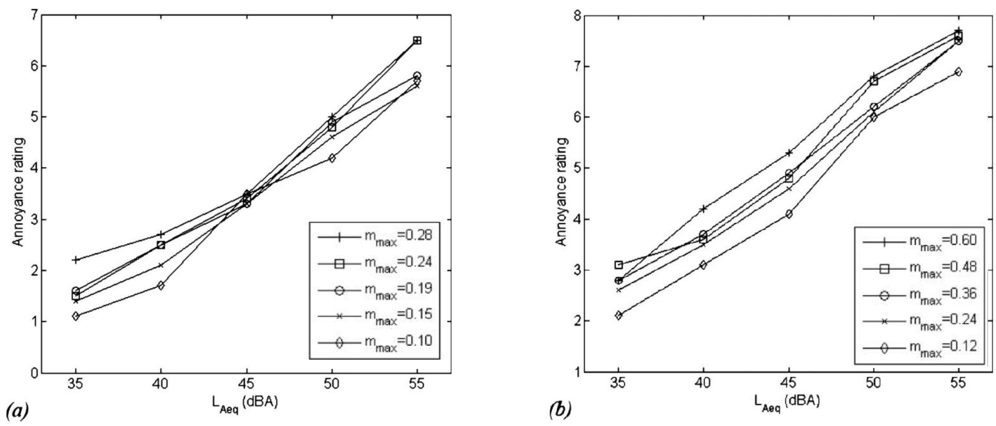

Figure 1: Association of amplitude-modulated wind turbine noise level with mean annoyance ratings over a range of modulation depths (as parameter) for two sample sets, one with higher low-frequency spectral content (left) and one with higher mid and high-frequency content (right), from (Lee, Kim, Lee, Kim, & Lee, 2009)

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[16] In terms of $\Delta L = 20\log_{10}(1+m/1-m)$ as defined by Fastl and Zwicker (2007), but replacing the general modulation factor *m* with the spectral maximum m_{max} obtained using a Fourier Transform method.

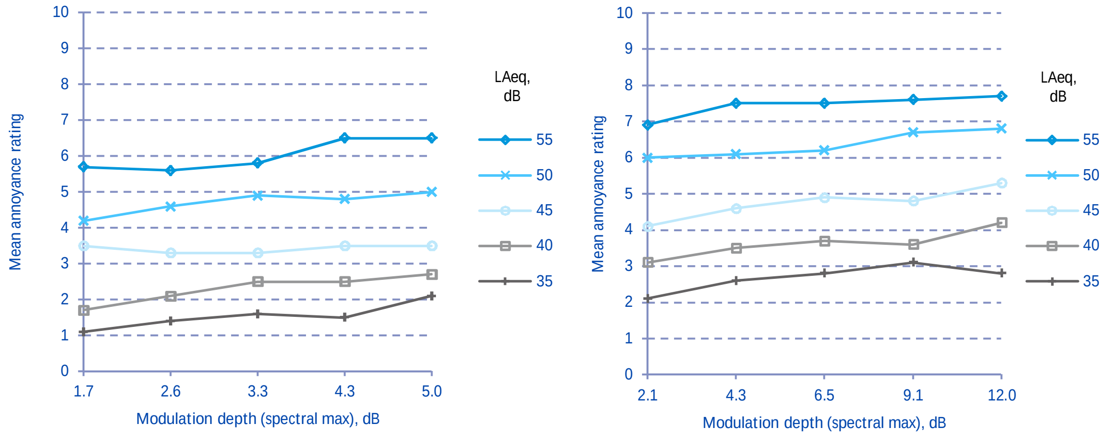


Figure 2: Estimated relationship between wind turbine noise amplitude modulation (maximum spectral modulation depth) and mean annoyance ratings corresponding with the results in Figure 1 with overall average level (L_{Aeq}[17]) as parameter, reanalysed from (Lee, Kim, Lee, Kim, & Lee, 2009)

DISCUSSION I

3.2.7 Great care and attention was applied to the stimuli used in this study to ensure that that the parametric changes were closely controlled. However, the method for obtaining subjective responses is questionable: the application of a social survey technique to a laboratory environment could have an uncertain influence on the results. For example, the briefing of the subjects is likely to affect their interpretation of how to rate 'annoyance', and any contextual information provided to subjects is not detailed. Furthermore, the scale used introduces the idea that the subject is likely to find the noise annoying, when this is not necessarily certain. Although having subjects rate 'annoyance' responses in a laboratory setting is not unusual, it does present potential problems: the responses assigned by subjects to their perception of the noise may not necessarily really reflect 'annoyance' given that people in a 'safe' and artificial environment would presumably feel little, if any, of the emotive experience that feeling real annoyance often entails.

3.2.8 The sample size used in the experiment is small (30 subjects, although again, not unusual for this type of study), and unlikely to be widely representative of a typical population of wind turbine noise-exposed communities (all subjects were aged 20-30 years). It is also noted that the delivery method used employed headphones, which, even with binaural processing, would not give a natural representation of WTN exposure within its typical context.

SUMMARY II

3.2.9 The second phase (II) is reported in two similar papers by Seong et al. (2013a) (2013b). The stimulus used was changed to the output from a simulation turbine noise model and a similar sample recruited (32 subjects aged 20-34) for further laboratory listening tests. A slightly different 7-point response scale was used to record annoyance. Good correlations were shown using linear regression for mean annoyance with equivalent level (L_{Aeq}), fluctuation strength[18], and maximum level (L_{AFmax}), with the correlation value increasing for each respective metric. However, only the maximum level correlation was shown to have equal-variance by residuals testing (i.e. that the regression can be said to be a good model for the relationship between the variables).

[17] A-weighted equivalent continuous sound pressure level.
[18] Defined in (Fastl & Zwicker, 2007). NB: Includes overall broadband noise level as a parameter.

3.2.10 An association was also indicated between annoyance and the simulated direction of incidence relative to the turbine. Examination of the associated model description (Lee, Lee, & Lee, 2013) shows that the position of highest annoyance corresponds to the direction in which both the level (L_{Aeq}) and modulation depth (defined as L_{AFmax}-L_{AFmin}) have high magnitudes; the position of lowest annoyance corresponds to the direction in which modulation depth is at its highest magnitude, but the overall time-average level is at its minimum (due to simulated interference effects in the crosswind direction).

DISCUSSION II

3.2.11 This study shows some interesting results and could indicate an avenue of further research; the authors were contacted to enquire about more recent research developments but no response was received prior to completing this review.

3.2.12 The results again indicate that modulation and level affect subjective laboratory ratings of annoyance, and that the level seems to have stronger influence.

OVERALL

3.2.13 The main conclusion drawn from these studies is that changes in the overall time-average level have a stronger influence on how perception of AM WTN is subjectively assessed than changes in the modulation depth, although the latter is shown to have an observable affect (as might be expected). Application of these lab results to a real situation should be approached cautiously in view of the limitations of the experimental approach and the subject sample.

STUDY B

SUMMARY

3.2.14 These studies formed part of a large-scale investigation into wind turbine noise in Japan, incorporating field measurements and social surveys along with the laboratory exposure-response studies into AM, low-frequency noise (LFN) and infrasound components.

3.2.15 Two papers by Yokoyama et al. (2014a) (2014b) report the results from tests designed to detect thresholds for perception of amplitude modulated LFN and infrasound in WTN. The six stimuli included three samples of recorded AM WTN with depths between 2.1 and 3.7 dB, measured as D_{AM}[19] (roughly equivalent to around 3-5 dB ΔL). The experiment was designed to detect the onset of sensation across the frequency range; it was found that low-frequency spectral components of the WTN below the 31.5Hz third-octave band were inaudible for the majority of subjects.

3.2.16 Another set of experiments continued the work by examining the thresholds of fluctuation sensation using AM WTN recordings; the experiment used filtering to modify the samples in a similar way to the LFN audibility threshold experiments, and it was found that spectral content below around 100 Hz did not contribute significantly to fluctuation sensation for the majority of subjects (Yokoyama, Sakamoto, & Tachibana, 2013) (Yokoyama, Koboyashi, Sakamoto, & Tachibana, 2015).

3.2.17 Further experiments reported by Yokoyama et al. (2013), (2015) directly examined the effect of varying the modulation depth of synthesised AM broadband noise (filtered to simulate WTN) on

[19] Defined as the width in dB between the 5th and 95th percentiles of the difference between fast and slow weighted sound pressure levels in a WTN sample (3-minute samples used).

the perceived fluctuation and 'noisiness' sensation by a method of paired comparison adjustment: 10s samples were compared with and without AM content at two overall time-averaged levels (35 and 45 dB $L_{Aeq,10s}$), and subjects adjusted the level of the AM sound until 'noisiness' was deemed equal with the unmodulated sample. The results broadly indicated a general increase in perceived 'noisiness' with AM depth, although the spread of the responses widened considerably as AM depth was increased, indicating greater uncertainty in the mean result. For AM depths less than 4 dB, the mean changes in the adjusted levels were no greater than 1dB, as shown in Figure 3. It can also be seen that when the signals were effectively identical (i.e. at 0 dB modulation depth), some respondents still made small adjustments of up to 2 dB, indicating the residual uncertainties involved in the perceptual comparison.

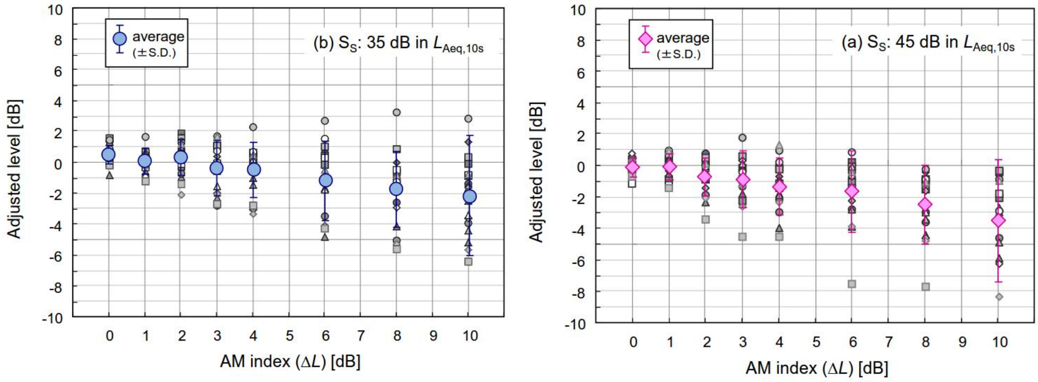
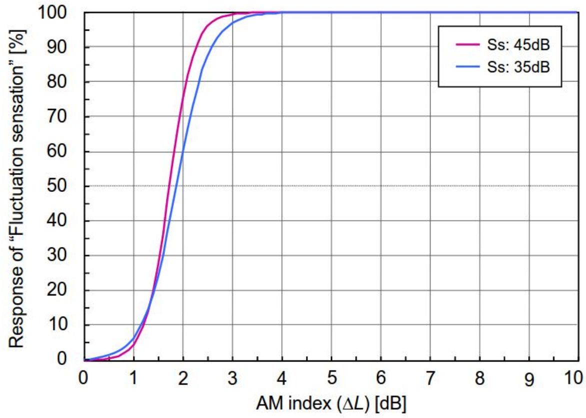


Figure 3: Level adjustments of amplitude-modulated noise to achieve equivalent perceived noisiness with a steady-state noise, from (Yokoyama, Koboyashi, Sakamoto, & Tachibana, 2015)

3.2.18 It is also noted that the mean differences tended to be slightly larger for the 45 dB L_{Aeq} stimuli compared with the 35 dB L_{Aeq} stimuli. Examination of the individual results indicates that one particular subject (represented with circular data points) consistently gave responses for the 35 dB stimuli that were opposite to the general trend, indicating their perception of the steady noise as 'noisier'. This would have influenced the mean differences somewhat, and this result is not replicated in the 45 dB stimuli set. Consequently it appears uncertain whether the results indicate a genuine perceptual difference between the two stimuli sets, or whether this result may reflect some uncertainty in the experimental design and, potentially, differing interpretations of the intended responses.

3.2.19 A subjective assessment of fluctuation sensation was made for each sample using descriptive onomatopoeic words (such as "*zah, zah*", "*guon, guon*"). This allowed an assessment of the AM depth onset of fluctuation sensation, which was analysed as around 2 dB Δ*L*; this is in agreement with the earlier findings of Vos et al. (2010a) [grey], as reported by van den Berg et al. (2011) [grey].



ΔL derived from $L_{Ap,F}$

Figure 4: Perception of Fluctuation in synthesised amplitude-modulated wind turbine noise, from (Yokoyama, Koboyashi, Sakamoto, & Tachibana, 2015)

3.2.20 The field study component of the research included measurements of WTN at 34 wind farms around Japan, from which useful data for 29 sites were analysed (Tachibana, Yano, Fukushima, & Sueoka, 2014). The social survey aspect of the work, reported by Kuwano et al (2014), did not specifically investigate the influence of AM in the responses received from the 1076 participants (including 332 respondents from 16 non-wind farm sites, used as a control group). The developed D_{AM} metric was applied to the measurements made at 18 of the wind farm sites, which was used to produce a distribution of occurrence of measured modulation depth in the field data, reproduced in Figure 5. The researchers suggested that the distribution indicated that AM might be above the threshold of perception in about 75% of the measured WTN data, at the measurement points. The noise measurement points at each site were uniformly distributed within a distance of 100-1000m from the turbines. The study does not clarify which measurement points were used (i.e. at what proximity to the turbines) to analyse the data to produce the D_{AM} distribution, so the applicability of the 75% AM perception statistic to the experience of residents cannot be ascertained.

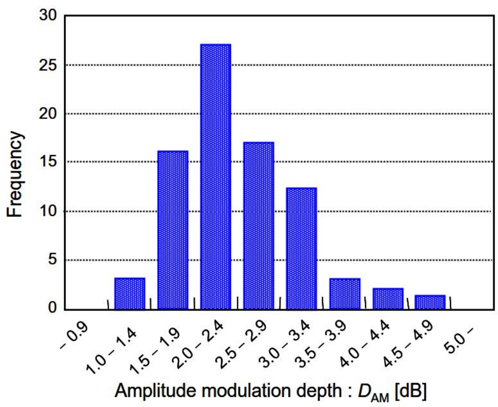


Figure 5: Distribution of D_{AM} in the field data from 18 Japanese wind farm sites, from (Tachibana, Yano, Fukushima, & Sueoka, 2014)

DISCUSSION

3.2.21 The approach of this study had some useful qualities. The laboratory components focussed on perception by i) identifying the onset of fluctuation sensation for subjects, and ii) rating their perception in terms of a subjective assessment of 'noisiness'. It avoided a requirement for subjects to rate 'annoyance', which is a potentially complex, emotional response to perception. Nonetheless, it is not clear how the subjects might have interpreted the request for evaluation of 'noisiness'; the spread in the results may reflect different interpretations, and the variation between individual responses would be exacerbated by the small sample size: results from 15 subjects were reported in the 2013 paper, with 17 reported in the 2015 version (the paper is not explicitly clear as to whether the latter was a fresh attempt at the experiment or simply added more subjects to the existing dataset, but the results presented are very similar). The limitations of the lab study in terms of the sample size and representativeness, as well as the stimuli used and the lab setting should be borne in mind when considering wider application.

3.2.22 The development of the D_{AM} metric was intended to provide a "*simple and practical*" method for measuring AM in WTN. Some shortcomings in applying this method to real long-term field data have been highlighted in later work by Large et al (2015) and by the IOA AMWG (2015a), due to its susceptibility to influence by extraneous non-WT noise. It is unclear whether this issue was detected by the original research team and to what extent the results reported by Tachibana et al (2014) may have been affected by extraneous noise, or what mitigating controls were put in place to protect against this possibility.

3.2.23 The conclusions that can be drawn from this study include i) the onset of fluctuation sensation for the sounds is somewhere around 2 dB modulation depth, using the AM index adopted by the Tokyo group; ii) there appeared to be relatively small perceptual differences (i.e. in terms of 'noisiness', which might be considered as the distinctiveness between the sounds used) for changes in modulation of less than 4 dB depth; and iii) for changes in modulation depth of 4 dB and above, perceived differences in 'distinctiveness' of the AM stimuli increasingly varied; a small number of the subjects perceived a relatively large difference, while the majority perceived differences in a smaller range, averaging to around 1.5-3.5 dB.

STUDY C

SUMMARY

3.2.24 Research was carried out by the Acoustics Research Centre at the University of Salford on behalf of RenewableUK (RUK) and reported by von Hünerbein et al (2013), (2015). A staged approach to the study investigated sensitivity to a range of possible parameters with a potential influence on perception of AM WTN. The noise exposure employed synthesised WTN samples that allowed the parameters to be systematically varied, including level, modulation depth, envelope shape, spectral character and modulation frequency. The results of the preliminary tests were used to identify which parameters would be carried forward for final testing, which included level and modulation depth; other parameters were either fixed at a representative setting or considered of negligible influence. In the final test subjects were asked to imagine the exposure as if they were at home relaxing in the garden, and some additional measures were taken to reinforce the contextualisation. The subjects rated their 'annoyance' using a modified scale based on ISO 15666:2003 (ISO, 2003).

3.2.25 As reproduced in Figure 6 and Figure 7, the results bear similarity to those obtained by Lee et al. (2009) (2011) (i.e. compare with Figure 1 and Figure 2, however, it should be noted that the 'modulation depths' used are derived using quite different methods in each study). Increases in average level corresponded with relatively large increases in the annoyance rating; increases in modulation depth (keeping average level constant) resulted in smaller changes in rated annoyance, which were not found to be statistically significant at the 5% level (although a relational trend can be observed). It was concluded that average level dominated the annoyance response (von Hünerbein & Piper, 2015).

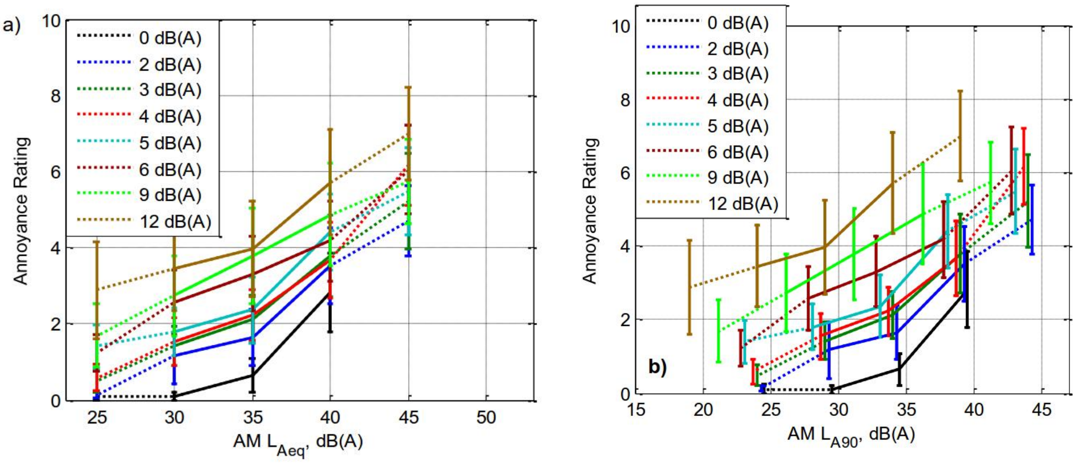


Figure 6: Association of amplitude-modulated wind turbine noise level measured as L_{Aeq} (left) and L_{A90}[20] (right) with annoyance ratings, with modulation depth as parameter, from (von Hünerbein, King, Piper, & Cand, 2013) – dotted lines indicate results from reduced sample, error bars: 95% confidence intervals (CI)

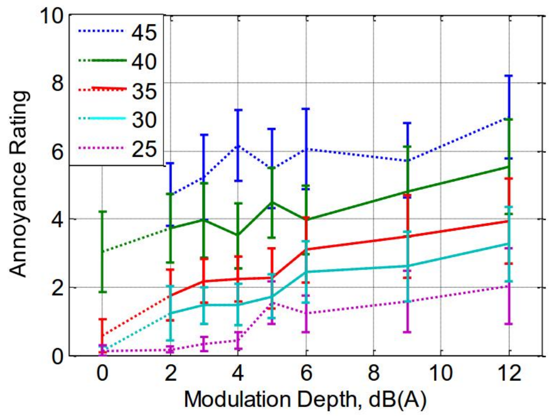


Figure 7: Relationship between modulation depth and annoyance rating with overall average level (L_{Aeq}) as parameter, from (von Hünerbein & Piper, 2015) – dotted lines indicate results from reduced sample, error bars 95% CI

3.2.26 The tests also examined the 'equivalent annoyance' using a method of paired comparison adjustment in a similar way to Yokoyama et al. (2013). The experiment compared an 'Adaptive Broadband Stimulus' (ABBS) signal (a noise signal of steady starting amplitude, that could be modified, or adapted, by the participant to achieve equivalence of annoyance with the paired AM signal). The results of this experiment broadly indicated that most subjects perceived relatively small or inconsistent differences for changes in modulation depths > 2 dB, even up to 12 dB depth, as reproduced in Figure 8. An anomalous result was obtained for 0 dB depth (comparison of identical stimuli), attributed to possible expectation bias amongst participants (i.e. they may have assumed that every stimuli pair presented must be different).

[20] A-weighted sound pressure level exceeded for 90% of the measurement interval.

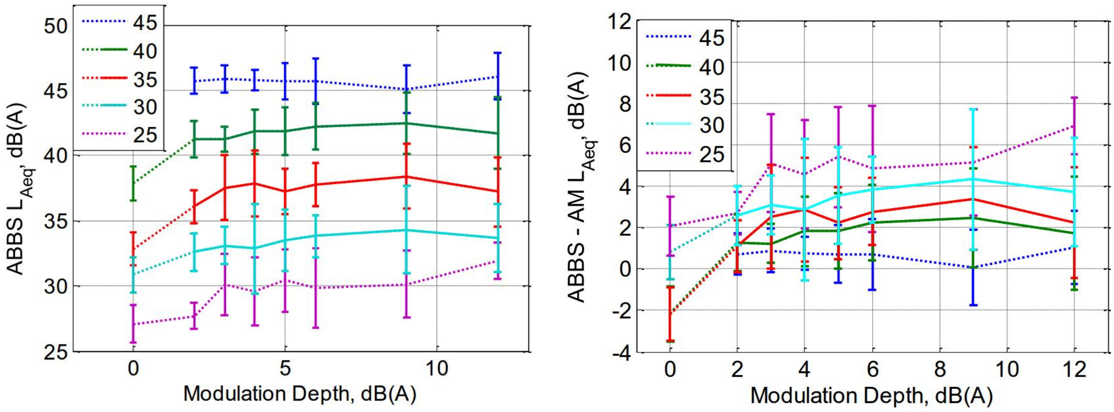


Figure 8: Level adjustments of broadband noise to achieve equivalent annoyance compared with amplitude-modulated noise of a fixed average level (as parameter), as adjusted levels (left), and normalised to adjustment level differences by subtracting the average level (L_{Aeq}) of the amplitude-modulated noise (right), reproduced from (von Hünerbein, King, Piper, & Cand, 2013) – dotted lines indicate results from reduced sample, error bars 95% CI

3.2.27 The analysis produced average adjustments of 1.7 dB at 40 dB L_{Aeq} and 3.5 dB at 30 dB L_{Aeq}; this trend (i.e. smaller adjustment differences with increasing level) was confirmed across the level range, with an overall average adjustment value of 2.3 dB. This scale of level adjustments is similar to those obtained by Yokoyama et al. (2015), despite differences in the experimental design: i) in the Salford study, subjects adjusted the levels to give equivalent 'annoyance' responses, whereas in the Tokyo study, subjects adjusted the levels to give equivalent perception of noisiness; ii) the modulation depth metrics used were derived using different approaches; iii) the adjustment method employed was the reverse in each study, i.e. one approach (Salford) adjusted the steady broadband noise to be subjectively equivalent to the AM, while the other (Tokyo) adjusted the AM to be equivalent to the steady broadband; and iv) the stimuli used and the delivery systems were slightly different.

3.2.28 The RUK study also analysed the same adjustments against the L_{A90} of the AM signal. The results of this analysis are shown in Figure 9.

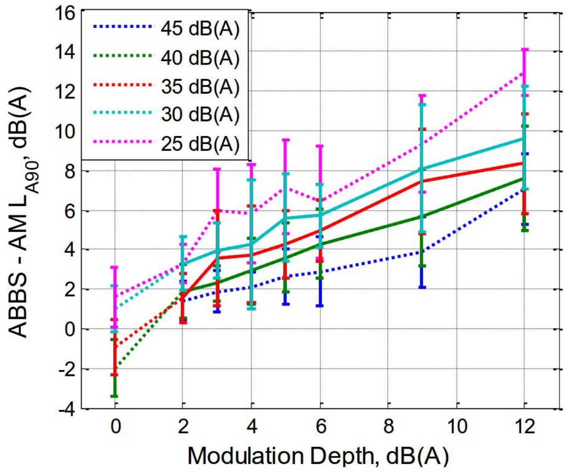


Figure 9: Level adjustments of broadband noise to achieve equivalent annoyance compared with amplitude-modulated noise of a fixed average level (L_{Aeq} as parameter), as normalised by subtracting the 90% exceeded level (L_{A90}) of the amplitude-modulated noise (right), from (von Hünerbein, King, Piper, & Cand, 2013) – dotted lines indicate results from reduced sample, error bars 95% CI

3.2.29 The results in Figure 9 appear to show a more linear relationship for L_{A90}-normalised equivalent annoyance with modulation depth than using the L_{Aeq} normalisation (for example, compare with the right side of Figure 8). In analysing these results, the study authors note that "*in summary L_{A90} might be a suitable parameter to express annoyance ratings in the psychoacoustic context and should be investigated more closely in future studies*". This is discussed further below.

3.2.30 In 'sensitivity tests' conducted using smaller sample sets, the authors examined a number of other parameters that were thought to have potential to influence the results, including modulation frequency. The results indicated that the AM signal with a 1.5 Hz modulation frequency was rated more annoying than a signal with a 0.8 Hz modulation frequency. This is also discussed further below.

DISCUSSION

3.2.31 The similarity of these results with those from Lee et al. (2011) is especially notable given that there were differences in the exposure method used: in particular the Salford approach (in the final test) delivered the stimuli over an ambisonic loudspeaker array rather than headphones. The scales used in the studies to measure response were also similar but had differences: the Salford approach allowed subjects to input their rating on a continuous scale, whereas the Seoul rating used a discrete numerical input. These factors might be expected to somewhat affect the outcome of the results, but there is a remarkable consistency between the study outcomes.

3.2.32 The L_{A90}-based analysis of the equivalent annoyance test results partly illustrate a feature of the synthetic stimuli employed; as the modulation depth increases and the average level (L_{Aeq}) is held constant, the L_{A90} is reduced. As a result, the normalisation of the adjusted broadband noise level by subtracting the amplitude-modulated L_{A90} results in a larger difference (between ABBS L_{Aeq} and AM L_{A90}), which increases in magnitude with increasing modulation depth. In field signals, this would not necessarily be the case, as the average level of a real modulating WTN signal is not constant, and could increase with increasing modulation depth, whereas the non-WT background noise may be relatively steady in level.

3.2.33 The sample size used for the final tests in the Salford study was again small, with 20 subjects, across an age range of 20-50 (average approx. 30). The recruitment process detailed suggests a risk of selection bias, in that it was clear that the study would be looking at the response to wind turbine noise, although it is acknowledged that it may have proved difficult to find willing participants for vaguer, masked study intent. Again, the representativeness of the sample to the wider population of WTN-exposed people must be questioned.

3.2.34 The aforementioned issues of briefing and applicability of lab-rated annoyance results are also relevant to this study: one external reviewer suggested that the context of 'relaxing in the garden' may not necessarily be compatible with the scenario in which AM WTN could be most problematic. For example, an alternative or augmenting scenario may have included 'trying to get to sleep on a summer night with the window open'. Similar types of laboratory tests conducted to specifically investigate LFN (not generated by wind turbines) have used a sleep/night-time scenario (Moorhouse, Waddington, & Adams, 2009) [black], which enables a comparison of sensitivity to be made; given the comparability with WTN this suggests a possible further avenue of investigation.

3.2.35 It was noted on review that the reported tests conducted to examine the influence of the stimulus envelope shape on the annoyance rating were carried out using a constant modulation depth close to the bottom of the range employed (1.7 dB). The results of this study and other works already discussed indicate that a depth of this magnitude would be very much on the edge of fluctuation perception, and so it is a fair assumption that varying skew and width of AM signals with such a small AM depth would be very difficult for subjects to perceive and distinguish. This also indicates another avenue of investigation that does not appear to have been fully explored in the literature, and may be of some value given the subjective descriptions (e.g. 'thumping') sometimes attributed to AM WTN, and often highlighted as the most disturbing to those affected.

3.2.36 The main exposure-response results were obtained using AM WTN stimuli with a modulation frequency of 0.8 Hz. The sensitivity test results indicated that increasing the modulation frequency to 1.5 Hz could result in increased absolute annoyance ratings. This suggests that the equivalent annoyance decibel ratings might also be expected to be slightly greater than those shown above. However, results from the sensitivity tests must be considered with caution: the sample sizes were considerably smaller than the main tests and consisted only of subjects that would normally be considered ‘expert listeners’, i.e. staff and students of the University Acoustics Research Centre.

3.2.37 The main conclusions drawn from this study tend to reinforce those obtained from the similar Seoul and Tokyo experiments: overall average level was the dominant factor in perception of the AM noise; once the sound was established as clearly modulating, further increases in modulation depth did not greatly affect the perception.

3.2.38 Consideration only of averages in the response results masks the extremities, in which some subjects noticed a larger perceptual change with much finer distinctions in modulation depth, while conversely some subjects actually indicated a lower annoyance with an increase in modulation depth. These observations illustrates the difficulty some subjects had in distinguishing the changes – this is reflected in the appended participant observations: “*sounds were perceived by a number of participants to be very similar*” (von Hünerbein, King, Piper, & Cand, 2013).

STUDY D

SUMMARY

3.2.39 This field study, reported by Bockstael et al. (2011) (2012), was aimed at investigating the connection between operational parameters recorded from a set of wind turbines, WTN exposure and annoyance self-reported by residents neighbouring the installation. It should be noted that the study followed complaints about WTN from the neighbours and a consequent mitigation strategy implemented by the operator. Self-reporting was enabled over a 6-month study period via an online application based on a simple question on annoyance and a 5-point response scale.

3.2.40 The study examined detailed aspects of turbine operation from the data supplied by the operator, including production yield, blade velocity and hub height wind speed. Meteorological data was also collected. Logistic regression was used to form a model of the statistically significant relationship between reported annoyance and blade velocity, which itself was related to the WTN level extracted from measurements at the properties. A ‘fluctuation indicator’ was derived using a Fourier transform method from minute-long samples of the noise measurements. This metric was found to broadly increase with increasing annoyance, as indicated in Figure 10. Unfortunately the scaling used for the derivation of this indicator is not fully explained and so direct comparison with other AM measures discussed is not possible. The extent of the error bars are probably a reflection of the very small sample size (3 regular respondent households from a sample of 8); in some cases the results indicate that a fluctuation of a relatively low level (measured by the indicator) could produce a ‘not at all’ annoyed report from some subjects, and an ‘extremely’ annoyed report from others.

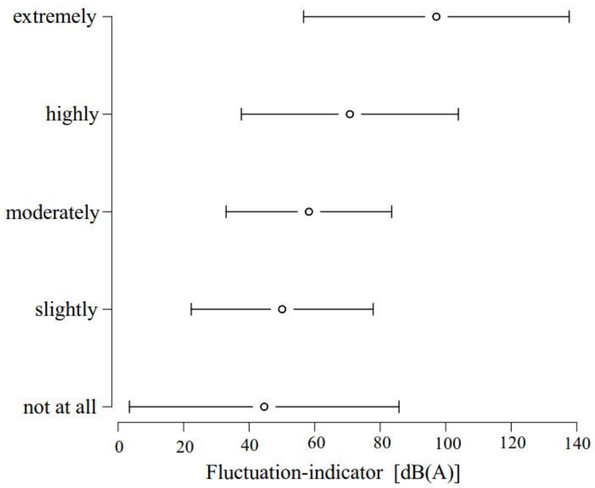


Figure 10: Relationship between fluctuation indicator and reported annoyance (error bars show +/-σ), from (Bockstael, Dekoninck, Can, Oldoni, de Coensel, & Botteldooren, 2012)

DISCUSSION

3.2.41 Given the context of existing noise issues at the site, the representativeness of the results for wider application is open to question. Nonetheless, this is the only study in which the perceptual response could be expected to be a strong representation of that felt by the subject within a suitable residential amenity context, i.e. their own home.

3.2.42 This study shows a good example of careful design and analysis of data for a field experiment. The considerable limitations due to the sample size and situational background (together with the difficulty in cross-comparison of the results due to the lack of clarity in the AM metric employed) restrict its wider application, but it might be regarded as a promising pilot study.

3.2.43 One suggestion made by a reviewer to improve the reliability of this type of response data collection in the field was for self-reports of perception to be prompted at irregular intervals, e.g. by SMS[21], perhaps reverting to self-prompted reporting during periods used for sleeping. This could improve the rate of responses from otherwise low-rate responders and widen the dataset for analysis. More importantly, it would help to reduce any bias potentially introduced by the natural tendency for some subjects to report when most annoyed and not at other times (as documented in this example).

3.2.44 One serious and inevitable drawback on this study is the lack of controls on confounding factors such as personal attitude etc., and this could be significant in a situation where respondents may already have a negative view of the noise source. Research discussed under the Category 2 studies highlight some of the factors shown to influence subjective responses in field survey work relating to WTN.

[21] Short message service (text messaging)

STUDY E

SUMMARY & DISCUSSION

3.2.45 Researchers at the University of Adelaide carried out a preliminary field study designed to test a wind turbine noise measurement and subjective response recording system (Nobbs, Doolan, & and Moreau, 2012). Automated measurements were conducted inside a resident's home near to an operational wind farm, triggered by the occupant and including a 10-point annoyance scale rating and optional notes. The recordings were analysed to produce a measure of AM depth and plotted against recorded annoyance rating, with no apparent association. The results of this study (apparently designed as a simple pilot test for the proposed AM measurement and rating system) are deemed to be of no meaning or use for this research, due to the smallest possible sample size (1), and the lack of any controls or analysis of confounding factors that may have influenced the results.

CATEGORY 1 CONCLUSIONS

3.2.46 The main conclusions from the Category 1 studies are summarised as follows:

- Within laboratory and field test environments, increasing overall time-averaged levels of AM WTN-like sounds showed a strong and significant association with increasing ratings of annoyance.
- Within a laboratory test environment:
  - subjects rated modulating WTN-like sound as more annoying than similar noise without significant modulation;
  - the onset of fluctuation sensation for a modulating WTN-like sound appeared to be in the region of around 2 dB modulation depth (the peak-to-trough level difference in the Fast-weighted sound pressure $L_{pA,F}$ time-series);
  - increasing modulation depth above the onset of fluctuation sensation showed a broadly increasing trend in mean ratings of annoyance, but changes in mean annoyance rating tended to be relatively small, sometimes inconsistent, and typically not statistically significant[22];
  - equivalent annoyance ratings of AM and steady WTN-like sounds derived by level adjustment did not show a very strong increasing trend with increasing depth of modulation; average differences were in the region of around 1.7-3.5 dB; and
  - equivalent 'noisiness perception' of WTN-like AM sounds compared with a steady sound showed a gradually increasing trend with modulation depth, but with a tendency for the spread in perceptual results to also increase. On average the differences were in the region of around 1.5-3.5 dB.
- Wider representativeness of both the laboratory and field results should be approached with caution: sample sizes are very small and may not be fully representative of the wider population of WTN-exposed people; stimuli employed in the laboratory often are very carefully controlled to allow fine adjustment of specific parameters – this kind of regularity in the signal will not be closely reflective of temporal variations experienced in the field, which may further affect subjective responses.

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[22] Subsequent research summarised in Annex 1 indicates a more consistent relationship between modulation depth and annoyance.

3.3 CATEGORY 2 PAPERS

INTRODUCTION

3.3.1 During the literature search, category 2 studies were broadly separated into the following sub-categories:

a. Primary study or review of elements of the human exposure-response relationship with AM WTN that did not meet the category 1 criteria

b. Case study examining un-scaled responses (e.g. complaints) to AM WTN exposure

c. Primary study or review of the human exposure-response relationship with non-wind-turbine amplitude-modulated noise (e.g. HVAC[23] plant)

d. Primary study or review of the human exposure-response relationship with WTN, without specifically addressing responses to quantified AM characteristics (priority given to studies investigating potential adverse health effects other than subjective annoyance, as the association of environmental noise, including WTN, with subjective annoyance has been well-established for some time)

e. Study examining further aspects of AM WTN with potential or partial relevance (excluding source generation theory / testing and AM measurement / quantification techniques)

f. Study examining the application of a planning control or penalty scheme for AM WTN

3.3.2 In addition, relevant publications from an “Independent Noise Working Group” made available on the website of Christopher Heaton-Harris MP (Conservative, Daventry) were also included in the review.

3.3.3 Unless otherwise indicated, the research papers discussed in this section were reviewed by the internal research team. The status of each paper is indicated in square brackets at first reference.

ASPECTS OF THE HUMAN RESPONSE TO AMPLITUDE-MODULATED WIND TURBINE NOISE EXPOSURE

Review Papers 1 & 2

3.3.4 A useful review of relevant literature is given by van den Berg (2009) [grey] and later by van den Berg (2011) [grey], including the following studies.

Psycho-acoustic characters of relevance for annoyance of wind turbine noise (Persson Waye & Öhrström, 2002) [black]

3.3.5 Five different WTN recordings were played to 25 subjects in a laboratory setting. In general, the sounds rated as more annoying were also given higher ratings on descriptors of “*lapping*” and “*swishing*”. Derived psychoacoustic metrics such as ‘fluctuation strength’ and ‘modulation %’ could not explain the variation in annoyance.

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[23] Heating, ventilation and air-conditioning

Perception and annoyance due to wind turbine noise – a dose-response relationship (Pedersen & Persson Waye, 2004) [black]

3.3.6 A cross-sectional field study incorporating social survey questionnaire results from 351 respondents in Sweden, over an area covering $30km^2$ and containing 16 turbines. Of those within the sample who reported noticing WTN (64%), around a third also reported being annoyed by a “swishing” character (a feature that was significantly correlated with noise annoyance), while annoyance due to “pulsating / throbbing” characteristics was also reported by around 1 in 5. Noise annoyance was also significantly correlated with further subjective factors including “attitude to visual impact”, “attitude to wind turbines” and “sensitivity to noise”.

The beat is getting stronger: the effect of atmospheric stability on low frequency modulated sound of wind turbines (van den Berg G. P., 2005) [black]

3.3.7 This paper provides a broad view of the issues surrounding AM WTN and potential effects on people. Measurement results from three sites are analysed to indicate typical fluctuation level variations (i.e. AM), focussing on the influence of the atmospheric conditions. The reported fluctuations in terms of the difference between the maximum and minimum sound pressure levels (L_{Amax} – L_{Amin}) are 4 to 6 dB for single turbines and 5 to 9 dB for multiple (i.e. a wind farm). However, the author acknowledges this measure can easily be influenced by incidental extreme values, and also results for the difference between the L_{A5} and L_{A95} measures, yielding somewhat lower values of 3 to 4 dB.

3.3.8 It is reported from the author’s experience of the Rhede wind farm (Germany/The Netherlands) that operations on a clear night at times produced a beating sound likened to “*distant pile driving*”, and that the sound character during the daytime (with low atmospheric stability) could be very different (i.e. less intrusive).

3.3.9 An analysis of the fluctuation strength metric is presented, indicating that a change in modulation depth ΔL from 3 to 6 dB for a broadband noise corresponded to an increase in fluctuation strength from negligible to 0.18 vacil. The conclusion is drawn that the fluctuations of modern wind turbines are likely to be readily perceivable under stable atmospheric conditions. Any possible links from the measured data with site-specific resident responses are not reported.

Auralization and assessments of annoyance from wind turbines (Legarth, 2007) [grey]

3.3.10 Five different WTN binaural recordings were made and auralised for different distances using a computer propagation model. Twenty subjects were played the recordings using headphones and simultaneously presented with a visual image of a turbine at an appropriate distance. AM was quantified using fluctuation strength applied to specific frequency bands relevant to the “swishing sound” (350-700 Hz) where fluctuation was stronger. A logistic regression model for annoyance was presented based on the relationship with L_{den}[24]. It was stated that the annoyance model could be “improved by including the metrics for prominent tones and for the swishing noise”, although the supporting results were not provided.

Response to noise from modern wind farms in The Netherlands (Pedersen, van den Berg, Bakker, & Bouma, 2009) [black]

3.3.11 Another cross-sectional field study, this time conducted in The Netherlands, analysed data collected from 725 respondents living within 2.5km of a wind turbine installation. Of those who

[24] ‘Day evening night’ equivalent noise level, i.e. a period-weighted L_{Aeq} measure commonly used for EU Directive noise mapping

noticed WTN at their dwellings (46%), 3 in 4 reported a "swishing / lashing" sound, while "thumping / throbbing" was reported by less than 10%, and few of the respondents described the WTN as low frequency. The results showed a strong correlation between noise annoyance and negative opinion of visual impact. Economic benefit from wind turbines was also significantly associated with the likelihood of a respondent reporting 'no annoyance', despite detection of the WTN being the same between benefit/no benefit comparison groups. A large proportion (40%) of respondents reported hearing WTN more clearly at night.

Effects of sound on people (van den Berg F. , 2011) [grey]

3.3.12 In reviewing the issue, the author proposes that the modulation component in WTN, when perceived, could be the most important factor influencing subjective disturbance, due to the unpredictability and perceived lack of control for those exposed.

Review Paper 3

Wind turbine noise: an overview of acoustical performance and effects on residents (van den Berg F. , 2013) [grey]

3.3.13 Includes a review of factors contributing to AM, and suggests that AM is reported to occur more often at night.

Review Paper 4

3.3.14 Another review of relevant literature is found in the report by the Council of Canadian Academies (2015) [grey], prepared for the Canadian Government, including (amongst reviews of the category 1 studies summarised in section 3.2) the following paper.

Psychoacoustic aspects of noise from wind turbines (Fastl & Menzel, 2013) [grey]

3.3.15 A laboratory study was conducted by exposing 13 subjects to a single recording of AM WTN at a range of levels; one of the samples had been modified to remove the AM component of the sound. Subjects rated annoyance using a 'free magnitude estimation' technique by stating a number for each sample but without any defined scale; these were then converted to relative annoyance ratings. A statistically significant relationship between the sound level or loudness and annoyance was shown, but there was no significant difference in rated annoyance between the modulated and un-modulated versions of the signal at equivalent loudness. No data to indicate a relationship for annoyance with modulation / fluctuation was presented, and the results did not include any quantification of AM signal content.

DISCUSSION

3.3.16 The papers reviewed in this section appear to reinforce the suggestions that periodic AM increases annoyance due to WTN, as does increasing level. A number of non-acoustic factors are also identified as influencing the annoyance attributed to noise.

CASE-STUDIES INVESTIGATING UN-SCALED HUMAN RESPONSE TO AMPLITUDE-MODULATED WIND TURBINE NOISE EXPOSURE

Acoustic noise associated with the MOD-1 wind turbine: its source, impact and control (Kelley, McKenna, Hemphill, Etter, Garrelts, & Linn, 1985) [grey]

3.3.17 A very early investigation into the disturbing ‘thumping’ noise, infrasound pulses and vibration experienced by neighbours of an experimental downwind[25] turbine installation. The study examined the source generation mechanisms and possible remedial measures. The source was identified as complex interactions between the rotating blades and the tower structure, exacerbated by local stall conditions and the design of the aerofoil. A number of possible design solutions were proposed, including a modified aerofoil shape and operational angle of attack.

3.3.18 This paper presents a technical and high quality investigation of a specific WTN problem. Increased (or ‘enhanced’/’excessive’ etc.) AM WTN associated with upwind turbines is most likely due to fundamentally different mechanisms than the blade-tower interaction case studied here, as shown in recent research developed by Makarewicz et al. (2015) [black], Oerlemans (2015) [black] Cand et al. (2015a) [grey] and Smith (2013) [grey]. Nonetheless, the information on the acoustical characteristics within residents’ rooms and the influence of meteorology provide some background information that may help to explain why the annoyance reported in some cases can be more intensive than might be expected from outdoor measurements or perception of AM WTN near to the turbines.

Wind turbine noise assessment in a small and quiet community in Finland (Di Napoli, 2011) [black] & ***Case study: wind turbine noise in a small and quiet community in Finland (Di Napoli, 2009) [grey]***

3.3.19 A field study carried out in response to complaints made to a local authority about noise from a single turbine installation.

3.3.20 Measurements were made over a day and night period primarily to quantify the sound power of the turbine. In addition the author analysed the data and recordings to examine spectral and AM content.

3.3.21 A number of relevant sound characteristics are noted: an apparent increase in low frequency noise around 40 Hz when hub height wind speeds increased above a particular value, modulating at the blade passing frequency (NB. this was noted from measurements made at close range to the turbine only; at further distances different sounds were noted, including a “rumbling”, “clapping” and “swish”); greatest modulation depths when the WTN aggregate level was steady, rather than in transition (i.e. the measured AM depth reduced when the overall turbine sound was increasing or decreasing due to changes in wind speed); evidence of ‘double peaks’ in the AM noise level, i.e. peaks occurring more often than the blade passing frequency.

3.3.22 It was noted that the maximum recorded AM depth in the measurement was around 5 dB, but no statistical analysis of the AM results is reported.

3.3.23 There is very little information provided on the complaints that triggered the study, and the measurements were necessarily carried out at closer range to the turbine than the locations of residential dwellings, due to very low audibility of the WTN during the survey.

[25] A downwind design places the blades downwind of the supporting tower; most modern turbines employ the opposite configuration, i.e. upwind.

3.3.24 The study makes some interesting observations and suggestions as to possible causes of the observed sound characteristics, such as blade-structure interactions, and blade phase interference.

Wind turbine amplitude modulation: research to improve understanding as to its cause & effect (Bullmore, Jiggins, Cand, Smith, von Hünerbein, & Davis, 2011) [grey]

3.3.25 This summary of AM WTN case-related measurements and complaint reports is provided by Bullmore et al. (2011), also reviewed by Bullmore et al. (2013) [grey], including the following study.

3.3.26 The results of an investigation by van den Berg, G.P. (2004) [black] indicated measured AM depths (in the A-weighted levels) at one site of up to 5 dB, and sounds that were described as 'pulse-like' and 'thumping', a character considered by the author likely to have contributed to annoyance reported by the residents. It is also noted that complaints were focussed in late evening and night-time periods.

Amplitude modulation and complaints about wind turbine noise (Gabriel, Vogl, Neumann, Hübner, & Pohl, 2013) [grey]

3.3.27 A medium-scale field study carried out to record complaints about WTN from neighbours of a wind farm in Germany. A questionnaire and complaints form were issued together with audio recorder to 212 residents. Sampled noise measurements were taken at specific outdoor locations, and meteorology was also recorded.

3.3.28 Around 45% of the sample returned complaint sheets. Analysis of the complaints sheets showed that around 32% of the sample made complaints about noise that were clearly related (by the complainant) to a subjective description fitting with AM. Compared with the total number of complaint sheets reported (95), this proportion was around 72%.

3.3.29 The authors note that the results show a distinct increase in complaints immediately after a public presentation of the project, which could be due to a) distinct operational or meteorological conditions that increased annoying noise from the site; b) increased noise sensitisation among residents (i.e. respondents becoming more conscious of the noise as a response to awareness of the investigation), c) a decrease in the possible perception of futility in complaining, or d) complainants seeking to maximise any subsequent action taken to reduce the operational capabilities of the wind farm. It is not possible from the presented information to understand which factors could have influenced the results.

3.3.30 Some of the audio recordings of noise made by the residents were analysed, and modulation metrics derived; the results presented show a relatively large sound pressure level difference of over 14 dB ΔL in and around the 160 Hz 1/3 octave band, although it must be presumed that this is a maximum difference as the sample durations and variation are not detailed. It is also noted that this sample represented the only AM WTN recording lasting longer than 1 minute from any of the 28 samples analysed; in all other cases any perceptible AM WTN lasted less than 10s.

3.3.31 The study was launched in response to concerns raised about WTN, and respondents were fully aware of the nature and intent of the investigation. As such there is a strong risk of selection bias in the results, which makes interpretation of the prevalence of AM annoyance from the complaints data potentially problematic. There is no detailed analysis presented of the complaints distribution, but it is noted that 95 complaints had been documented from 10 residents. Of these, 80% were reported in relation to the night-time or early morning. This suggests that, for those making complaints, these periods are especially critical.

3.3.32 There is interesting speculation in the paper on the possibility of short periods of AM being an 'attention trigger' that provides a pathway towards increased noise disturbance, rather than being highly disturbing in and of itself. This suggests a possible avenue of further research.

Noise characteristics of 'compliant' wind farms that adversely affect its neighbours (Large & Stigwood, 2014) [grey]

3.3.33 This is a discussion paper incorporating field data from 4 wind farm sites where complaints about noise have been recorded or made known to the authors. Details of the complaints themselves (e.g. status, frequency, distribution, time of day etc.) are not presented.

3.3.34 The study examines relatively short sampled periods of measurement data recorded at each site, and analyses the samples using a range of AM assessment metrics to compare the results.

3.3.35 A speculative discussion on nuances of AM WTN perception, based on an analogy with musical dynamics and expression, is presented as a set of possible psychoacoustic explanations for subjective responses.

3.3.36 All of the response evidence presented is anecdotal and un-scaled, and wider representativeness would not be reliable: non-acoustic factors contributing to complaints at the sites cannot be ruled out or the potential effects isolated (for example, attitude of the complainants, attitude of the site operators, history of planning and development of the sites, visual impacts, sensitisation due to the investigative work etc.). No causal relationship between the noise characteristics and complaints (as suggested by the authors) could be robustly established from the data.

3.3.37 The objective of the paper is really to raise a wide range of discussion points and questions about character assessment, rather than to derive an exposure-response relationship (while numerical AM values are quoted for the samples analysed, this is primarily with the aim of comparing demonstrable efficacy of different measures in quantifying AM, and showing high ratings, despite apparent compliance with national guidelines).

3.3.38 This study provides an interesting discussion with lots of pertinent questions raised but few answers given. It does raise the important point as to the likely success or otherwise of a penalty system aimed solely at controlling AM in isolation, rather than looking more broadly at combinations of characteristics, as well as the cumulative effects of intermittency, duration and changes in character.

Initial findings of the UK Cotton Farm Wind Farm long term community noise monitoring project (Stigwood, Stigwood, & Large, 2014) [grey]

3.3.39 This paper reports analysis of 10 months' field data measured near to a UK wind farm, with the intent of establishing prevalence of occurrence of AM, investigating the relationship with wind behaviour, and examination of different AM assessment metrics.

3.3.40 In reviewing the earlier work published by RUK (von Hünerbein, King, Piper, & Cand, 2013), the authors point out the potential problems with translating laboratory annoyance rating methods to the annoyance experienced by WTN-exposed populations, due to the contextual and stimulus differences (these issues have also been discussed in section 3.2).

3.3.41 There is very little analysis of subjective responses, although the authors note that the community have made complaints to the local planning authority concerning noise. A section of the paper is also dedicated to a description of an online software platform devised by the authors to allow members of the public to subjectively rate recordings made at the monitoring location.

Perception and effect of wind farm noise at two Victorian wind farms (Thorne, 2014) [grey]

3.3.42 This report was prepared at the request of residents living in the vicinity of a wind farm subject to complaints about WTN. The version reviewed comprises an update to the original 2012 publication.

3.3.43 The study investigated the possible relationship between adverse health effects and WTN exposure in the local population at two sites. Questionnaires were issued to 25 participants to enable self-reporting of a range of possible factors, including sleep disturbance, annoyance and sensitivity. The questionnaires included use of some recognised health / quality of life metrics.

3.3.44 The results show a very high proportion of self-reported sleep disturbance (over 90%), and annoyance (over 80%) attributed to WTN exposure. The report argues that adverse health effects due to WTN are marked by a range of acoustical thresholds, including:

- 32 dB $L_{Aeq,10min}$ outside a dwelling
- 22 dB $L_{Aeq,10min}$ inside a dwelling
- "*Unreasonable or excessive modulation*" in audible, regularly varying[26], WTN[27]: 4 dB AM depth (peak-trough) is 'unreasonable'; 6 dB AM depth is 'excessive'

3.3.45 The results reported suggest the participants feel strongly that their quality of life has worsened due to the presence of the wind farms. However, the suggestion that specific health effects are attributable directly to the wind farm noise exposure (and AM in particular) are not supported by the evidence presented.

3.3.46 There are details provided in the paper to demonstrate how the apparent health effects reported have been linked to the specific acoustic thresholds identified. The author notes that the report is in summary form, which may explain the lack of supporting analysis; it is also stated that cause and effect information was submitted during related planning hearings and a 2011 Australian Senate Inquiry, but is not presented in the paper. The Senate Inquiry concluded that there was insufficient rigorous research to establish whether adverse health effects were caused by WTN exposure (The Senate Community Affairs Reference Committee, 2011).

3.3.47 Despite the presence of a range of non-specific questions about noise within the questionnaire, which would in other situations typically be used to mask the intent of the survey, the context of the study (within planning hearing / inquiries) means that the respondents would be likely to have already been fully aware of the study objectives and hypotheses.

3.3.48 This is a cross-sectional field study conducted with a small sample size (25), no equivalent control group and within the context of a planning inquiry; wider applicability of the results is therefore limited.

Quantifying the character of wind farm noise (Hansen, Zajamšek, & Hansen, 2015) ***[grey]***

3.3.49 This paper analysed data obtained during a monitoring program carried out by the South Australia Environmental Protection Agency in response to noise complaints relating to Waterloo Wind Farm, the results and data from which are freely available online (South Australia Environmental Protection Agency, 2015).

3.3.50 Hansen et al. (2015) selected a sample of the diary entries completed by neighbouring residents and corresponding periods of the noise monitored at locations nearby. The diary entries, which included an unclearly-scaled subjective rating of "*strength of noise event*" (rated 1-4) together with descriptive words to qualify the nature of the sound (e.g. "*rumbling, thumping*") and confirmation of whether the turbines were turning at the time of the entry, were compared with a wide range of

[26] The criterion is defined as applying to WTN that exceeds the numerical AM thresholds for a total of 1 minute or more in a 10-minute period.
[27] Measured in terms of short-term L_{Aeq} or L_{pAF} using 100 to 125ms averaging.

possible AM assessment metrics to detect any relationship. There is no description of the briefing that residents may have received to gain an understanding of the intention of the noise strength rating. No agreement was observed for the subjective rating with the AM metrics, but better agreement was obtained by comparison with loudness[28]. A-weighted, C-weighted and G-weighted sound pressure levels were also presented but not mentioned in the analysis discussion.

3.3.51 The representativeness of this study is limited due to the likely selection bias, the relatively small sample (four respondents' diaries), and the very short duration of audio data analysed (a total of 50 minutes).

Measurements demonstrating mitigation of far-field AM from wind turbines (Cand & Bullmore, 2015b) [grey]

3.3.52 This study presents results from an investigation into remedial measures designed to reduce the occurrence of transient blade stall, believed to be the primary source mechanism in generating a high degree of AM.

3.3.53 Data from two different sites are included, both of which are reported as having been subject to AM WTN-related complaints, and a different mitigation strategy is examined at each, i) physical treatments directly on the blades, and ii) software modifications to reduce the angle of attack during the conditions (i.e. specific wind speed ranges) in which high AM had been associated with complaints. Measurements were conducted at multiple synchronous positions at both sites, including near and far field locations, over a period of months, although the datasets were reduced in both cases: at the blade-treated site to consider only data obtained during shutdown of un-treated turbines; at the modified-software site only periods known to have generated prominent AM were analysed, with matched post-mitigation measurement periods.

3.3.54 The results are presented in a different form for each site: at the blade-modified site, the prevalence of AM periods in which the measured modulation (quantified in terms of AM magnitude rating[29]) was above a defined threshold (set to ≥ 3 dB) were recorded as proportions of the total measurement dataset (10 hours pre-treatment, 23 hours post-treatment). It was shown that, over a similar wind speed range, the prevalence of AM with a magnitude above the threshold for more than 30s in a 10-minute period was around 50% prior to the treatment, reducing to slightly over 3% following the blade modifications.

3.3.55 For the modified-software site, the results are presented in terms of the AM magnitudes measured over the wind speed range for each condition. The analysis indicates a reduction in AM magnitude at the worst-case wind speed of around 0.5 dB on average, and 1 dB for the upper 68% confidence interval (CI). Further statistical analysis of these results to examine the results could lend greater support to the conclusions and establish the significance of the pre- and post-treatment differences.

3.3.56 In terms of changes in the subjective response, very little information is given beyond noting that for the modified-software site, complaints were understood to have subsided following implementation of the strategy. Another dimension to the study might have looked more closely at the subjective element, to establish the efficacy of the treatment from an exposure-response perspective. It is clear however that the focus of the experiment was aimed towards validating the suspected cause of increased AM severity at the same time as testing effective mitigation measures. The results suggest that relatively small reductions in AM of the order of a few dB (in terms of the magnitude metric used) may have an effect in reducing complaints (and by

[28] Evaluated according to the model proposed by Fastl and Zwicker (2007)
[29] The metric developed by the IOA AMWG specifically to quantify the AM component of WTN.

extension, annoyance), although further testing and analysis would be needed to investigate this fully.

DISCUSSION

3.3.57 The case-study research has value in highlighting the issue of AM in WTN, and provides persuasive supporting evidence, in the form of complaints or descriptions, that is an important factor in determining or exacerbating subjective annoyance responses. The research also points towards increased sensitivity to AM during quiet periods typically used for rest and relaxation, i.e. evening and night-time.

3.3.58 Case-study research has the drawback of limited wider applicability; in some cases the studies are carried out in response to complaints about WTN, and as such it is impossible to isolate effects caused by acoustic phenomena from the influence of non-acoustic factors that modify responses.

3.3.59 Recent work has highlighted the typical causes of increased AM from wind turbines, and the potential for methods of mitigation.

HUMAN RESPONSE TO NON-WIND-TURBINE AMPLITUDE-MODULATED NOISE EXPOSURE

The identification and subjective effect of amplitude modulation in diesel engine exhaust noise (Kantarelis & Walker, 1988) [black]

3.3.60 This study presented simulated diesel engine noise modulating at around 8 Hz with two different AM depths (5 and 13 dB) and was rated for subjective annoyance on a 10-point scale.

3.3.61 The authors suggest the results indicate an association between AM and annoyance for this type of noise, although information on the exposure and subject group is not reported, and there is no statistical analysis included to support the finding. The presented results appear to show a slight increase in rated annoyance for the greater modulation depth, but there is no unmodulated 'control' sound, and without an indication of the number of subjects and associated spread in the results it is difficult to have confidence in the conclusion. There is a clearly-observable relationship between increasing maximum level (L_{Amax}) and rated annoyance for both modulation depths.

Review Paper

3.3.62 A useful review of further material is provided by van den Berg (2011), covering the following papers.

Annoyance caused by constant-amplitude and amplitude-modulated sounds containing rumble (Bradley, 1994) [black]

3.3.63 A laboratory experiment examining subjective response to synthesised fluctuating noises designed to resemble HVAC[30] sources. A total of 9 subjects (age range 16-50) were asked to compare both modulated and un-modulated test sounds 'containing rumble' (i.e. with greater energy in the low frequencies) with a reference steady noise and adjust the test signals to be equally annoying with the reference. Two modulation depths and five modulation frequencies (in steps between 0.25 and 4 Hz) were used to modulate the low frequency content of the test signal;

[30] Heating, ventilation and air conditioning

although the overall AM depths of the final signals are not given, the L_{10}-L_{90} parameter[31] was shown to be around 3-5 dB over the 31.5 – 250 Hz octave bands.

3.3.64 On average, for the particular case of a 2 Hz modulation frequency, subjects attenuated the modulated test signal by an extra 4 dB when compared with the equivalent un-modulated test signal, both paired against the reference. Unfortunately there is virtually no information presented on the recruitment and briefing of the subjects, so their understanding and any contextualisation of equalising 'annoyance' is unknown.

The effect of fluctuations on the perception of low frequency sound (Moorhouse, Waddington, & Adams, 2007) [black]

3.3.65 This study, also later documented by Moorhouse et al. (2009) and Moorhouse et al. (2013) [black], was part of a Defra[32]-funded investigation into low frequency noise (LFN) disturbance and methods for assessing complaints.

3.3.66 A total of 18 subjects were recruited for the laboratory experiment, with an average age range of 32-62 (overall average 50), intentionally including 3 subjects self-reportedly highly sensitive to LFN. The results from the subjects were analysed both combined and separately in 3 groups divided according to both sensitivity and age. The briefing given to the subjects is detailed, and was based around the subject determining whether they felt they would find a presented sound acceptable if they heard it within their own home. This study also presented a night-time condition, switching the lights off and asking the subject to evaluate the sounds as if they were trying to get to sleep.

3.3.67 The stimuli presented included both real recordings and artificially-generated low frequency tonal signals. Subjects adjusted the level of the presented signal until deemed acceptable within the scenario context. The fluctuation in each signal was quantified using the percentile level difference L_{10}-L_{90}. The results indicated that the average acceptability thresholds were around 5 dB lower for fluctuating sounds with L_{10}-L_{90} values above 5 dB, when compared with those for steady sounds. Fluctuating sounds with L_{10}-L_{90} of around 4 dB had average thresholds of 1-4 dB lower than the steady sounds. The results were interpreted as evidence to support an assessment scheme for fluctuating LFN based on a 5 dB penalty value applied to sounds incorporating modulation exceeding 4 dB L_{10}-L_{90} (Moorhouse, Waddington, & Adams, 2013)[33]. A second criterion also required the noise under assessment to have a rate of change in fast-weighted[34] sound pressure level exceeding 10 dB/s.

3.3.68 The results are presented as averages without error bars, and there is limited statistical analysis presented to lend additional weight to the conclusions (this may be due the small sample size, which would limit the usefulness of significance testing). Nonetheless, it is informative to see a difference in sensitivity (i.e. in terms of mean acceptability thresholds) expressed by subjects for a simulated night-time situation, a contextual factor was not addressed in the category 1 laboratory studies reviewed in section 3.2. In this case the average threshold differences (i.e. between stimuli with or without modulation) for the tonal signals between day and night-time were shown to be in the region of 3-4 dB.

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[31] The difference between the 10th and 90th percentiles of the signal sound pressure level
[32] Department for Environment, Food and Rural Affairs (UK)
[33] This publication comprised an erratum slightly modifying the original conclusion stated in the related paper.
[34] Time-weighting used to evaluate root-mean-square sound pressure, fast = 0.125s.

A comparison of the temporal weighting of annoyance and loudness (Dittrich & Oberfeld, 2009) ***[black]***

3.3.69 This laboratory study presented 12 subjects (mostly students, aged 20-31 years) with artificial randomly fluctuating broadband noise. It was shown that the variation of the stimuli in terms of standard deviation σ had a significant effect on rated annoyance but not on estimation of loudness; paired stimuli with σ = 4 dB were judged more annoying than those with σ = 2 dB, despite having equal L_{eq}.

Annoyance caused by low frequency sounds: spectral and temporal effects (Vos, Houben, van der Ploeg, & Buikema, 2010b)

3.3.70 In this laboratory study, 32 subjects (half with mean age 26, and half with mean age 53) were presented with a range of AM stimuli, including a 31.5 Hz tone, 31.5 Hz 1/3-octave bandpass filtered pink noise and road traffic-like filtered broadband noise, all modulated at 1 Hz frequency. AM depths of 6 and 12 dB were used for the broadband noise, with an additional depth of 18 dB used for the tones and 1/3-octave band noise.

3.3.71 The results for the tone signals showed a significant effect of both loudness and AM depth on rated annoyance. The stimuli were presented at 10, 25 and 40 phon loudness; for the 25 and 40 phon tones, the modulated versions were given significantly higher mean annoyance ratings compared with the unmodulated, with rated annoyance apparently increasing up to 12dB depth; at 18 dB AM depth there was no significant increase, suggesting subjects could not distinguish between 12 and 18 dB AM depth.

3.3.72 The results for 1/3-octave band noise showed no relationship with AM.

3.3.73 The results for the AM broadband noise again showed a significant increase in rated annoyance for modulated versus unmodulated, but there was no significant difference between the 6 and 12 dB AM depths used, again suggesting subjects had difficulty making a distinction once AM was detected in the signal.

3.3.74 In another experiment the subjects were played sound recordings of fluctuating aircraft and road traffic noise, which were compared with steady noise modified to have equal spectral content to the modulating sounds. The results for the sound recordings showed no significant effect due to fluctuation, but a strong relationship between overall time-average level and rated annoyance.

3.3.75 The author suggests that the results may indicate an equivalent annoyance steady noise level difference in the region of around 10 dB for the AM depths tested (i.e. ≥ 6 dB ΔL). This value appears to have been obtained by comparing the results from the artificial signal tests with those from the sound recordings.

Effects of sound on people (van den Berg F. , 2011) [grey]

3.3.76 In summarising the above studies, van den Berg concludes that the laboratory work indicates an association of increasing annoyance with AM broadband noises compared with the steady equivalent, but that the effect on annoyance may not continue to increase with greater modulation depth. The equivalent annoyance level difference (i.e. steady vs. modulating noise) is suggested as at least 3 dB.

Other Papers

3.3.77 Further studies identified in the literature search include the following publications.

Sound characteristics in low frequency noise and their relevance for the perception of pleasantness (Bengtsson, Persson Waye, & Kjellberg, 2004) [black]

3.3.78 This study was aimed at investigating subjective response to HVAC-like noise within the context of an occupational environment. 30 subjects were presented with an artificial stimulus combining recorded HVAC sound with filtered noise and modulating tones.

3.3.79 The subjects generally showed a preference for noise modulating at frequencies as far from the 2-6 Hz interval as possible within the 0.1-10 Hz range used, essentially confirming findings from earlier studies, including those reported by Fastl & Zwicker (2007). There was no investigation of the effect of altering modulation depth.

Annoyance of time-varying road traffic noise (Kaczmarek & Preis, 2010) [black]

3.3.80 This laboratory experiment prepared four auditory scenarios by arranging recorded road traffic passes into different temporal configurations, controlling the total number and type of vehicles within each structure. Nineteen subjects (aged 19-24) rated annoyance for 3 variations of each of the scenarios using an 11-point scale, and psychoacoustic parameters for each stimulus were also calculated.

3.3.81 The results showed that rated annoyance was significantly correlated with fluctuation strength, loudness and roughness. There were significant differences in the rated annoyance between the different temporal structures / scenarios. However, the differences were relatively small, in total (highest to lowest) spanning around 1 interval on the annoyance scale, based on averaged results. The scenario with highest annoyance ratings was composed from regularly spaced car passes at around 0.2 Hz (i.e. 5 second gaps between events), whereas the least annoying comprised discrete groups of 24 passes at around 2 Hz.

Spectral and modulation indices for annoyance-relevant features of urban road single-vehicle pass-by noises (Klein, Marquis-Favre, & Weber, 2015) [black]

3.3.82 This study used experimental results from a listening test with 14 subjects to derive proposed new measures for subjective characteristics, including the temporal description ‘sputtering’. Sputtering was found to have a correlation with the fluctuation strength metric, however this type of character is typically found in engine-like noises and unlikely to have wider applicability to WTN. There was no separate examination of modulation depths or frequency.

DISCUSSION

3.3.83 Most of the research in this section appears to support the idea that modulated noises are generally considered less pleasant than a steady equivalent at the same energy-average level. The metrics used to quantify modulation and the stimuli types vary considerably between studies, but broadly-speaking this difference in perception might be translatable to a level difference somewhere in the region of around 3-4 dB on average. It is noted that the stimuli used in the studies varied and was not necessarily WTN-like; in one study using broadband noises, a greater difference of up to 10 dB was proposed, though this conjecture was based on a comparison between different stimulus types.

3.3.84 There is some evidence to indicate that sensitivity to a modulating noise is greater in the context of a ‘getting to sleep’ situation than in a general ‘relaxation’ setting.

HUMAN RESPONSE TO WIND TURBINE NOISE EXPOSURE (HEALTH EFFECTS)

3.3.85 The literature search highlighted at least 30 separate papers that could be included in this category using the relatively specific search criteria defined in section 2. Since the vast majority of these studies were not deemed directly relevant to the aims of the project (as they did not attempt to quantify the AM component in the exposure), only a relatively small proportion have been reviewed, with the emphasis firmly on recent systematic reviews of the existing literature and large-scale epidemiological field studies aimed at establishing the likelihood of relationships between WTN and a range of possible health effects. Although somewhat relevant (since WTN inherently involves a degree of AM), this section is not intended to be an exhaustive review of individual studies into general WTN (i.e. where AM is not quantified) and health effects. Instead, a summary set of conclusions are presented based on interpretation of the main study outcomes and the weight of the evidence.

3.3.86 The following studies have been considered:

- ***Health impact of wind farms*** (Kurpas, Mroczek, Karakiewicz, Kassolik, & Andrzejewski, 2013) [black]
- ***Systematic review of the human health effects of wind farms*** (Merlin, Newton, Ellery, Milverton, & Farah, 2013) [grey]
- ***Wind turbine noise and health study – summary of results*** (Health Canada, 2014a) [grey], including supporting information from[35]:
  - ***Self-reported and objectively measured health indicators among a sample of Canadians living within the vicinity of industrial wind turbines: social survey and sound level modelling methodology*** (Michaud, et al., 2013) [grey]
  - ***Health impacts and exposure to sound from wind turbines: updated research design and sound exposure assessment*** (Health Canada, 2014b) [grey]
- ***Wind turbines and health: a critical review of the scientific literature*** (McCunney, Mundt, Colby, Dobie, Kaliski, & Blais, 2014) [black]
- ***Health effects related to wind turbine noise exposure: a systematic review*** (Schmidt & Klokker, 2014) [black]
- ***Wind turbines and human health*** (Knopper, et al., 2014) [black]
- ***Social survey on wind turbine noise in Japan*** (Kuwano, Yano, Kageyama, Sueoka, & Tachibana, 2014) [black]
- ***Wind turbine amplitude modulation & planning control study – Work Package 3.2: Excessive amplitude modulation, wind turbine noise, sleep and health*** (Hanning, 2015) [grey]
- ***Understanding the evidence: wind turbine noise*** (Council of Canadian Academies, 2015) [grey]
- ***The effect of wind turbine noise on sleep and quality of life: a systematic review and meta-analysis of observational studies*** (Onakpoya, O'Sullivan, Thompson, & Heneghan, 2015) [black]

3.3.87 On review of these publications, it is clear that the study of human health effects (such as stress, anxiety, sleep disturbance, tinnitus, psychological and mental health) potentially caused by WTN exposure is a developing area of research, and there remain differences of opinion in the

[35] Subsequent to completion of the literature review component of this research, the final results of this study have been published in peer reviewed literature, listed in Annex 3. The published results confirm the earlier preliminary findings, i.e. the study found no significant association between the reported WTN levels (up to 46 dB(A) outdoors) and self-reported or objective measures of sleep disturbance.

literature. The following conclusions are considered by the internal research team to represent the current state of knowledge:

- There is strong evidence to show that exposure to WTN can cause increased annoyance amongst exposed populations.
- There is evidence to suggest that exposure to WTN is associated with increased risk of sleep disturbance for external WTN levels exceeding 40 dB(A). Much of the research indicates that where sleep disturbance is identified, this is more closely associated with annoyance than with levels of WTN exposure. For many people within exposed populations, it therefore seems likely that sleep disturbance may occur as a result of increased annoyance due to the presence of wind turbines, and at least part of this annoyance can be explained by the noise component (other factors are also important as discussed below). In other words, sleep disturbance could be an indirect effect of WTN exposure in cases when an individual feels increased annoyance, but direct causality cannot currently be robustly and consistently demonstrated.
- Similarly to sleep disturbance, there is limited evidence to indicate that increased stress or anxiety are associated with WTN exposure, and any effect may also be indirectly due to heightened annoyance responses rather than as a direct result of exposure.
- There is a body of evidence, generally anecdotal, suggesting a range of other possible (adverse) health effects and quality of life impacts that some people attribute to WTN exposure. These cases are not currently supported by the weight of the epidemiological evidence. It is acknowledged that prolonged exposure to levels of environmental noise has been linked with long-term health issues (WHO, 2011), but such effects have so far not been consistently or robustly demonstrated in the case of wind farm noise. Again, this could be explained by the small numbers of exposed persons and the relatively low levels of noise emitted, as well as further subjective modifying factors discussed below.
- A range of non-acoustic factors have been identified as potentially contributing to or modifying the annoyance that some people feel and attribute specifically to noise from wind farms. These include:
  - Specific visual impacts (shadow flicker, lights, rotation);
  - General attitude to wind farm appearance in the landscape;
  - Direct economic benefits from wind energy generation or specific wind turbine installations;
  - General attitudes to wind energy generation;
  - Type of area (urban / rural);
  - Exposure to positive / negative media coverage of wind energy and wind farm noise, and the activities of campaign groups; and
  - Sensitivity to noise and possible sensitisation due to awareness of wind farm noise research.

DISCUSSION

3.3.88 On the basis of this review, it is considered that at the current time there is insufficient evidence to indicate that the AM component in WTN at typical exposure levels directly causes any significant adverse effects beyond increased annoyance. However, it is noted that virtually none of the reviews of health effect studies explicitly address quantified AM exposure within the noise, and almost all solely consider time-averaged levels in their findings.

3.3.89 Since it is generally accepted that environmental noise can cause sleep disturbance (WHO, 2009), it seems likely that the apparent difficulty in consistently demonstrating a direct causal relationship between WTN and sleep disturbance in the field might be partly explained by the relatively low levels of WTN compared with other forms of environmental noise to which people are quite often exposed. Nonetheless, it should be noted from the research already discussed that increased distinctiveness of WTN is attributable (in part) to AM, and so it is not an unreasonable assumption that in the cases where people feel annoyed, and AM increases their annoyance, any indirect effects that may be associated with this annoyance, such as sleep disturbance or stress, could be exacerbated. In cases where people are situated in close enough proximity to hear WTN when trying to sleep, it is also possible that greater AM will increase the direct risk of disruption to sleep, in particular to the period of 'getting to sleep', due to increased awareness of and focus toward the noise; this suggestion seems to be somewhat supported by anecdotal descriptions, however more research would be needed to investigate this fully.

3.3.90 The publication by Hanning (2015) is notable here mainly as it appears to be somewhat in opposition to the findings of many of the above studies and reviews. The paper has also been reviewed by the independent external reviewers and is discussed below in sections 3.3.136 to 3.3.138. It is noted that the paper highlights supporting evidence from the case-study conducted by Thorne (2014), which has also been reviewed in the relevant section herein; it is considered there is little robust analysis in the case-study that upholds the specific findings claimed and subsequently quoted by Hanning (2015). Two other primary study references used to establish the author's conclusions stem from research reported by Nissenbaum et al. (2012) [black] and Krogh et al. (2011) [black]. Concerns about the potential for significant risk of bias introduction in the designs of these studies and a questionable approach to the results analyses and subsequent conclusions have been raised by McCunney et al. (2014) and Ollson et al. (2013) [grey].

3.3.91 The great difficulty of isolating potential confounding factors in the field studies is clear: many of the review papers highlight sources of potential bias that are not considered to be adequately controlled in the primary research. There is also a significant drawback in that the studies are cross-sectional, and so it is not possible to assess the existence of health issues prior to exposure to WTN, and consequently causality. Moreover, it is not possible to assess the specific effects, including annoyance, which could be attributed to a change in the local noise environment as opposed to an on-going or 'steady state' situation. The 'change' situation is arguably more immediately relevant in a 'complaints' context, since the initial response would be to the introduction of a new wind energy installation or, alternatively, expansion of an existing one. Research based on a steady state situation may under- or overestimate the response to WTN in general, and to AM in particular.

3.3.92 It is debatable as to whether further observational studies of a cross-sectional design will add value to the existing knowledge base, and may serve only to further cloud the issue due to the difficulties in isolating confounding factors. Future field studies should consider the potential for a longitudinal design, with effective masking and control groups in place to minimise some of the risks of bias. Well-designed studies considering quantified AM exposure-response would be valuable. In particular, objective measures of health, such as those used in the Health Canada (2014a) research (including sleep actimetry[36], stress hormone and blood pressure measurements), could serve to verify data obtained from typical self-reporting methods such as questionnaires and interviews.

[36] A non-invasive method of monitoring human rest/activity cycles in medical studies

FURTHER RELEVANT STUDIES

Audible amplitude modulation - results of field measurements and investigations compared to psychoacoustical assessment and theoretical research (Stigwood, Large, & Stigwood, 2013) [grey]

3.3.93 This study is a discussion document providing background, features, possible causes and contributing factors of AM WTN. The discussion draws on examples derived from measurements at 13 wind farm sites in the UK.

3.3.94 The main conclusions are that AM propagation is affected by meteorology and air profiles, WTN AM depth at some sites reaches 6-10 dB under some conditions, measurement of AM WTN is problematic and unlikely to be successfully conducted by regulators, and that psychological aspects relating to specific characteristics of the sound may play an important role in subjective responses.

3.3.95 This paper presents a very thorough analysis of a limited set of measurement data. It makes the useful observation that the atmospheric conditions that may contribute to higher risk of increased AM (such as stable atmospheres, temperature inversions, etc.) are more likely to occur during the evening, night or early morning.

WIND FARM PUBLICATIONS PRODUCED BY AN 'INDEPENDENT NOISE WORKING GROUP'

3.3.96 This section outlines a review of a recently-published portfolio of documents reporting on aspects of AM WTN that are relevant to this research. The aims and objectives of the authors are outlined, followed by reviews of the individual reports. It is understood that these papers have been presented to a number of Government departments, and DECC made a specific request to the research team to ensure that they were included in the formal review.

3.3.97 The documents discussed in this section were examined by the independent external reviewers. NB. All review commentary in this section is directly quoted from the review summaries received, as indicated by text in blue font. Any text added by the internal research team is indicated [in square brackets].

3.3.98 It was not possible within the scope limitations of the review to exhaustively check all source references and analyses made within these publications. Consequently the validity and accuracy of interpretative review and analysis of reference literature contained therein has necessarily been taken at face value.

Wind Turbine Amplitude Modulation & Planning Control Study – Terms of Reference (Independent Noise Working Group, 2015) [grey]

SCOPE

3.3.99 This document defines the Independent Noise Working Group (INWG) terms of reference (TOR), taking a holistic view of the current problem with wind turbine AM noise.

3.3.100 It is in response to real concerns about the strategy being implemented by the wind power industry via the IOA.

3.3.101 It was felt that the IOA AM study and report would be narrowly defined with limited scope to address the real problems of AM noise at both existing and new wind turbine sites.

3.3.102 The Objectives of the INWG were given as:

- To protect communities and wind turbine neighbours from amplitude modulation noise.
- This protection is urgently needed by communities close to existing wind turbines, wind turbines where planning consent has been given but the turbines not yet constructed and wind turbines being proposed through the planning system.

3.3.103 The document sets out the membership of a Steering committee which will define the TOR and a set of four deliverables:

- Report providing a rationale for introducing effective controls
- Workable and tested AM planning control or condition for new turbine schemes
- Effective method to control AM noise from turbines where planning consent has already been given
- Produce evidence to demonstrate the effectiveness or otherwise of the AM planning condition being proposed by the IOA NWG

3.3.104 The document sets out plans for wider consultation.

3.3.105 The TOR notes that the report and recommendations will be subject to a thorough review process plus an EHO panel to test the proposed AM control method.

3.3.106 The TOR set out the various Work packages

- WP1: Define and quantify AM
- WP2: Literature and evidence review
- WP3: Effects of AM
- WP4: Den Brook
- WP5: Draft AM planning condition
- WP6: Control of AM noise from existing wind turbines
- WP7: Test the IOA NWG proposed AM planning condition
- WP8: Review the IOA AM study and methodology
- WP9: The Cotton Farm monitoring experience

QUALITY, ROBUSTNESS, RELEVANCE

3.3.107 The TOR document itself, being reviewed here, talks of the Steering Group developing the TOR, [which raises the question as to whether] the TOR were changed during the course of the project.

3.3.108 The document is particularly relevant to the issue of what constitutes adequate planning conditions and effective control measures.

Wind turbine amplitude modulation & planning control study – Work Package 1: The fundamentals of amplitude modulation of wind turbine noise (Yelland, 2015) [grey]

SCOPE

3.3.109 This paper explores aspects of AM and EAM[37] relating to their definition, causes and measurement.

3.3.110 [The] main chapter headings are:

- *The Characteristics of AM and EAM*
- *Causes of AM – wind shear, transient stall pressure pulses, vortex shedding, blade/tower interaction etc.*
- *The RUK*[38] *report*
- *Measurement problems*

QUALITY, ROBUSTNESS, RELEVANCE:

3.3.111 Much of the section on Conclusions does not actually relate to the preceding content but includes unrelated comment on such issues as [in the INWG author's view] the increasing inadequacy of the ETSU document and the nocebo[39] effects. There are also alarmist comments on potential health hazards and anecdotal claims about various serious effects on animal life, e.g. aborted mink.

3.3.112 The report is very strong, clear and objective on the technicalities of the characteristics and causes of AM. However, when it comes to comments on the RUK report, the tone changes completely. [The INWG author of the paper] starts by impugning the motives of the authors [of the RUK report], the links with industry, lack of peer review etc. He states that the report is "*technically unsound and highly misleading*".

3.3.113 An example of the tone used:

> "*The claim of 'peer reviews' by an author's colleagues who rely on the same customer base and belong to the same professional institution as the author is worthless and serves only to demean the author and the institution.*"

Wind turbine amplitude modulation & planning control study – Work Package 2.1: Review of reference literature (Cox, 2015) [grey]

SCOPE

3.3.114 This work package presents the results of a review of the literature WTN. Over 160 documents were reviewed by the INWG for this study of AM.

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[37] Excessive/excess/enhanced amplitude modulation
[38] RenewableUK – renewable energy trade association (UK)
[39] Describes a response that is caused by a subject's expectation of adverse effects from a stimulus - in this case, exposure to wind farm noise

3.3.115 The report reviews the literature relevant to WTN AM and consolidates the reference material considered by the INWG in the various work packages (WP) making up the study into AM.

3.3.116 Objectives are given as:

- *Review the evolution of knowledge regarding WTN and AM;*
- *Collate the reference literature relevant to this INWG study of WTN AM and produce a common reference list for the study work packages;*
- *Provide a short description of each reference document*

3.3.117 The main chapter headings (which give an indication of the 'tone' of the report) are:

- *Executive Summary*
- *Introduction*
- *Knowledge Evolution*
- *The Case regarding Low Frequency Noise*
- *The Case Against ETSU*

CONCLUSIONS FROM THE PAPER

3.3.118 This review of evidence spanning over 30 years shows a clear evolution of knowledge relating to the science behind WTN and its effects on people. Starting with the NASA research conducted during the 1980s through to the NIA[40] inquiry report of March 2015 and beyond, many of the key scientific aspects are now well understood and well defined.

3.3.119 The most important conclusion from this evidence is that [in the INWG author's view] the official UK WTN guidance, ETSU, is totally unfit for purpose and is failing to protect against the effects of EAM noise. Despite it being updated and acquiring an IoA-developed Good Practice Guide, it was [in the INWG author's view] developed using evidence relevant only to small turbines far removed from the 80m hub height devices being deployed almost twenty years later, and does not reflect the more recent science.

3.3.120 [Original INWG author's description] *Throughout this period since 1997 the wind industry, aided by its acoustic, political and legal consultants has sought to hide the true science behind EAM in WTN and its effects on people though a concerted strategy of obfuscation and political interference. This has been aided by compliant government officials who have been focused on removing barriers to the deployment of wind power generating capacity and by the wind industry effectively taking control of the Institute of Acoustics (IOA). The IOA Good Practice Guide to the application of ETSU subsequently approved by government is an example of how commercial interests and political lobbying have triumphed against science and wind turbine neighbours. At no point does it tackle any of the issues identified by the research into EAM that we have reviewed above. Complaints regarding wind turbine noise currently classified as AM or EAM or OAM[41] or 'greater than expected AM' by the wind industry is an obfuscation of the true nature of*

[40] Northern Ireland Assembly
[41] 'Other' amplitude modulation, another description for AM outside the expected norm.

the problem. As a result, all efforts to date by third parties to have the ETSU noise guidelines revised or replaced with a science-based alternative have been successfully resisted.

QUALITY, ROBUSTNESS, RELEVANCE

3.3.121 The conclusions listed above are not listed as overall conclusions of the report. They come at the end of section 3 on knowledge evolution, which is a discursive and somewhat rambling account of 30 years of research. AM features highly in this account in a rather unstructured way. There are no helpful conclusions on AM itself. Other main parts deal with 'LFN' and the 'Case against ETSU'.

3.3.122 Much of the rest of the report is taken up with extensive summaries of literature.

Wind turbine amplitude modulation & planning control study – Work Package 2.2: AM Evidence Review (Large, 2015) [grey]

SCOPE

3.3.123 This work package deals only with audible EAM. It looks primarily at measurements of AM in support of its existence and prevalence. It looks secondly at reports of AM, which is a limitation of this review as it relies on anecdotal evidence.

3.3.124 This work package is not intended to be a discursive document but simply as a collation of evidence with a brief resume of the AM noted in the relevant study or research project.

CONCLUSIONS OF THE PAPER

3.3.125 [Original INWG author's description] *There exists an international history of evidence that documents the presence and regular occurrence of AM. Empirical data and subjective reports demonstrate that the manifestation of AM and the presence of AM within wind farm noise are effectively linked to increased annoyance. [This review] of AM research provides only a summary of documents and measurements from a single UK consultancy and open-access papers. Access to papers published in subscription-only journals or to the resources available to larger consultancies can only be expected to increase documented cases of AM and provide further evidence supporting the prevalence of AM.*

QUALITY, ROBUSTNESS, RELEVANCE

3.3.126 The title is misleading in that the evidence is a 'mish-mash' of reported complaints, comments on research papers, plus objective measurement data assessed as constituting AM.

3.3.127 The papers included some of those being considered by [the current study on behalf of DECC] such as Lee et al. (2009). However, no systematic assessment is made.

3.3.128 Appendix A [in the paper] gives a table of more than 70 sites where complaints were noted. This seems unrelated to the main text. No documentary evidence is provided about the form of complaint, e.g. written, telephone etc.

Wind turbine amplitude modulation & planning control study – Work Package 3.1: Study of noise and amplitude modulation complaints received by local planning authorities in England (Sherman, 2015) [grey]

SCOPE

3.3.129 [Original INWG author's description] *This study uses survey data to provide insights into the current views of involved English Local Planning Authority (LPA) professionals on how to prevent, control and mitigate industrial wind turbine noise including the phenomenon of excess amplitude modulation (EAM) that gives rise to most complaints. The three questions asked were:*

- *Have you received noise complaints?*
- *Have you received AM complaints? And*
- *If yes, how do you deal with them?*

CONCLUSIONS FROM THE PAPER

3.3.130 [Paraphrased from the INWG author's description] In England, 54 LPAs from 203 responses report having received complaints about noise from industrial wind turbines. Of these 54 LPAs, 17 report having also investigated complaints about EAM. There is a high level of awareness amongst LPAs of EAM, but no consistent approach to complaints. 'Noise only' complaints are generally resolved but most 'AM related' complaints remain unresolved and there is no working solution to the problem. EAM is more common than suggested by government policy. Compliance with ETSU does not correspond with likelihood of AM complaints. EAM nuisance is a 'noise character' not a 'noise level' issue. Guidance is needed on detecting and remedying EAM.

QUALITY, ROBUSTNESS, RELEVANCE

3.3.131 A number of inherent limitations of the study are acknowledged by the author – including that the overall number of noise complaints about WTN or EAM cannot be accurately established. In addition, the survey was introduced via a letter from Christopher Heaton-Harris MP that may have influenced the number and nature of LPA responses: 203 LPAs responded from 265 "*relevant*" LPAs (i.e. deemed likely to have experience of turbines by the authors) within an overall total of 423 LPAs in England. This is an unusually high response rate for a survey of this type. [Responses were based on] only three simple questions. [There are] some inherent limitations to the methodology. The author has relied upon the fuller responses received from a subsample of respondents to produce the discussion.

3.3.132 The statement in 1.1 of the Executive Summary that EAM "*gives rise to most complaints*" is a little misleading because, for example, the total number of complaints cannot be accurately established; the complaints information may be skewed by responses from one or two LPAs; and only 17/54 of those LPAs reporting complaints specifically said they were about AM. However, the author may be drawing on additional information supplied by LPAs to support this statement.

3.3.133 There is no time-frame mentioned in the survey questions, so, the numbers of reported complaints should be regarded as all-time totals and trends over time cannot be reliably ascertained.

3.3.134 There is no attempt to provide context by comparing the reported numbers of complaints about WTN with the total number of consented turbines, nor with the reported numbers of noise complaints about other sources that are received by LPAs,in particular by Environmental Health Practitioners (EHPs).

3.3.135 There is no detailed analysis of why only 4 Noise Abatement Notices were "*considered or served*". A constructive suggestion from one LPA that 'Energy Generation' should become a specific Land Use Category to facilitate a more systematic consideration of wind farms (and solar farms) in the planning system may be worth examining as part of the wider aspects of [the current study on behalf of DECC]. The analysis lacks wider context.

Wind turbine amplitude modulation & planning control study – Work Package 3.2: Excessive amplitude modulation, wind turbine noise, sleep and health (Hanning, 2015) [grey]

SCOPE

3.3.136 Relevant aspect of [the] review: review of effects of EAM on people living close to wind turbines in terms of annoyance, sleep and health effects. In fact [there is] not a lot on AM in the report.

CONCLUSIONS FROM THE PAPER

3.3.137 [As presented]

- Current setback distances for wind turbines recommended by ETSU are not safe for health.
- Reports that wind turbine noise is more annoying than aircraft, road and rail noise, controlling for intensity.
- Disputes that WTN is masked by background noise.
- Suggests that there are effects of low frequency noise on health.
- AM [is deemed] more annoying than unmodulated WTN. [The INWG author] suggests that 2dB AM depth is negligible, 4dB is unreasonable and 6dB is excessive.

QUALITY, ROBUSTNESS, RELEVANCE

3.3.138 A selective review of peer-reviewed literature plus internet-based reports and anecdote. The literature review is not systematic and the interpretation and conclusions are selective. There is little consistent evaluation of the different strengths of the evidence although some studies are pointed out as being uncontrolled. [There is] not a lot on AM in the report.

Wind turbine amplitude modulation & planning control study – Work Package 4: Den Brook (Hulme, 2015) [grey]

SCOPE

3.3.139 To document legal, planning and technical aspects surrounding the Den Brook (North Tawton, West Devon) planning conditions[42]. Den Brook Judicial Review Group (DBJRG) established to ensure acoustic impacts from proposed wind turbines were properly "*conditioned and controlled*" and to represent the interests of local residents. Work package 4 describes the Den Brook timeline where it relates to amplitude modulation.

3.3.140 This paper presents the process of agreeing the conditions for AM in wind farm operations at Den Brook. Inevitably it presents the case from one side.

CONCLUSIONS FROM THE PAPER

3.3.141 [According to the INWG author] The EAM conditions imposed [at Den Brook] seem unclear. Suggestion that conditions might be unenforceable due to false positive background noise. The condition 20 methodology alone cannot reliably distinguish periods of data that do/not contain AM.

QUALITY, ROBUSTNESS, RELEVANCE

3.3.142 The paper outlines the disputes between the developer, the planning authorities and courts and the DBJRG. Technical details on noise are relatively limited. [According to the INWG author] Initial acoustic assessments by the developers were "*found to be flawed*" so the initial planning permission was quashed. The developer then submitted a proposal for substantially weakening the noise conditions; examination on behalf of DBJRG found this to be flawed too. The developer then devised a written scheme. However, precautions taken within this scheme (stage 4c) to filter out "*apparently invalid complaints*" revealed "*substantial discrepancies*" – meaning that EAM noise would be "*significantly and materially understated*". In further meetings it was conceded that EAM is not a rare occurrence. Following this DBJRG plan to carry out 24/7 noise monitoring.

3.3.143 This paper presents the process of agreeing the conditions for AM in wind farm operations at Den Brook. Inevitably it presents the case from one side. The process as reported here is conflictual and does not show parties in a good light. It is also clear that the issues generate high levels of emotion.

[42] A number of references are made to the "Denbrook" AM condition in various documents. It should be noted there is: a) the AM condition as originally applied at the first Inquiry (referred to as the 'original'); b) the AM condition as amended through the course of various legal challenges; and, c) the AM condition as it currently stands at the time of writing (referred to as the 'final') following a recent amendment by the applicant and subsequent legal challenge.

Wind turbine amplitude modulation & planning control study – Work Package 5: Towards a draft AM condition (Large, Stigwood, & Bingham, 2015) [grey]

SCOPE

3.3.144 [INWG author's description] *Four main methods for assessing or limiting EAM have been critically examined in this work package. These methods are representative of the range of assessment / control methods currently proposed for EAM. Each method was tested with real world data from six different sites ranging from smaller single turbines to large wind farm developments. The methods tested were the RenewableUK template planning condition, a methodology proposed by RES[43] for the Den Brook case, the original Den Brook EAM condition and the Japanese DAM[44] methodology. In addition BS4142:2014 and BS4142:1997 were tested with data from two of the six sites.*

CONCLUSIONS FROM THE PAPER

3.3.145 [INWG author's description] *This work package shows that existing methods of controlling and assessing AM can be successfully modified and implemented to provide a prescriptive and unified assessment process for EAM. Where wind farm noise level and wind farm noise character require simultaneous assessment the use of BS4142:2014 is recommended. The difficulty of rating EAM for frequency of occurrence and duration in the absence of research looking at long term impact of EAM and subjective response is acknowledged.*

3.3.146 It is concluded that "*assessment of the extent of impact should remain the responsibility of those assessing and enforcing impact*".

3.3.147 [Original INWG author's description] *There are several different methodologies for deriving an AM value but two main differences in how this relates to a control for AM. Firstly the AM value can be used to derive a penalty that ultimately influences the overall noise limit. Thus, AM is controlled by way of lowering the noise level or noise exposure level. Examples include the RenewableUK method. Secondly the AM value is used to judge whether or not AM is acceptable. A higher AM value indicates that AM is not acceptable and that the noise must be mitigated, the lower the value the more likely it will be considered reasonable. Thus the AM value is treated as a trigger point for mitigation measures. Examples include the Den Brook condition. BS4142 provides a hybrid methodology where a penalty is derived to acknowledge intrusive character features and applied to the overall noise level, but importantly this is then compared to the background sound level rather than a threshold noise limit. This latter method has the benefit of adding context to the assessment, both in terms of context of the noise within a specific environment and a human / subjective context.*

QUALITY, ROBUSTNESS, RELEVANCE

3.3.148 First impression is that this is a thorough and balanced review. It contains relevant detail on the derivation of suitable planning conditions and any wider approach to control the impact of AM in the planning system.

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[43] Renewable Energy Systems (developer of the Den Brook Wind Farm)
[44] Refers to the AM depth metric D_{AM}, discussed in section 3.2

3.3.149 The report predates the recommendations of the IOA AMWG[45] for the IOA preferred AM indicator but it uses an approach to compare the available AM indicators that addresses the need for such indicators to go beyond the (acoustic) identification and quantification of AM and to relate to the (human) impact of the noise in a way that will work robustly and fairly in a wider (planning and complaints assessment) context.

3.3.150 The report contains a brief but useful discussion of how the impacts of other sources of noise with character are currently assessed, including judgements of acceptability.

3.3.151 The report contains a useful discussion of the Government's six [tests] for planning conditions with a focus on WTN and a further six objectives that the authors consider desirable.

3.3.152 The need for the chosen AM indicator to relate to the assessment of impact is highlighted and the report provides a logical process diagram to assist with the derivation of a suitable AM planning condition.

3.3.153 The various reviewed AM indicator methodologies are grouped into one of four categories in a useful table that highlights the current differences in approach:

a) Application of a penalty to overall noise limit.
b) Trigger value.
c) Derivation of AM indicator only (no application to impact assessment).
d) Use of context/human judgement.

3.3.154 The report finds that several of the available methodologies work to some extent and could be applied, with some adaptions, to produce a workable method for assessing and controlling EAM.

3.3.155 There is detailed discussion about the strengths and weaknesses of the different methods, including a favourable appraisal of a BS4142:2014 type of approach to the control of wind farm noise with character.

3.3.156 The following quotation is relevant:

> "*There is currently little knowledge or understanding of how features such as frequency and duration, context with background sound environment and time of occurrence specifically impact on the perception of EAM. Based on experience gained from impact of other noise sources it is expected that the more frequent and long lasting the EAM the more intrusive. Evidence suggests that those impacted by noise with character do not habituate to the noise but conversely become sensitised.*"

3.3.157 The discussion concerning the absence of a clear dose-response relationship is particularly pertinent:

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[45] Amplitude modulation working group, formed from membership of the IOA and the Chartered Institute of Environmental Health at the behest of Government to investigate the formulation of a metric for quantification of AM WTN.

"*However, it is common for all noise with character that the more periods of intrusion, the longer the noise occurs, the more noise penetrates dwellings and cannot be escaped, the more noise sensitive periods are effected* [sic] *(i.e. sleep vs. labour or rest and relaxation), then the greater or more extreme the impact will be. It is suggested that in the absence of any clear dose response relationship assessment of these aspects remains addressed through subjective, professional judgement and on the basis that intrusion of more sensitive activities and areas of a dwelling should be prevented.*"

3.3.158 The report recommends that two separate assessment/enforcement methods for EAM should be used. Where the noise from a wind farm is steady, continuous and anonymous ETSU-R-97 could continue to be used for assessment at the planning stage and for compliance testing. Where wind farm noise complaints indicate a variety of impacts including noise level, noise character, and/or tonality then BS4142:2014 can be used as a stand-alone assessment independent of any other assessment. It is suggested that the rating noise level of the wind farm/wind turbine noise should not exceed +10dB above the background sound level. There is no detailed analysis of the implications of this suggestion, in particular whether or not the adoption of such a criterion would have an undue effect on the day to day operation of wind farms.

Wind turbine amplitude modulation & planning control study – Work Package 6.1 (inc. 6.1a Supplementary Paper): Legal issues: the control of excessive amplitude modulation from wind turbines (Cowen, 2015) [grey]

SCOPE

3.3.159 [INWG author's description] *The Objectives of this Work Package are:*

- *Objective 1 – To assess the legality of the Den Brook Condition relating to EAM following the judgement of the Court of Appeal;*
- *Objective 2 – To assess the legal appropriateness of other remedies such as Statutory and Private Nuisance that have been recommended since that judgement or may be available to persons affected by EAM;*
- *Objective 3 – To recommend the most appropriate course of action that will provide legal protection to residents hosting wind farms should EAM occur.*

CONCLUSIONS FROM THE PAPER

3.3.160 [INWG author's description] *Objective 1 has been met by a complete review of the situation regarding a planning condition to control EAM since the judgment of the Court of Appeal in the Den Brook case. The advantage of this procedure is that a suitably worded condition strikes at the heart of this problem. However, it also has to be acknowledged that there are procedures to be followed and these can take time. The question is whether this is the most effective way of addressing the problem.*

3.3.161 [INWG author's description] *Objective 2 has been addressed through discussion of other remedies available under the TCP*[46] *Act if a planning condition is in place, namely the power to serve a stop notice, to serve a breach of condition notice or to seek an injunction. Of these, a Stop Notice runs the risk of substantial compensation being paid and a Breach of Condition notice*

[46] Town and Country Planning

does not have real 'teeth'. However, if an injunction can be obtained, this is likely to be a powerful tool. It may be expensive and perhaps risky to obtain, but if the Court should grant one, it should quickly resolve the problem. It cannot be considered costlier or more protracted that alternative approaches such as SN[47]*.*

3.3.162 [INWG author's description] *In answering Objectives 2 and 3, other potential remedies have been considered. Some of these such as SN have been actively advocated by the Wind Industry and supported by Planning Inspectors. Evidence however suggests that an Abatement Notice is not an effective control to protect nearby residents from EAM. Others such as private nuisance and similar legal actions have been considered but these place too much risk and burden on residents for a problem not of their making with likely long term adverse financial implications. They may however be the only remedies available if a suitably worded condition is not imposed in the Planning Certificate. The inability of the alternative procedures to bring about effective control and exemption from those procedures in some cases may indicate action under the EHRC*[48] *is the only realistic option. This is also a complex, potentially lengthy and dauntingly uncertain process.*

3.3.163 [INWG author's description] *Consideration has also been given to Blight action. This could provide a speedy remedy if there were power to enforce it but, under the current law, this is not an option that is open to residents.*

3.3.164 [INWG author's description*] A final purpose of this paper is to recommend the most effective course of action to protect residents if there is a potential problem caused by EAM from a wind farm or turbine. While no course of action may provide the speedy remedy that is sought, it is firmly recommended that the adoption of a modified Den Brook type condition is appropriate.*

QUALITY, ROBUSTNESS, RELEVANCE

3.3.165 [This is a] carefully written legal review that recommends that control of AM through the planning system is the most appropriate formal/legal course of action, and that the [original] Den Brook condition is the most suitable of the conditions currently available.

3.3.166 This paper assumes that the EAM problem exists, is sufficiently widespread and of such impact (on residential amenity, health and quality of life) that it should be subject to formal control.

3.3.167 The conclusion supports the use of a modified Den Brook condition but it is caveated that a "*suitably worded alternative condition may need to be drafted*" and "*imposed in every planning permission for a wind turbine unless there are clear reasons to show that it is unnecessary*".

3.3.168 The paper describes legal issues surrounding the need for a suitable EAM planning condition, but contains no new proposals.

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47 Statutory Nuisance
48 European Convention on Human Rights

Wind turbine amplitude modulation & planning control study – Work Package 6.2: Control of AM noise without an AM planning condition using Statutory Nuisance (Gray, 2015) [grey]

SCOPE

3.3.169 To contrast the effectiveness of Statutory Nuisance versus a statutory planning condition for dealing with AM noise from wind turbines.

CONCLUSIONS FROM THE PAPER

3.3.170 [Paraphrased from INWG author's description] Statutory Nuisance is a reactive response to complaints about noise from a householder to the local authority. It does not offer the same protection in law as a clearly defined AM planning condition. Statutory Nuisance should be a fast remedy but it is not. The consequence of using Statutory Nuisance seems to be that the wind farm operator has no legal obligation to control WTN AM. ETSU guidance allows a small amount of AM up to 3dB close to turbines – but apparently this doesn't deal with AM further than 50m from the WT. Despite many complaints about noise reportedly no EHOs have shut down or restricted the activity of wind turbines. Reluctance by local authorities (LAs) to use SN for fear of counter loss of income claims from WT owners. Fines are relatively small for WT owners. DEFRA Guidance for LAs is not practically helpful.

3.3.171 If "*average dB readings fall within the ETSU LA90 limits, which by design ignore the contribution from the peaks of noise, then the peaks and troughs of AM noise can be at any level of modulation.*"

3.3.172 Example given of Cotton Farm, Cambridgeshire, where continuous noise monitoring demonstrated more EAM than was anticipated.

3.3.173 [INWG author's description] *Statutory nuisance is therefore unlikely to provide a route to resolving an EAM problem. A planning condition is required.*

QUALITY, ROBUSTNESS, RELEVANCE

3.3.174 A reasonable case is made here (particularly because of the permanent nature of the noise source and the possibility of designing in mitigation at the development stage) that a statutory nuisance approach is not the right way to approach this and does weight the outcomes in favour of wind turbine owners.

3.3.175 A planning condition would be better. There is an issue here about if annoyance is largely dependent on sound intensity will a simple reduction in sound intensity reduce the effect on annoyance or distress specifically related to AM?

Wind turbine amplitude modulation & planning control study – Work Package 8: Review of Institute of Acoustics amplitude modulation study and methodology (Cox, 2015) [grey]

SCOPE

3.3.176 [INWG author's description] *To review and summarise the activities of the Institute of Acoustics and its Noise Working Groups with respect to wind turbine noise amplitude modulation.*

CONCLUSIONS FROM THE PAPER

3.3.177 [INWG author's description] *This chronology of the activities by the IOA shows that its NWG and specialist subgroup the AMWG devoted to the study of excess amplitude modulation have consistently operated for the benefit of the onshore wind industry in the UK and to the detriment of local communities hosting wind turbines. This is also arguably against both the IOA code of ethics and that of the Engineering Council. The effect has been to both obfuscate and hide problems related to wind turbine noise assessment from government and from the Planning Inspectorate. Whether or not this behaviour is carried forward into the future remains to be seen (July 2015).*

QUALITY, ROBUSTNESS, RELEVANCE

3.3.178 This paper contains allegations of conflict of interest, and professional malpractice that are outside the scope of this review.

3.3.179 However, paragraph 49 contains a useful critique of the IOA AMWG consultation that is of direct relevance and is therefore reproduced below:

"Comments on, and criticism of, the IoA AMWG consultation document include:

- *The definition of EAM is too narrow as there are also many variable sound characteristics other than simply modulation depth that contribute to what is generally considered as EAM;*
- *Turbine sound emissions also include low frequency sound both audible and non-audible that should not be ignored as it all contributes to the sensation effect;*
- *Consideration of LFN is conspicuously absent from the consultation document. By excluding frequency data below 100Hz, much of the low frequency energy will be eliminated resulting in EAM being under reported;*
- *Turbine sound and EAM should be measured where people will experience it. This should include close to buildings where reflections can affect the noise levels and inside buildings where room resonance effects combined with low background noise can amplify its effects;*
- *Class 1 instrumentation as recommended by the IOA NWG in their Good Practice Guide have been shown to be inadequate in that its 'noise floor' is too high for low background noise environments and is unsuitable for the low frequency measurement capability required for wind turbine sound;*
- *The IOA and wind industry appear obsessed with 'automating' the AM measurement process using software. This will have the effect of removing transparency from the process when what is required is a simple transparent process that a local authority EHO can carry out with or without an acoustics consultant;*
- *The IOA AM study is too narrowly defined and avoids looking at the big picture with regard to AM and how it affects people. This IoA AM study is also widely seen as another wind industry attempt at obfuscation to ensure EAM planning conditions will not unduly constrain wind power development and has nothing to do with protecting those affected by the noise.*"

3.3.180 Observations on these points, based on the subset of literature that has been reviewed as part of [the current study on behalf of DECC], are as follows:

- There is evidence in the reviewed research literature that other WTN and AM characteristics, in addition to modulation depth, are likely to be relevant to adverse effects such as annoyance and sleep disturbance. There is a lack of well-designed long term field based dose-response research in this field.
- There are some attempts in the reviewed research literature to include noise measurements both inside and outside homes, and to relate this to human

response, however a number of difficulties and shortcomings in the assessment of both dose and response have been identified in the reviewed research.

- There are a number of competing demands that are important in the choice of a suitable AM indicator. For the purposes of setting an effective policy control criterion the indicator will need to be more than 'simply' a technically robust metric. In [the opinion of the reviewer], in addition to transparency, repeatability and reproducibility, the indicator will also need to be relevant to perception and to the management of impact (on residential amenity, health and quality of life).
- The [the current study on behalf of DECC] has attempted to systematically identify and review all relevant research literature, particularly on the effects of AM on people. However, there are difficulties in conducting longer term ('big picture') field studies and there are limitations in the amount and quality of the underlying research.

Wind turbine amplitude modulation & planning control study – Work Package 9: The Cotton Farm monitor experience (Gray & Tossell, 2015) [grey]

SCOPE

3.3.181 [INWG author's description] *To document the experience of fighting a wind farm application and the decision to carry out long term noise monitoring by the local community to prove the existence and frequency of noise emanating from a newly built wind farm.*

CONCLUSIONS

3.3.182 [INWG author's description] *Existing wind turbines, as has been proven by the Cotton Farm monitor experience, should be constantly monitored and the data recorded. There has to be a clear understanding of the problems caused by noise and a clear directive for immediate action by the authorities and operators when unacceptable noise conditions do occur. The experience pioneered by the local community around the Cotton Farm wind farm proves this is not only practical but essential for legal and health reasons.*

QUALITY, ROBUSTNESS, RELEVANCE

3.3.183 Continuous unattended noise monitoring (over 2.5 years), met data and resident complaint logs are available. It is not clear if this can be linked with operational data from turbines themselves. There may be an opportunity to undertake dose-response analysis of the data being collected at Cotton Farm but this is not discussed or reported here. It's difficult to assess quality and robustness of measurement of dose and/or response from the information provided. [Response is not scaled on any] standardised rating of annoyance. Residents are able to decide when to complete diaries and how to describe the effects.

3.3.184 Only one measurement position is being used for long term measurements so [the data] may not be representative of levels at all properties.

3.3.185 It is likely only to be those who object to the wind turbines or WTN that are taking part in this project so there is an unavoidable risk of bias.

3.3.186 [There is] no information of direct relevance to [the current study on behalf of DECC] but possible relevance to compliance monitoring [in relation to] planning conditions and to future design of longer term field research studies.

CATEGORY 2 CONCLUSIONS

3.3.187 The category 2 papers reviewed in section 3.3 provide supporting evidence that:

- Perception of amplitude modulation in WTN and other environmental sounds affects subjective annoyance;
- There is an potential association between WTN-related annoyance and increased risks of sleep disturbance and stress;
- There are other non-acoustic factors that play an important role in influencing the subjective annoyance attributed to noise from wind turbines, including sensitivity, attitude, situation, aesthetic perception and economic benefits; and
- Annoyance due to AM WTN seems to be increased during normal resting periods, i.e. late evening / night-time / early morning. This could be due to increased sensitivity, greater AM prevalence or magnitude (e.g. due to diurnal variations in atmospheric conditions) or a combination of these factors.

3.4 LIMITATIONS OF EVIDENCE

3.4.1 The following paragraphs list recommendations for future research based on the identified limitations of the category 1 & 2 papers, and summarises how the conclusions of these papers can be used in their current form.

CATEGORY 1 PAPERS

3.4.2 None of the laboratory studies reviewed address possible differences in sensitivity that might be encountered in different contexts, for example, when trying to get to sleep at night-time. Further work to closely investigate the effects of potential differences in diurnal sensitivities to AM WTN would be informative. Any laboratory results should also be compared or augmented with field study data. This could be especially valuable in view of the results of broader field studies (discussed further in section 3.3), some of which report increased complaints due to WTN in the night-time hours, and generally include much larger samples than the Category 1 studies reviewed.

3.4.3 The limitations of an artificial environment present significant difficulties for achieving wider applicability of the results. One particular difficulty with the laboratory studies that focussed on rating absolute annoyance is the relatively short duration of the stimuli generally used compared with what may be encountered in the field. Consequently, 'annoyance' ratings obtained in this way are unlikely to be closely representative of the potentially emotional response that could be experienced by people over varying exposure durations, periods and intermittency, and within other contexts and environments. There was only a single field study (D[49]) identified with potentially useful exposure-response data in this area, which unfortunately had drawbacks of a small sample and high potential for bias. A strong need has been identified for studies focussing on quantifying exposure-response relationships that reflect conditions likely to be experienced by those within the exposed population. The Tokyo study (B) did include large-scale field measurements and social survey data, producing exposure-response relationships for time-averaged levels (L_{Aeq}) (Yano, Kuwano, Kageyama, Sueoka, & Tachibana, 2013). The study also analysed measurement data from 18 wind farm sites, and applied the developed AM metric to produce an estimate of fluctuation sensation at the measurement points. However, the group

[49] (Bockstael, Dekoninck, Can, Oldoni, de Coensel, & Botteldooren, 2012); (Bockstael, Dekoninck, de Coensel, Oldoni, Can, & Botteldooren, 2011)

have not yet published an investigation of direct links between the perceptual results on AM with those obtained from the social survey work. Any such link, if established, could provide potentially valuable information in this area.

3.4.4 None of the category 1 studies reviewed directly investigated the effect of *changes* in an existing noise environment due to (the introduction of) AM WTN, which understandably in a laboratory setting would be very difficult to design representatively. Further work in this area could be valuable, and would ideally be investigated via a longitudinal field study, in which noise measurements and associated social survey data are obtained in an area prior to an impending wind turbine installation that is later developed. Post-installation measurements and survey data, including those from a control group not exposed to WTN could then be compared to establish changes in the environment due to (AM) WTN and any associative changes in perceptual response. Unfortunately it must be acknowledged that this type of study design could be difficult to realise, not least because of the relatively small proportion of the UK population exposed to WTN, and the sensitivities surrounding wind farm proposal sites and public awareness. Further field studies and the implications of the lack of assessment of noise environment changes are discussed in the Category 2 papers section 3.3.

CATEGORY 2 PAPERS

3.4.5 A number of avenues of future investigation are raised:

- Longitudinal field studies incorporating subjective *and* objective measures of response to WTN exposure, with quantification of AM verified with measurement data.
- Studies aimed at identifying the influence of AM WTN exposure on observed responses in realistic situations, specifically addressing:
  - duration;
  - magnitude;
  - frequency of occurrence;
  - both ‘steady state’ and ‘change’ environments; and
  - differences in sensitivity over a range of applicable contexts (e.g. including rest / sleep periods).
- Research to further establish the effectiveness (in terms of subjective perception and response) and availability of mitigation methods for AM in WTN.

SUMMARY

3.4.6 None of the available research reviewed as part of this study has been designed to answer the main aim of the study in its entirety. That research would have ideally included a longitudinal field-based exposure-response study, specifically quantifying both the AM character of WTN, and a scaled response from the sample subjects. The Category 1 study results have questionable applicability to a wider population, due to limited sample representativeness and associated potential for bias (which may be practically unavoidable in laboratory studies), whereas the Category 2 studies generally do not directly address the issue of AM WTN exposure-response (and also carry potential risks for bias). A meta-analysis of the identified studies was not possible due to the incompatibility of the various methodologies employed.

3.4.7 In order to progress this study, it has been necessary to look at all of the available research and make some professional judgements to link the various relevant elements together. This process has been undertaken by the researchers, and reviewed by the independent external reviewers. It should therefore be recognised that the discussions and recommendations made are based on professional judgement and consideration of the best currently available evidence.

3.5 INSTITUTE OF ACOUSTICS METHOD FOR RATING AM

3.5.1 As noted in paragraph 1.1.6, the IOA AMWG have been working on the development of a method for the collection of data for subsequent identification and then rating of amplitude modulation in wind turbine noise. A draft of the Final Report "*A Method Rating Amplitude Modulation in Wind Turbine Noise*" (IOA AMWG, 2016) was made available to our project team in January 2016 for review by the internal research team. The draft Final Report contained the group Terms of Reference in Appendix A and Scope of Work in Appendix B.

SCOPE

3.5.2 [AMWG author's description] *This document has been prepared by the Amplitude Modulation Working Group (AMWG) established by the UK Institute of Acoustics (IOA) to propose a method or methods for measuring and rating amplitude modulation (AM) in wind turbine noise. Amplitude modulation (in this context) is a regular fluctuation in the level of noise, the period of fluctuation being related to the rotational speed of the turbine. This characteristic of the sound might be described by a listener as a regular 'swish', 'whoomph' or 'thump', depending on the cause and the severity of the modulation.*

CONCLUSIONS FROM THE PAPER

3.5.3 [AMWG author's description] *As a result of this analysis, and taking input from the responses to the Discussion Document, the AMWG has now identified a method (the 'Reference Method') for adoption in reliably identifying the presence of amplitude modulated wind turbine noise within a sample of data, and of deriving a metric that, in the AMWG's view, best represents the degree of amplitude modulation present. The method is described in detail in Section 4. It is essentially a development of the 'Hybrid Reconstruction' method (i.e. Method 3) previously described in the Discussion Document* (IOA AMWG, 2015a)*. It also draws on elements of the proposed Methods 1 and 2 and incorporates a newly developed 'prominence' criterion which has been found to be very effective at discriminating wind turbine AM from other sources, thereby reducing (but not eliminating) the need for detailed scrutiny of the data.*

3.5.4 [AMWG author's description] *Although* [the Reference Method] *is relatively complex, a degree of complexity is considered inevitable in a method that is sufficiently robust for determining compliance or non-compliance with specific thresholds or limits. A simple preliminary assessment method (the Indicative Method) is also described; this may be useful in some situations where wind turbine AM is subjectively apparent and when noise measurements with minimal contamination by other noise sources are available. However, the Indicative Method must be used with caution and is to be considered as secondary to the Reference Method and in no circumstances as a substitute for it.*

QUALITY, ROBUSTNESS, RELEVANCE

3.5.5 This report contains the details of the work undertaken by the IOA AMWG leading to their recommendation of a 'preferred' metric for AM. A definition for AM is provided, and the limitations of the metric to turbines of typically 500 kW and above are noted due to a focus on turbines with a rotational speed of less than 32rpm.

3.5.6 The report describes the various steps involved with the rating method, illustrating the process in flow charts. The various steps are explained in more detail in the text, with worked examples, and references to the work undertaken or additional research that underpinned the decision making process. The various decisions on analysis techniques are set out and justified. An additional 'prominence test' has been added to the method which further serves to identify clear WTN AM in a range of corrupted signals, addressing a previously identified weakness of other analysis methods.

3.5.7 The report also includes a summary of responses to points raised during the consultation stage in Appendix C, which covers the IOA AMWG's response to many of the points raised in the INWG's WP8 (see 3.3.179).

3.5.8 The methodology proposed by the IOA AMWG has been designed to provide a robust method for providing a precise and reliable determination of the presence of AM within wind turbine noise. As discussed below, the final metric is compatible with several of the Category 1 studies. However, as the AMWG authors note, the method will not necessarily be applicable to turbines of less than 500 kW, or with rotational speeds in excess of 32rpm. Further work would also be needed to develop a method for smaller turbines.

3.5.9 The Institute of Acoustics report is directly relevant to this study as it offers the definitive position of an industry body with a wealth of experience in acoustics and WTN. The IOA AMWG-proposed WTN AM metric is designed to work effectively for field data, addressing the difficulties encountered in analysing real WTN signals for AM content. Their report demonstrates that in overcoming the problems associated with earlier metrics, the proposed metric could provide a robust means for rating AM for assessment in a planning compliance situation. The report also demonstrates that the proposed metric can, over the range of interest, effectively be substituted for the metrics used in the laboratory studies reported by von Hünerbein et al (2013) (2015), and by Yokoyama et al (2013) (2015) with relatively small differences, indicating that values of the IOA AMWG metric can be related directly with the exposure-response research results discussed herein.

4 FACTORS AFFECTING DEVELOPMENT OF A PLANNING CONDITION

4.1 PLANNING POLICY GUIDANCE

4.1.1 Planning Policy for wind turbines in the United Kingdom is devolved to authorities in England, Wales, Scotland and Northern Ireland. Where developments may otherwise be refused, it is normal for planning conditions to be imposed which are designed to mitigate the adverse effects of the scheme. The objectives of planning are best served when the power to attach conditions to a planning permission is exercised in a way that is clearly seen to be fair, reasonable and practicable.

4.1.2 In England, paragraph 206 of the National Planning Policy Framework states "*Planning conditions should only be imposed where they are:*

1. *necessary;*
2. *relevant to planning and*
3. *to the development to be permitted;*
4. *enforceable;*
5. *precise; and*
6. *reasonable in all other respects."*

4.1.3 The policy requirement above is referred to in the NPPF as the 'six tests'. Similar guidance for the use of planning conditions is used by all Devolved Authorities. The key questions that arise against each test are listed in Table 5 (taken from the Communities website[50]).

Table 5: Validity Tests for Planning Conditions

TEST	KEY QUESTIONS
1. Necessary	• Will it be appropriate to refuse planning permission without the requirements imposed by the condition? → A condition must not be imposed unless there is a definite planning reason for it, i.e. it is needed to make the development acceptable in planning terms. → If a condition is wider in scope than is necessary to achieve the desired objective it will fail the test of necessity.

[50] http://planningguidance.communities.gov.uk/blog/guidance/use-of-planning-conditions/application-of-the-six-tests-in-nppf-policy/

Table 5: Validity Tests for Planning Conditions	
2. Relevant to planning	• Does the condition relate to planning objectives and is it within the scope of the permission to which it is to be attached? → A condition must not be used to control matters that are subject to specific control elsewhere in planning legislation (for example, advertisement control, listed building consents, or tree preservation). → Specific controls outside planning legislation may provide an alternative means of managing certain matters (for example, works on public highways often require highways' consent).
3. Relevant to the development to be permitted	• Does the condition fairly and reasonably relate to the development to be permitted? → It is not sufficient that a condition is related to planning objectives: it must also be justified by the nature or impact of the development permitted. → A condition cannot be imposed in order to remedy a pre-existing problem or issue not created by the proposed development.
4. Enforceable	• Would it be practicably possible to enforce the condition? → Unenforceable conditions include those for which it would, in practice, be impossible to detect a contravention or remedy any breach of the condition, or those concerned with matters over which the applicant has no control.
5. Precise	• Is the condition written in a way that makes it clear to the applicant and others what must be done to comply with it? → Poorly worded conditions are those that do not clearly state what is required and when must not be used.
6. Reasonable in all other respects	• Is the condition reasonable? → Conditions which place unjustifiable and disproportionate burdens on an applicant will fail the test of reasonableness. → Unreasonable conditions cannot be used to make development that is unacceptable in planning terms acceptable.

4.1.4 In considering a planning condition to control AM, it is noted that the project team does not contain legal expertise, but does have a wealth of experience of writing planning conditions. For this reason, an expert legal opinion should be sought to ensure that any AM condition derived from the output of the report stands up to scrutiny, as would happen in most planning situations as a matter of course.

4.1.5 In order to meet the 'six tests', the following aspects are considered by the project team to be important:

→ The presence and level of AM should be robustly identified, ideally objectively;

→ The threshold of unacceptability should be clearly stated (i.e. the point at which the control mechanism begins;

→ The enforcement of the control method should reflect other factors such as the frequency of occurrence, and time of day;

→ The control method should be clear and unambiguous; and

- The intent of the condition should be to prevent unacceptable impacts, avoid significant impacts, and mitigate to minimise other adverse impacts from AM and WTN. It is likely that for most sites that this condition will be 'mitigating' by bringing about a reduction in the level of AM using engineering methods, such as blade modifications or operational controls. Where the level of AM cannot be reduced, then the control method or 'penalty' should bring about a reduction in the overall time-averaged level of WTN during breach conditions.

4.1.6 Further discussion on these tests is included in Section 4.5.

4.2 FURTHER PLANNING CONDITION CONSIDERATIONS SUGGESTED BY THE INWG

4.2.1 In WP5, the INWG has proposed that there are additional objectives that are desirable for any planning condition to control AM should meet. These are suggested as:

> "*a. The condition must work with real world data. As described above this can vary from single turbines to multiple turbines. It might include cases where a clean AM peak to trough is visible in data and cases where the trace is influenced by multiple peaks and is less clearly defined. It must be able to deal with influences from other noise sources.*
>
> *b. The condition must be comprehensible and practicable to implement. This is both in terms of accessing the location of compliance monitoring but also in the actual assessment of compliance. The condition should be aimed at those most likely to use it, local authority officers, and the tools and skills available to them. It should not require specialist expertise to interpret the data.*
>
> *c. The condition should relate to the impact it is being designed to prevent. Any control should take account of the psychoacoustic response associated with the impact and reported complaints in existing cases.*
>
> *d. The condition should be transparent. The methodology of the condition should be clear and detail any data manipulation or filtering steps. The ability to test data for compliance should be open access including any software required to analyse the data.*
>
> *e. Others have proposed the preference for the condition to be workable with large amounts of data and therefore be largely automated.*
>
> *f. Most importantly it must be shown that the condition is effective, the control(s) must prevent periods of adverse AM.*"

4.2.2 Some of these suggestions are arguably already inherent in the 'six tests'. Any other proposals are not contained in Government planning policy, and therefore fall outside the scope of this study.

4.3 EXISTING PLANNING CONDITIONS

4.3.1 The existence of AM within WTN was acknowledged in ETSU-R-97 (1996), but the types of turbines then in existence were substantially smaller than those found on the larger wind farm sites now. The emergence of AM as being a potential problem grew during the 2000s, and a planning condition to control AM was first discussed and imposed by the Inspector for the Den Brook scheme in 2009. Additional research has since been carried out to further the knowledge of AM, and this has resulted in evolutions of the (original) 'Den Brook condition', and a planning condition proposed by RUK based on their own funded research.

4.3.2 Discussion of these planning conditions and the potential limitations of these conditions are included in the IOA AMWG consultation documents (IOA AMWG, 2015b), and the INWG WP5

(Large, Stigwood, & Bingham, 2015). Whilst there is broad agreement between the various documents on the limitations of the existing conditions, there are differences of opinion on the methods needed to rectify them.

4.4 OTHER POTENTIAL PLANNING CONDITION METHODS

4.4.1 The INWG WP5 review proposes additional methods using the Japanese D_{AM} method, BS4142:1997 (BSI, 1997) and BS4142:2014 (BSI, 2014). They conclude that the D_{AM} method works for sites where levels are not heavily influenced by extraneous noise and that a methodology following the requirements of BS4142:2014 also worked well.

4.4.2 It should be noted that the BS4142:2014 method contains a number of objective and subjective elements, which work well at the planning adjudication stage when the relative merits of each element can be debated and agreed, but introduce additional uncertainty when it comes to enforcement. The 'new' penalty method within BS4142 has not yet been tested in the field, and it is unclear at the present time whether the more subjective tests would work as intended; an element that could be acceptable to one enforcement officer may be unacceptable to another, leaving the operator uncertain as to the level of penalty they will be exposed to. A more objective approach would be more likely to comply with the one of the 'six tests' that advocates precision.

4.5 DISCUSSION

4.5.1 In order to recommend a planning control for AM, the various component parts have been broken down as suggested in paragraph 4.1.5. It should be noted that the information provided upon which to base the writing of a planning condition has been designed only for new planning applications. The applicability for use in Statutory Nuisance investigations on existing wind turbine sites has not been considered as part of this review, since methodologies and acceptability criteria are different to those used for planning enforcement. It is possible that the method may be used as an objective test as part of a nuisance investigation, subject to further testing and evaluation.

IDENTIFICATION AND RATING OF AM

4.5.2 Of the various methods discussed previously, the internal research team considers that the IOA AMWG proposals for the AM metric provide the most robust method available for the identification of AM. The metric is compatible with the available Category 1 papers reviewed, and with the available evidence on exposure-response, subject to the limitations previously noted. The methodology is objective, precise, and has overcome many of the criticisms of previously used metrics for AM in the field. It is acknowledged that the IOA AMWG method does not include some subjective elements which may be relevant to the human perception of AM, (such as impulsivity, distinctiveness, etc.) but the use of these is not clearly supported in the available research, and therefore cannot be recommended at this time.

THRESHOLD OF EXCESSIVE AM

4.5.3 The setting of a threshold for excessive AM is not straightforward. The available research does not identify a clear onset of increased annoyance from AM. The research also does not identify a clear level at which the impact of WTN or AM becomes 'significant', 'excessive' or 'unacceptable'. It *does* suggest an onset of *perception* for AM at about 2 dB (peak-to-trough level difference in the Fast-weighted sound pressure level), and an association of rising annoyance with increasing depth of AM above 2 dB, when relating to L_{Aeq}. Moreover, the research highlights a very strong relationship between annoyance and the overall time-averaged level of noise, with the presence of AM in the noise increasing the annoyance.

4.5.4 As the setting of the threshold of excessive AM is related to current Government policy, it is helpful to review the available policy evidence. ETSU-R-97 is recognised as Government guidance by all of the Devolved Authorities, and notes that the *"modulation of blade noise may result in a variation of the overall A-weighted noise level by as much as 3 dB(A) (peak to trough)… if there are more than two hard, reflective surfaces then the increase in modulation depth may be as much as +/- 6 dB(A) (peak to trough)*". This statement relates to the available turbines at the time, and it is often alleged that it does not necessarily translate to the taller turbines in use now. However, the IOA AMWG report notes that *"On the basis of the comments in ETSU-R-97, the value of 3 dB ('level of AM' or 'modulation depth') is sometimes referred to as the 'expected level' of AM. The Den Brook AM condition*[51] *adopts a 3 dB peak-to-trough value as the threshold above which AM is deemed to be 'greater than expected'"* (IOA AMWG, 2016). The 3 dB value is not supported in any of the available research as being the onset of unacceptable AM, but that does not mean that it is not an appropriate policy stance if there is sufficient policy support towards on-shore wind turbines.

4.5.5 More research is needed to test whether 3 dB peak-to-trough is still 'normal' today (i.e. typical with current turbine models), as, by necessity, the threshold could not penalise the level of AM that was considered to be 'normal' unless this was shown to give rise to complaints; this is not yet proven in the available research. Indeed, commentary from the INWG WP5 concludes that "*If the Den Brook condition (a peak to trough method) were to be treated as a simple metric or trigger value a higher peak to trough value in the region of 6dB would need to be used"* (Large, Stigwood, & Bingham, 2015).

4.5.6 A recently published report[52] on a long term field study of AM from wind farm noise in Massachusetts from both flat and mountainous sites concluded that *"while amplitude modulation is correlated with various meteorological parameters, prediction of the level of amplitude modulation at typical residential distances would not be reliable or practical. At these distance, local and regional background sounds have a significant impact on modulation depth. The analysis shows that larger modulation events (over 4.5 dB) can and do occur at the flat sites, but these events were observed less than 0.13% of the time. They were less common at the mountainous site (0.004%), likely because the multiple turbines at this site turn asynchronously, which tends to blur out modulation events."* This would lend some weight towards confirming that the ETSU-R-97 considerations relating to AM remain valid at least for the 78-80m hub height turbines that were included in the study.

4.5.7 The above statements highlight the variability in AM, and have formed the basis for the subsequent planning conditions drafted to date. ETSU-R-97 states that the absolute noise limits were chosen reflecting the AM character expected, with the addition of a penalty for tonality. It is clear from this statement that the character included the degree of AM experienced from the turbines existing at the time of writing, and therefore it could be considered that, if that AM character has materially changed, then the setting of the absolute limits should be reviewed. ETSU-R-97 also acknowledged that the noise limits were chosen to provide "*a reasonable degree of protection*", or to put it another way, the potential for some loss of local amenity in favour of wider national economic and sustainability benefits of renewable energy. This statement reflects the policy stance adopted by the UK Government at the time ETSU-R-97 was written, and may need to be reviewed against the various planning policies of the respective Governments today. For example, in England the aims of the NPPF are to avoid noise giving rise to significant adverse impacts, mitigate and reduce other adverse impacts, and identify and protect areas of tranquillity. It is unclear if the noise limits in ETSU-R-97 would still accord with these current aims without the policy support for on-shore wind.

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[51] see http://www.masenv.co.uk/Den_Brook_AM_Condition

[52] *Massachusetts study on wind turbine acoustics* (RSG et al., 2016)

4.5.8 It is also recommended that, as the AM control will target an element considered as 'above normal' in the ETSU-R-97 guidance, the control should be over and above the existing provisions for adverse sound characteristics, i.e. the control for AM should be considered in addition to the existing provision for tonality. This recommendation is not unprecedented: tonality and other adverse acoustic characteristics (impulsivity, intermittency etc.) are also considered separately within BS 4142:2014 (BSI, 2014), which is supported by the research cited in the standard. It follows that the two decibel WTN character penalties (tonality and modulation) should be additive in this case.

4.5.9 Successive UK Governments to date have stated their support for onshore wind, and confirmed the reliance on the ETSU-R-97 guidance, although the UK Government has set out proposals to end financial subsidies for new onshore wind projects across Great Britain and has introduced additional planning considerations for projects in England through a Parliamentary statement[53] . It could be argued that there is policy support for the choice of a 'normal AM' unacceptability limit (or a higher cut-in for the 'penalty'), whatever normal may be considered to be. This is based on the current policy statements, and may be subject to a wider review by the relevant Government Departments in the future.

4.5.10 To summarise the potential range of excessive AM thresholds, and initially generalising for the sake of simplicity, i.e. not taking into account whether the threshold relates to a single instantaneous event or the average of a series of events:

- the onset of perception for AM is around 2 dB 'peak-to-trough value';
- 'Normal AM' is considered to be in the range 2 to 6 dB 'peak-to-trough value'; and
- 'Excessive AM' may be above 6 dB 'peak-to-trough value'

4.5.11 In the Phase 1 report, it was suggested that it may be possible to define the AM penalty range in terms of the effect levels defined in the Noise Policy Statement for England (DEFRA, 2010) for the:

- No Observed Effect Level (NOEL);
- Lowest Observed Adverse Effect Level (LOAEL); and
- Significant Observed Adverse Effect level (SOAEL).

4.5.12 Planning Practice Guidance issued in 2014[54] added a further effect level for impacts increased beyond the SOAEL range:

- Unacceptable Adverse Effect level (UAEL).

4.5.13 Based on the research, the NOEL would likely be set at 2 dB, since up to 2 dB there is no apparent perception for most people. It would not be possible to set a LOAEL, SOAEL or UAEL without taking other factors into account such as the absolute noise level, which is outwith the scope of this report, and contextual factors considered below.

4.5.14 As noted, the choice of a threshold level only addresses a component of the expected response or effect, with how often and when the threshold is breached being important as well. Wind turbine operations can vary considerably over the course of even a 10 minute period, where wind

[53] http://www.parliament.uk/documents/commons-vote-office/June%202015/18%20June/1-DCLG-Planning.pdf
[54] http://planningguidance.communities.gov.uk/blog/guidance/noise/noise-guidance/

speed and directions can change. Similarly, noticeable AM can occur as infrequent short bursts, or continuously in long periods of several hours. Whilst the number of incidences of 'unacceptable AM' are disputed, there now seems to be a broad consensus emerging in the most recent research (e.g. INWG WP5) that a single 10 second breach occurring over a period of two weeks would not be sufficient cause for planning enforcement, whereas a two hour continuous period occurring for several nights in a row clearly would. This suggests that an AM 'accumulative dose' might be the way forward, similar to the daily dose used for vibration in British Standard BS 6472:2008 (BSI, 2008), in which exposure levels and durations aggregate into a single number for easy analysis. There is currently no research to support the development of a suitable AM accumulative dose parameter, although one may be desirable if, through experience or further research, a suitable parameter and dose can be defined.

4.5.15 Analysis of the RUK conditions reveals that (presumably in order to account for frequency of occurrence), the amount of AM is rated for a 10 minute period (consistent with the ETSU-R-97 time periods for noise level), and a best fit line is drawn for each of the 10 minute periods at each integer wind speed. The penalty is then derived from the best fit curve. No separate account is made for time of day. This method is consistent with that used for the derivation of noise limits within ETSU-R-97 (albeit without the separation of day and night periods), and makes some attempt to account for duration of exposure. However, by averaging what is already an average number of AM peaks, there is the potential to under-rate the level and duration of AM. This in turn could potentially lead to a lower level of protection in some situations. Whilst this could be overcome with setting a lower threshold of unacceptability, this may not be reasonable given that the solution may also affect non-AM periods and / or may not be supported by the available research.

4.5.16 As previously noted, analyses of the evidence indicates that:

- The 'penalty' scheme should be linked to the absolute level of the noise; and
- It may be appropriate to set a sliding scale of 'penalty' since overall average levels are controlled at present using the L_{A90}.

4.5.17 In view of the limited specific, robust research into the effect of duration and frequency of occurrence of AM exposure on the response, gauging acceptability at the current state of knowledge is largely reduced to professional judgement; these judgements can be made at the enforcement stage.

4.5.18 Acousticians and planning decision makers are used to making occurrence frequency and duration judgements for noise sources as a matter of routine, the general rule being that the more often it occurs, and the more sensitive the time period, the more likely it is to need controlling. It is widely reported that complaints related to AM occur in the early to late evening, night, and early morning periods of the day (these are the periods of highest wind shear, and the periods when properties are most likely to be occupied), which covers a wider period than just the night time – a factor that needs to be recognised when setting the penalty level as different noise limits can apply during these times. That is not to say that AM does not need to be controlled at other times if it does occur.

4.5.19 To summarise the difficulty in identifying how often the AM threshold needs to be breached to trigger a penalty, it is concluded that there is currently no identified targeted research on which to base this decision. It is therefore recommended that the judgements on when enforcement action[55] is taken will be reliant on professional judgement based on elements such as the time of day, the number and frequency of occurrence of the 10 minute breaches. Clearly, the expectation would be that the more breaches that occur over a given time period, the more adverse the response effect, and the more unacceptable the potential impact. However, in line with other policy guidance, such as the NPPF in England, the context of potential environmental effects also needs to be considered when defining the parameters of a condition; sensitivities of receptors vary, as do the environments in which they are located. It could be that the respective Government Departments consider it necessary to be prescriptive over the interpretation of compliance, but as stated before, a 'one size fits all' solution may not work as intended.

4.5.20 The prevalence of unacceptable AM has not been evaluated as part of this study, and current state of the art is that the likely occurrence cannot be predicted at the planning stage. That does not preclude future research to determine the likelihood of AM occurring coming forward, and the development of a risk based evaluation, or similar. Due to the lack of ability to predict AM occurring on a site, and the reported difficulties in applying Statutory Nuisance provisions to control AM on existing sites, it is likely that the default position for a decision maker would be to apply the condition on all sites unless evidence is presented to the contrary.

CONTROL SCHEME FOR AM

4.5.21 As noted in paragraph 4.1.5, the main purpose of the control or 'penalty' is to bring about a reduction in the impact as a result of the period of unacceptable AM, and as currently proposed this consists of a two-tiered approach. The first tier would be seeking a reduction in the depth and/or occurrence of AM of ≥3 dB depth (rated using the IOA metric) by way of engineering methods, i.e. reduce the AM to an acceptable degree of impact. Where the degree of AM cannot be reduced, then, in order to prevent, avoid or mitigate the impact, the penalty should bring about a reduction in the overall average level of WTN during periods of complaint / breach conditions[56]. Therefore a decibel penalty added to the overall average noise level during periods of unacceptable AM should lead to a breach of the planning condition for the overall average level of wind turbine noise, and subsequent action to reduce the noise level to bring the site back into compliance.

4.5.22 Therefore in its simplest form, the condition would be worded to the effect that, where an AM exceedance in level and duration occurs, steps must be taken to reduce the AM, or to reduce the overall noise level. The work by Cand et al. (2015b) shows two potential methods for reducing AM, one involving a modification to the turbine blades, and one through reprogramming of the turbine to reduce periods of blade stall. Although these methods are relatively new, both were demonstrably successful at reducing AM, but it is not necessarily expected that either of these methods will be available to every model of turbine. In this situation, the Category 1 papers by von Hünerbein et al. (2015) and Lee et al. (2011) clearly show that to reduce annoyance at the same level of AM, a suitable reduction in absolute noise level would be effective.

4.5.23 Planning conditions based on the RUK proposal suggest a penalty starting at 3 dB of AM (albeit rated using a slightly different parameter to the IOA metric now proposed) and a sliding penalty scale from 3 to 5 dB, which is similar to the tonal penalty in ETSU-R-97 as shown in Figure 11.

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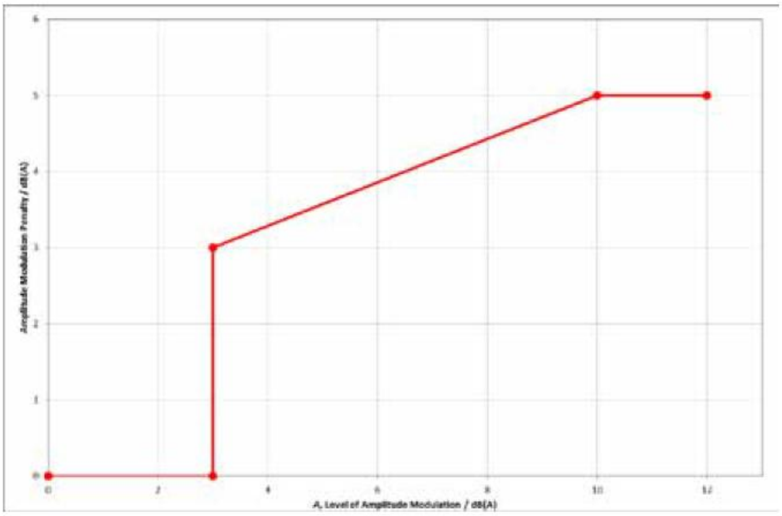
[55] It is noted that the NPPF (for England) states that enforcement action is discretionary, and local planning authorities should act proportionately in responding to suspected breaches of planning control. It therefore follows that not every breach of the AM condition would lead to enforcement and / or require the operator to take action. This may not be the case in other areas.

[56] Whilst the inherent problem of a 'reactive' approach to control AM is acknowledged, it would be unreasonable to penalise operators when periods of AM are not cause for complaint, thus the condition is targeted only to periods that give rise to valid / justified complaints. It is possible that high levels of AM may occur at other times of the day which, for a number of reasons, do not lead to complaints.



The interpretation of this penalty scheme is as follows:

- *for AM with a peak to trough level of < 3 dB there is no AM penalty*
- *for AM with a peak to trough level of 3 – 10 dB there is a sliding scale of penalties ranging from 3 – 5 dB*
- *for AM with a peak to trough level of ≥ 10 dB there is 5 dB penalty.*

Figure 11: RenewableUK Proposed Penalty Scheme[57]

4.5.24 The internal research team have compared the RUK penalty scheme to the outcomes of the research review, and concluded the following:

- The onset for the penalty at 3 dB of AM (derived from the IOA metric) appears to be consistent with starting the penalty scheme above the level of AM currently considered to be 'normal', and representative of the approximate onset of fluctuation perception for the majority of people;
- The magnitude of the decibel penalty starting at 3 dB is considered appropriate, for two main reasons:
    i. A 3 dB difference represents a reduction that would be expected to be clearly noticeable by people in the real situations that the penalty is intended to address;
    ii. Although the laboratory studies examining the equivalence of an AM signal with a steady-amplitude noise suggest a smaller 'lower bound' penalty of around 1.5-1.7 dB, the evidence is based on tests conducted using a modulation frequency of less than 1 Hz; to support the use of the penalty up to the slightly higher rotational speeds considered (equivalent to a blade-pass frequency of around 1.6 Hz), a 3 dB penalty would be more appropriate[60].
- The research evidence behind a sliding penalty above the 3 dB onset (e.g., in contrast with a stepped increase) is not definitive, but the general principle that increasing depths of AM should be avoided is considered reasonable[58]; and

[57] *The Development of a Penalty Scheme for Amplitude Modulated Wind Farm Noise Description and Justification*, (RenewableUK, 2013).

- The upper penalty magnitude of 5 dB initially appears to be higher than the evidence suggests would represent perceptual equivalence with a steady noise; typically, the laboratory adjustments to make a modulating noise subjectively equivalent with a steady noise are no more than around 3.5 dB[59]. However, these results are typically based on a modulation frequency of slightly below 1 Hz. In view of the intention to control AM impacts in the range up to (approximately) 1.6 Hz, an upper penalty limit of 5 dB is considered appropriate[60].

4.5.25 The above considerations are based on the available evidence, and the limitations identified.

4.5.26 ETSU-R-97 accommodates different noise lower bound limits for day and night time[61], the latter being less stringent. Application of the above penalty method without further consideration of this difference could in some cases result in a situation in which an AM-penalised WTN level does not breach the associated limit (implying no requirement for enforcement action), despite on-site evidence to the contrary. The conclusions drawn from the category 2 studies indicate that the greatest period of residential AM sensitivity is typically sunset to sunrise, with more focus around the onset of sleeping hours. Therefore it is recommended that to account for the higher ETSU-R-97 lower bound limits at night, an additional allowance be added to the penalty at night equivalent to the difference between the night and day limits for each integer wind speed bin. NB. This addition would not apply to situations in which specific planning conditions dictate the limits to be set as lower for night-time than for daytime.

4.5.27 Therefore the resulting action imposed on the operator during periods of AM complaint would be to either:

a) reduce the degree of AM to below the 3 dB rating threshold during the complaint periods identified; or

b) reduce the penalised overall time-average level below the limit. The sliding scale decibel AM penalty would be added to the overall noise level (day or night), plus the addition of X dB at night (where X is the difference between the night and day limits for each integer wind speed bin, applicable if, and only if, the numerical limit for night-time is set higher than that for daytime), again during the periods in which AM impacts had been identified.

4.5.28 It is acknowledged that enforcement of the planning condition relating to the overall time-average level of noise requires consideration of the background noise level, and methods are currently in place to account for background based either on averaging in situations where the turbine noise level is close to or below the prevailing background noise level, or by periodic shut-down of the turbines. This ‘averaging’ may not be a suitable approach for the determination of a specific 10 minute period of an AM breach, and an alternative method may be required to be devised or agreed as part of the enforcement process, along with the less desirable option (for operators) of a periodic shut-down.

4.5.29 With current technologies, mitigation in most cases will likely be achieved through pitch control of the turbine blades, or in the worst case the switching off of one or more turbines during periods of

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58 This is also supported by the subsequent research summarised in Annex 1.
59 This is also supported by the subsequent research summarised in Annex 2.
60 Human sensitivity to modulation in a noise signal has been shown [e.g. by Fastl & Zwicker (2007)] to rise with increasing modulation frequency to a peak within the range of around 2-6 Hz (4 Hz is the peak value most often-quoted).
61 Daytime is defined in ETSU-R-97 as 07.00 to 23.00, and has lower bound limits of 35-40 dB L_{A90}. Night time is defined as 23.00 to 07.00 and has a lower bound limit of 43 dB L_{A90}

unacceptable AM. Note that a more proactive mitigation solution is desirable as opposed to a reactive one, but it may not be possible to separate out periods of AM leading to complaint from the available meteorological data, resulting in mitigation being applied at times not leading to AM complaints. Further research by turbine manufacturers and wind farm operators may assist with making more effective proactive solutions in the future, which could help to reduce curtailments to energy yield, as well as minimising the noise impacts.

4.5.30 This method is by necessity an interim recommendation based on the available evidence to date, and supplemented with professional experience. It is suggested that any planning condition derived from this report would be subject to a period of testing and review. The period should cover a number of sites where the condition has been implemented, and would be typically in the order of 2-5 years from planning approval being granted. The review would involve the analysis of any new AM research at the time, and case studies from sites where a condition has been implemented.

SUMMARY OF PLANNING CONDITION CONSIDERATIONS

4.5.31 To summarise, the planning condition to control AM should apply during periods of complaints, and first seek to reduce the AM in the WTN, since this is a trigger for increasing annoyance. Where this is not possible, it is recommended that the 'penalty' should bring about a reduction in the overall noise level during complaint / breach periods, since this also controls the annoyance response. An outline suggestion for a possible condition is as follows (noting that the example given is intended for information only; the setting of specific planning conditions is a matter for Local Planning Authorities (LPAs) to determine, and producing a recommendation for a specific condition wording to be applied by LPAs is not within the scope of this research report. Legal advice would need to be sought to ensure any proposed condition meets the NPPF 'six tests' requirements):

> During periods of complaint, the IOA metric should be applied to the data collected[62] to derive the reconstructed AM values for consecutive 10-minute periods. For each period with an AM value of equal to or greater than 3 dB, a penalty should be assigned in accordance with Figure 11, and added to the absolute level of noise. Each summed value of Overall average level (corrected for background where necessary) + AM penalty + Tonal Penalty (if applicable) should be binned into wind speeds of 1 m/s intervals over the range of the data for when the turbine is operating and complaints occurring. Where the number of 10-minute breaches at any given wind speed during the period of complaint is considered to be unacceptable, the operator should be required to submit details of a scheme describing proposals for suitable mitigation of the unacceptable AM periods to reduce the number of breaches during the operational conditions giving rise to the complaint, to that considered acceptable by the relevant authority.

4.6 OPERATIONAL IMPACTS AND MITIGATION

4.6.1 It is to be expected that any reduction in operational capacity of a wind turbine will have an impact on the power generation of the development, and consequent reduction in the operating revenue. It is not known at this stage whether an AM control can be brought in by Government as a

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[62] Data should be collected in accordance with the IOA Supplementary Guidance Note 5 at http://www.ioa.org.uk/sites/default/files/IOA%20GPG%20SGN%20No%205%20Final%20July%202014.pdf (Checked 29.03.16)

practical enhancement to the existing planning guidance, or whether it would be necessary to consider it as a formal change of policy.

4.6.2 In either event, it is helpful to ascertain the likely burden to industry of the proposed changes through consideration of the engineering/cost trade-offs of possible mitigation measures. The last work package in the RUK study is an investigation on the likely cause of AM, and the suggested methods of mitigation. These include pitch control on the blades, reprogramming the power curve of the turbine to avoid stall conditions, and, ultimately, curtailment of the turbine completely in the wind conditions where it occurs. The results will vary from one site to the next due to different turbine models, and different wind regimes.

4.6.3 A potential cause of unacceptable AM is the occurrence of blades stalling only during part of the rotation. This mechanism is described in (Cand & Bullmore, Understanding amplitude modulation of noise from wind turbines: causes and mitigation, 2015a) along with results of mitigation measures involving both modifications of the blades and the operational characteristics of wind turbines.

4.6.4 Although the modification of blades is mentioned as a potential mitigation measure, costs and details related to these modifications are not currently available. Therefore only the curtailment strategies involving changes to the operational characteristics of wind turbines can be estimated. Also it should be borne in mind that turbines cannot be programmed (at the current state of the art) to respond to individual 10-minute breaches, and therefore a proactive mitigation strategy may currently also have to target non breach periods without complaints in order to address the meteorological periods during which complaints occur.

4.6.5 Wind speed will impact on the yield and therefore the cost of any curtailment strategy. More accurate estimates could be made where the site in question is known. The impact of the curtailment strategy itself is also very site-specific. It is therefore concluded that insufficient data exists on which to accurately predict the likely impact of restrictions imposed on a wind turbine as a result of having to comply with an AM penalty. The expectation is that this could range between 0 and 5% in terms of yield reduction, but at sites more prone to AM the value could be greater.

5 CONCLUSIONS

5.1 AM

5.1.1 WSP | Parsons Brinckerhoff has undertaken a review of research into the effects of and response to the acoustic character of wind turbine noise (WTN) known as Amplitude Modulation (AM). The objective was to review the current evidence on the human response to AM, evaluate the factors that contribute to human response, and to recommend how excessive AM might be controlled through the use of a planning condition.

5.1.2 The work has involved the collation and critical review of relevant papers, existing planning conditions, and existing planning policies where they relate to AM from wind turbines. The review established a clear need for AM control, a clear link between overall turbine noise level and annoyance, and a correlation between the degree of AM and an equivalent level without AM. It also established that the sensitive period for wind farm neighbours to AM coincides with operational conditions (between sunset and sunrise) where the prevalence of AM occurs. These findings raise the question about whether the noise limits in ETSU-R-97, which are generally higher at night, accord with current Government policies to avoid, significant adverse noise impacts, and mitigate or minimise adverse impacts.

5.1.3 Based on the evidence found, a recommendation has been made on the elements required to construct a planning condition to control AM. It is noted that the AM control has only been designed for use with new planning applications, and applicability for use in Statutory Nuisance investigations on existing wind turbine sites, where the regime is different and outside the project scope, has not been considered as part of this review.

5.1.4 Any condition developed using the elements proposed in this study should be subject to a period of testing and review. The period should cover a number of sites where the condition has been implemented, and would be typically in the order of 2-5 years from planning approval being granted.

5.2 PROPOSAL FOR PENALTY SCHEME

5.2.1 The review found that the penalty scheme should include the following elements:

- ✓ The AM condition should cover periods of complaints (due to unacceptable AM);
- ✓ The IOA metric should be used to quantify AM;
- ✓ Analysis should be made using individual 10 minute periods, applying the appropriate decibel ‘penalty’ to each period (according to the regime illustrated in Figure 12), with subsequent wind speed analysis;
- ✓ The AM decibel penalty should be additional to any decibel penalty for tonality;
- ✓ An additional decibel penalty is proposed during the night time period to account for the current difference between the night and day limits on many sites to ensure the control method works during the most sensitive period of the day;
- ✓ Professional judgement should be used for planning enforcement of the AM condition in terms of frequency and duration of breaches identified; and

- ✓ The scheme is designed for upwind, 3-bladed turbines with rotational speeds up to 32 RPM[63]. Further research would be needed to address turbines with blade-pass frequencies higher than 1.6 Hz.

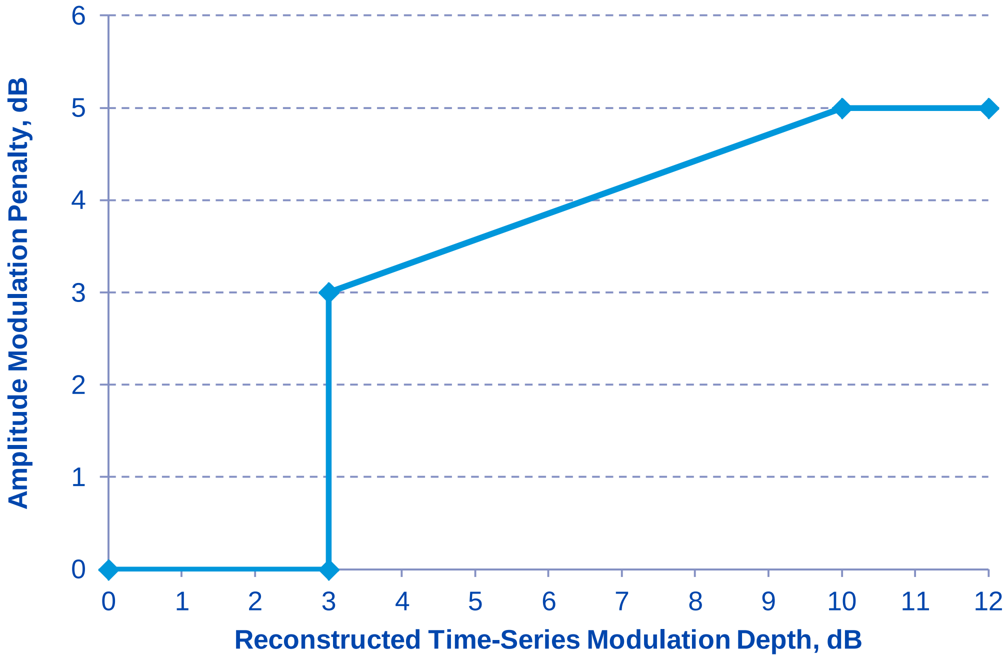

Figure 12: Proposed Level Penalty Regime

5.2.2 Further research has been recommended to supplement the limitations of the available research which underpins the above recommendation, although if the proposed penalty system, when implemented in a suitable planning condition, achieves the aim of reducing the impact from AM, then this research may not be required.

[63] Specifically, the IOA metric is limited to a working upper modulation frequency of around 1.6 Hz, and the exposure-response research underpinning the proposed penalty system addresses modulation frequencies up to approximately 1.5 Hz. This does not preclude faster rotating turbines with lower numbers of blades, provided the blade-pass frequency is no higher than 1.6 Hz.

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Appendix A

GLOSSARY & CONCEPTS

GLOSSARY

Term	Description
Amplitude Modulation	The variation of amplitude with time. In the context of rotating machines, e.g. wind turbines, the modulation of the amplitude typically has a periodic character.
Amplitude Modulation Factor	The degree of variation in a modulated sound pressure relative to its mean value. Modulation factor is defined as $(A_{max} – A_{min}) / (A_{max} + A_{min})$, where A is the signal amplitude.
AM Depth / Modulation Depth	The depth of amplitude modulation in a signal with varying level is a measure of the difference between the highest (peak) and lowest (trough) levels. In real signals the peak and trough levels vary and there is no agreed definition in this context. Typically for WTN, the modulation depth is taken as the peak-to-trough level difference ΔL (dB) between the L_{pAF} level envelope, or the 'short term' L_{Aeq} integrated over contiguous 100-125ms periods. As the peak/trough levels will typically vary, the overall 'modulation depth' within an interval is sometimes established via a statistical method, e.g. arithmetic averaging. As a simple level difference parameter, modulation depth is often applied to filtered sound pressure levels (e.g. A-weighted, or individual third-octave bands). Therefore comparisons of 'modulation depths' must be made with caution; the sound level parameter must be identical for comparability. See the Concept Diagrams for an illustration.
A-Weighting	The human ear can detect a wide range of frequencies, from 20Hz to 20kHz, but it is more sensitive to some frequencies than others. Generally, the ear is most sensitive to frequencies in the range 1 to 4 kHz. The A-weighting is a filter that can be applied to measured results at varying frequencies, to mimic the frequency response of the human ear, and therefore better represent the likely perceived loudness of the sound. SPL readings with the A-weighting applied are sometimes denoted as 'dB(A)', or with the weighting subscripted in the level descriptor, e.g. 'L_{pA}'.
Background Sound or Background Noise	A component of the ambient sound environment, comprising the steady sounds underlying those sources that fluctuate in level within a period of consideration. This can be evaluated using the L_{90} metric. In UK wind turbine noise assessments, background sound levels are typically established from statistical analysis of relatively long periods of measurements. When sound is considered 'unwanted' it is usually termed 'noise'.
Band-Pass Filter	A band-pass filter allows defined sound frequencies with a certain range (or band) to pass with little or no impediment, while removing or impeding any other frequencies in the signal.
Blade Passing Frequency (BPF)	The frequency with which a blade passes any particular point in a rotation cycle per second. Applicable to any rotating mechanism with blades (fans, turbines etc.). BPF is related to revolutions-per-minute (RPM) as BPF = Number of blades × RPM/60.
C-Weighting	As for A-weighting, but only follows the frequency sensitivity of the human ear at very high noise levels. The C-weighting scale is quite flat, and therefore includes much more of the low-frequency range of sounds than the A scales.

GLOSSARY

Term	Description
Decibel (dB)	The logarithmic decibel scale is used in relation to sound. The decibel scale compares the level of a sound relative to another. The human ear can detect a wide range of sound pressures, typically between $2x10^{-5}$ and 200 Pa, so the logarithmic scale is used to quantify these levels using a more manageable range of values.
Equivalent Continuous Level ($L_{eq,T}$)	The Equivalent Continuous Level represents a theoretical continuous sound, over a stated time period, T, which contains the same amount of energy as a number of sound events occurring within that time, or a source that fluctuates in level. For example, a noise source with an SPL of 80 dB(A) operating for two hours during an eight-hour working day, has an equivalent A-weighted continuous level over eight hours of 74 dB, or $L_{Aeq,8hrs}$ = 74 dB. The time period over which the L_{eq} is calculated should always be stated.
Fast/Slow Time Weighting	The sound pressure level is calculated from the root-mean-square (RMS) value of the instantaneous acoustic pressure. Calculation of the RMS value requires a finite time interval over which to calculate the mean. Sound level meters use a time-weighted average, which multiplies the squared pressure sample by an exponential function of the constant time interval over which the average is calculated. Standard time constants in current use include 'Fast' and 'Slow', which have values of 0.125s and 1s respectively, and are represented by designated subscripts attached to a level descriptor, e.g. $L_{p,F}$; L_{Smax} etc.
Fluctuation Sensation	The auditory perception of a sound which exhibits temporal variation.
Fluctuation Strength	A psychoacoustic metric for perception of sounds that fluctuate in amplitude, based on the model devised by Zwicker and Fastl. Parameters included in the model are modulation frequency, modulation factor and overall sound level. Measured in units of *vacil*, where 1 vacil is the fluctuation strength of a 60dB 1kHz sinusoid 100% modulated (i.e. modulation factor = 1; see footnote[64]) at a modulation frequency of 4Hz.
G-Weighting	As for A-weighting, but G-weighting is designed to reflect human response to infrasound. The curve is defined to have a gain of zero dB at 10Hz. Between 1Hz & 20Hz the slope is approximately 12dB per octave. The cut-off below 1Hz has a slope of 24dB per octave, and above 20Hz the slope is -24 dB per octave.

[64] In general the modulation factor and modulation percentage do not take the same value, but in the special case of an AM sinusoid, they are equal.

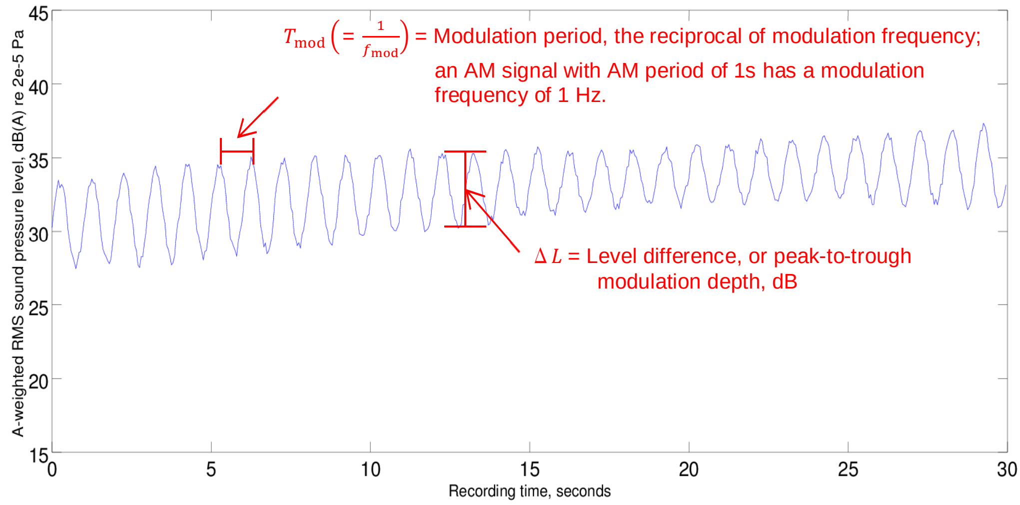
GLOSSARY

Term	Description
L_{90} or L_{A90} (and/or other 'percentile' measures)	Represents the SPL which is exceeded for 90% of the measurement time, expressed in dB or dB(A). L_{A90} is typically used to quantify background sound levels and, in the UK, wind turbine noise levels. In UK WTN assessment, the L_{A90} is used as a proxy level for the L_{Aeq}. This is because the L_{Aeq} is more susceptible to influence by non-WTN sounds in the environment, and WTN is generally relatively steady in level, compared with many other environmental noise sources. Other percentile levels such as L_{01}, L_{10}, L_{50}, L_{99} etc. can be used in various types of noise assessment. As an RMS SPL-based statistical level, the percentile measures should normally also have the time weighting included in the descriptor, as well as the time period of the measurement, e.g. $L_{AF90,10min}$.
Level Difference Δ*L*	In the context of amplitude modulation, the level difference expresses the difference in level between the highest and lowest amplitudes in the signal, and is also called the peak-to-trough level, or '*modulation depth*'. The level difference is related to the modulation factor *m* (see '*amplitude modulation factor*') by the expression $\Delta L = 20\log_{10}[(1 + m)/(1 - m)]$. A difference in sound levels is expressed in terms of dB. See the Concept Diagrams for an illustration.
Level Envelope	The envelope of a signal describes its variation in amplitude over time, and 'encloses' the signal levels.
Longitudinal and Cross-Sectional Studies	A longitudinal study is conducted by making observations from the same sample at more than one point in time. A cross-sectional study examines results observed from a sample at a single point in time (or cross-section).
Masking Noise	The human perception of a sound is affected by the presence of other audible sounds. Noise can provide masking for sounds that would otherwise be more clearly perceived. A masked sound may appear less distinct or may even not be detectable at all by a listener when a masking noise is present. In some situations, such as wind farms with residential neighbours, some masking noise (such as wind blowing through local vegetation) may be desirable.
Modulation Frequency / Period	The frequency of modulation is the number of times within a second that the amplitude fluctuates over the observed cycle, i.e. from maximum to minimum and back to maximum. The period of modulation is the reciprocal of frequency, i.e. the length of time between two amplitude peaks in a modulation cycle. See the Concepts Diagrams for an illustration.
Octave Band or Third Octave Band	A sound consisting of more than one frequency can be described using a frequency spectrum, which shows the relative magnitude of the energy in the different frequencies within it. The possible range of frequencies is continuous, but can be split up into discrete bands, often an octave or third-octave in width. Each band is referred to by its centre frequency, e.g. (for octave bands) 63 Hz, 125 Hz, 250 Hz, 500 Hz, 1 kHz etc. Separation of the spectrum in this way is typically implemented via band-pass filters.
Periodicity	A sound wave with a repeating form can be described as periodic. The level of a sound with periodic amplitude displays a regular fluctuation, although the peaks and troughs in the level may still vary.

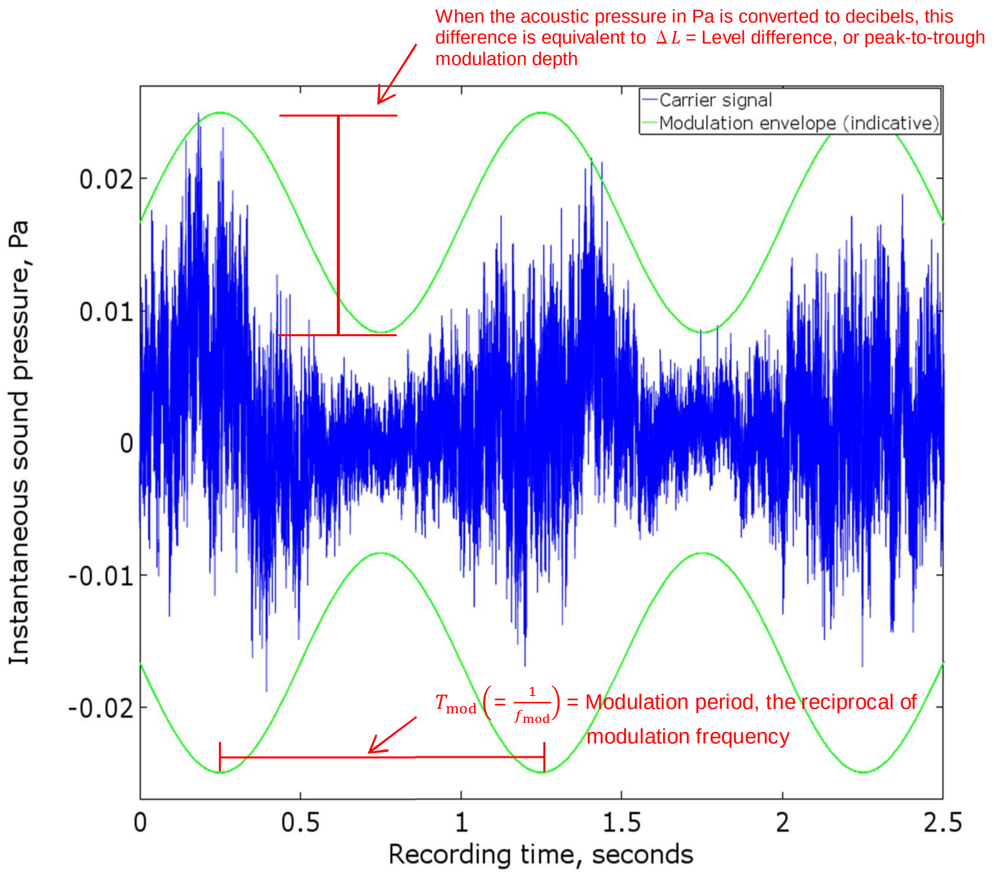
GLOSSARY

Term	Description
Pink Noise	Noise in theoretical acoustic terms is sound energy with random variation. 'White' noise has equal sound energy at every frequency; 'pink' noise has a sound energy that is inversely proportional to frequency, which results in a more low frequency sound compared with white noise.
RMS/root-mean-square sound (acoustic) pressure	Acoustic pressure waves comprise perturbations of air pressure, and the instantaneous pressure values at any given point in space therefore take positive and negative values around the mean, which is the steady local atmospheric pressure. In order to represent a meaningful amplitude, it is necessary to square the values (to make all values positive), calculate the mean (over some time interval), and take the square root of the result. The acoustic energy (or power, for finite signals) can be described by the mean-square of the pressure amplitude. The square root reduces the mean-square value to linear (amplitude), rather than squared, units.
Sound Pressure Level (SPL)	The Sound Pressure Level has units of decibels, and compares the level of a sound to the smallest sound pressure generally perceptible by the human ear, or the reference pressure. It is defined as follows: SPL (dB) = $10 \text{ Log}_{10}(P/P_{ref})^2$ Where P = root-mean-square (see '*RMS*') sound pressure (in Pa) P_{ref} = Reference pressure $2\text{x}10^{-5}$ Pa An SPL of 0 dB suggests the sound pressure is equal to the reference pressure. This is the approximate threshold of normal hearing. An SPL of 140 dB represents the approximate threshold of pain. SPL is also often denoted as 'L_p'.
Spectral content	Sounds are typically made up of acoustic energy present in many frequencies of the audible spectrum. The frequency spectrum describes this signal 'content'.

CONCEPT DIAGRAMS



The RMS sound pressure level shown in the above diagram is evaluated over a (short) averaging time and therefore represents the ‘level envelope’ of the signal rather than instantaneous sound pressure values. The envelope concept is also illustrated below, related to instantaneous acoustic pressure.



The diagram above shows a pink noise carrier signal modulated in level by a sine wave.
NB: Concept plots show simulated signals and do not display real wind turbine noise data.

Appendix B

FULL LIST OF PUBLICATIONS

AUTHOR	YEAR	TITLE	PUBLICATION	STATUS	CATEGORY
Abbasi, M, et al.	2015	Impact of Wind Turbine sound on general health, sleep disturbance + annoyance of Workers - a pilot Study in ManjilWind Farm, Iran	Journal of Environmental Health, Science and Engineering	[black]	2d
Abbasi, M, et al.	2015	Effect of Wind Turbine Noise on Workers' Sleep Disorder: A Case Study of ManjilWind Farm in Northern Iran	Fluctuation and Noise Letters	[black]	2d
Aslund,MLW et al	2013	Projected contributions of future wind farm development to community noise + annoyance levels in Ontario, Canada	Energy Policy	[black]	2e
Bakker,RH et al	2012	Impact of wind turbine sound on annoyance, self-reported sleep disturbance + psychological stress	Science of the Total Environment	[black]	2d
Bauer,M et al	2015	Investigation of perception at infrasound frequencies by functional magnetic resonance imaging fMRI and magnetoencephalography (MEG)	International Congress on Sound and Vibration	[grey]	2e
Bengtsson,J et al	2004	Sound characteristics in low frequency noise + their relevance for the perception of pleasantness	Acta Acustica united with Acustica	[black]	2c
Berger,RG et al	2015	Health-based audible noise guidelines account for infrasound + low-frequency noise produced by wind turbines	Frontiers in Public Health	[black]	2d
Bockstael,A et al	2012	Reduction of wind turbine noise annoyance- an operational approach	Acta Acustica united with Acustica	[black]	1
Bockstael,A et al	2011	Wind turbine noise - annoyance + alternative exposure indicators	Forum Acusticum	[grey]	1
Bolin,K	2007	Investigating the audibility of wind turbines in the presence of vegetation noise	International Meeting on Wind Turbine Noise	[grey]	2e
Bradley,JS	1994	Annoyance caused by constant-amplitude and amplitude-modulated sounds containing rumble	Noise Control Engineering Journal	[black]	2c
Brink,M et al	2010	Field study of the exposure-annoyance relationship of military shooting noise	Journal of the Acoustical Society of America	[black]	2c

AUTHOR	YEAR	TITLE	PUBLICATION	STATUS	CATEGORY
Bullmore, A et al	2011	Wind turbine amplitude Modulation- Research to Improve Understanding as to its Cause & Effect	International Meeting on Wind Turbine Noise	[grey]	2a
Bunk,O	2009	Investigation of day-/nighttime differences in sound emissions of high wind energy systems	Euronoise	[grey]	2e
Cand,M et al	2015	Practical Investigations of AM Mitigation	Acoustics 2015	[grey]	2b
Cand,M et al	2015	Measurements demonstrating mitigation of far-field AM from wind turbines	International Meeting on Wind Turbine Noise	[grey]	2b
Cand,M et al	2015	Understanding amplitude modulation of noise from wind turbines- causes and mitigation	Acoustics in Practice	[grey]	2b
Cassidy,M et al	2015	Addressing the Issue of Amplitude Modulation- A Developer's Perspective	International Meeting on Wind Turbine Noise	[grey]	2f
Council of Canadian Academies	2015	Understanding the evidence - wind turbine noise	Independent report	[black]	2d
Cowen,R	2015	INWG Work package 6.1A- Legal issues - the control of excessive amplitude modulation from wind turbines	Independent report	[grey]	2f
Cowen,R	2015	INWG Work Package 6.1A – Legal Issues: the Control of Excessive Amplitude Modulation from Wind Turbines Supplementary Paper	Independent report	[grey]	2f
Cox,R	2015	INWG Work Package 8 - Review of Institute of Acoustics Amplitude Modulation Study and Methodology	Independent report	[grey]	2f
Cox,R et al,	2015	INWG Work Package 2.1 - Review of reference literature	Independent report	[grey]	2e
Crichton, F et al	2015	Health complaints + wind turbines-the efficacy of explaining the nocebo response to reduce symptom reporting	Environmental Research	[black]	2d

AUTHOR	YEAR	TITLE	PUBLICATION	STATUS	CATEGORY
Crichton,F et al	2015	Framing sound- using expectations to reduce environmental noise annoyance	Environmental Research	[black]	2e
Cummings, J	2013	The Variability Factor in Wind Turbine Noise	International Conference on Wind Turbine Noise	[grey]	2f
Davis,J et al	2007	Noise Pollution From Wind Turbines - Living with amplitude with modulation, lower frequency emissions and sleep deprivation	International Meeting on Wind Turbine Noise	[grey]	2e
DEFRA	2008	Research into improvement of management of helicopter noise - nanr235-project-report	Independent report	[grey]	2e
Di Napoli,C	2009	Case study- wind turbine noise in a small+ quiet community in Finland	International Meeting on Wind Turbine Noise	[grey]	2b
Di Napoli,C	2011	Wind turbine noise assessment in a small and quiet community in Finland	Noise Control Engineering Journal	[black]	2b
Di Napoli,C et al	2015	Current challenges of assessing excess amplitude modulation character in wind turbine noise during EIA/planning phase	International Meeting on Wind Turbine Noise	[grey]	2f
Dittrich,K et al	2009	Comparison of the temporal weighting of annoyance + loudness	Journal of the Acoustical Society of America	[black]	2c
Falourd,X et al	2015	Low Frequency Amplitude Modulation related to Doppler frequency shift: an experimental study of a 101m diameter wind turbine in a swiss valley.	International Meeting on Wind Turbine Noise	[grey]	2e
Fastl,H et al	2013	Psychoacoustic aspects of noise from wind turbines	Inter-noise	[grey]	2a
Feder,K et al	2014	An assessment of quality of life using the WHOQOL-BREF among participants living in the vicinity of wind turbines.	Environmental Research	[black]	2d
Fredianelli,F et al	2014	Looking for a wind turbine noise legislation paying attention to annoyance: which metric?	International Congress on Noise as a Public Health Problem	[grey]	2f
Gabriel,J et al	2013	Amplitude Modulation and Complaints about Wind Turbine Noise	International Conference on Wind Turbine Noise	[grey]	2b

AUTHOR	YEAR	TITLE	PUBLICATION	STATUS	CATEGORY
Gray,B	2015	INWG Work package 6.2- Control of AM noise without an AM planning condition using Statutory Nuisance	Independent report	[grey]	2f
Gray,B	2015	INWG Work Package 9 – The Cotton Farm Monitor Experience	Independent report	[grey]	2e
Hanning,C et al	2011	Selection of outcome measures in assessing sleep disturbance from wind turbine noise	International Meeting on Wind Turbine Noise	[grey]	2d
Hanning,CD	2015	INWG Work package 3.2- Excess amplitude modulation, wind turbine noise, sleep and health	Independent report	[grey]	2d
Hansen, KL et al	2015	Quantifying the character of wind farm noise	International Congress on Sound and Vibration	[grey]	2b
Health Canada	2014	Wind Turbine Noise and Health Study- Summary of results [online]	Independent report	[grey]	2d
Health Canada	2014	Health impacts and exposure to sound from wind turbines - Updated research design + sound exposure assessment [online]	Independent report	[grey]	2d
Hulme,M	2015	INWG Work Package 4 - Den Brook	Independent report	[grey]	2e
Inagaki,T et al	2015	Analysis of aerodynamic sound noise generated by a large-scaled wind turbine and its physiological evaluation	International Journal of Environmental Science and Technology	[black]	2a
Jabben,J et al	2012	Options for assessment and regulation of low-frequency noise	International Meeting on Low Frequency Noise and Vibration	[grey]	2e
Janssen,SA et al	2011	A comparison between exposure-response relationships for wind turbine annoyance and annoyance due to other noise sources	Journal of the Acoustical Society of America	[black]	2d

AUTHOR	YEAR	TITLE	PUBLICATION	STATUS	CATEGORY
Janssen,SA et al	2009	Exposure-response relationships for annoyance by wind turbine noise: a comparison with other stationary sources	Euronoise	[grey]	2d
Jeffery,RD et al	2014	Industrial wind turbines and adverse health effects.	Canadian Journal of Rural Medicine	[black]	2d
Kaczmarek,T et al	2010	Annoyance of time-varying road-traffic noise	Archives of Acoustics	[black]	2c
Kageyama,T et al	2014	Exposure-response relationship of wind turbine noise with subjective symptoms on sleep and health: a nationwide socio-acoustic survey in Japan	International Congress on Noise as a Public Health Problem	[grey]	2d
Kantarelis,C et al	1988	Identification+subjective effect of AM in diesel engine exhaust noise	Journal of Sound and Vibration	[black]	2c
Kelley,ND et al	1985	Acoustic noise associated with the MOD-1 wind turbine- its source, impact and control	Independent report	[grey]	2a
Klein, A et al	2015	Spectral + modulation indices for annoyance-relevant features of urban road single-vehicle pass-by noises	Journal of the Acoustical Society of America	[black]	2c
Knopper, LD et al	2011	Health effects and wind turbines- a review of the literature	Environmental Health	[black]	2d
Knopper, LD et al	2014	Wind turbines and human health	Frontiers in Public Health	[black]	2d
Kugler,K et al	2014	Low-frequency sound affects active micromechanics in the human inner ear	Royal Society Open Science	[black]	2e
Kurpas,D et al	2013	Health impact of wind farms	Annals of Agricultural and Environmental Medicine	[black]	2d
Kuwano, S et al	2014	Social survey on wind turbine noise in Japan	Noise Control Engineering Journal	[black]	2d

AUTHOR	YEAR	TITLE	PUBLICATION	STATUS	CATEGORY
Kuwano, S et al	1999	Loudness, annoyance + unpleasantness of amplitude modulated sounds	Inter-noise	[grey]	2c
Large, S et al	2015	INWG WP5- Towards AM planning condition	INWG	[grey]	2f
Large, S et al	2014	Noise characteristics of 'compliant' wind farms that adversely affect its neighbours	Inter-noise	[grey]	2b
Large,S	2015	INWG Work Package 2.2 - AM Evidence Review	Independent report	[grey]	2e
Laszlo, HE et al	2012	Annoyance and other reaction measures to changes in noise exposure: a review	Science of the Total Environment	[black]	2e
Lee,S et al	2011	Annoyance caused by amplitude modulation of wind turbine noise	Noise Control Engineering Journal	[black]	1
Lee,S et al	2009	An estimation method of the amplitude modulation in wind turbine noise for community response assessment	International Meeting on Wind Turbine Noise	[black]	1
Legarth,SV	2007	Auralization + assessments of annoyance from wind turbines	International Meeting on Wind Turbine Noise	[grey]	2a
Lenchine,VV	2009	Amplitude modulation in wind turbine noise	Acoustics 2009	[grey]	2a
Lichtenhan,J et al	2013	Amplitude modulation of audible sounds by non-audible sounds - understanding the effects of wind turbine noise	International Congress on Acoustics	[grey]	2a
Magari,SR et al	2014	Evaluation of community response to wind turbine-related noise in Western New York State	Noise and Health	[black]	2d
Marshall Day Acoustics	2013	Examination of the significance of noise in relation to onshore wind farms	Independent report	[grey]	2e
Matsuda,H et al	2012	Measurement of Psychological Response and Evaluation of Task Performance on Low-frequency Sound	International Meeting on Low Frequency Noise and Vibration	[grey]	2c
McCunney,RJ et al	2014	Wind Turbines and Health A Critical Review of the Scientific Literature	Journal of Occupational and Environmental Medicine	[black]	2d

AUTHOR	YEAR	TITLE	PUBLICATION	STATUS	CATEGORY
Merlin,T et al	2013	Systematic review of the human health effects of wind farms	Independent report	[black]	2d
Michaud,DS et al	2015	Effects of Wind Turbine Noise on Self-Reported and Objective Measures of Sleep	Sleep	[black]	2d
Michaud,DS et al	2013	Self-reported and Objectively Measured Health Indicators Among a Sample of Canadians Living Within the Vicinity of Industrial Wind Turbines: Social Survey and Sound Level Modelling Methodology	Noise News International	[grey]	2d
Moorhouse, AT et al	2009	A procedure for the assessment of low-frequency noise complaints	Journal of the Acoustical Society of America	[black]	2c
Moorhouse, AT et al	2007	The effect of fluctuations on the perception of low frequency sound	Journal of Low Frequency Noise, Vibration and Active Control	[black]	2c
Nissenbaum, M et al	2011	Adverse health effects of industrial wind turbines: a preliminary report	International Congress on Noise as a Public Health Problem	[grey]	2d
Nissenbaum, MA et al	2012	Effects of industrial wind turbine noise on sleep and health	Noise and Health	[black]	2d
Nobbs,B et al	2012	Characterisation of noise in homes affected by wind turbine noise	Acoustics 2012	[black]	1
Onakpoya,IJ et al	2015	The effect of wind turbine noise on sleep and quality of life: A systematic review and meta-analysis of observational studies	Environment International	[black]	2d
Pawlaczyk-Luszczynsk,M et al	2014	Evaluation of annoyance from the wind turbine noise: A pilot study	International Journal of Occupational Medicine and Environmental Health	[black]	2d
Pawlaczyk-Luszczynsk,M et al	2013	Assessment of annoyance due to wind turbine noise	Meetings on Acoustics	[grey]	2d

AUTHOR	YEAR	TITLE	PUBLICATION	STATUS	CATEGORY
Pedersen, E	2011	Health aspects associated with wind turbine noise: results from three field studies	Noise Control Engineering Journal	[black]	2d
Pedersen,CS et al	2012	Low-frequency noise from large wind turbines-additional data+assessment of Danish regulations	International Meeting on Low Frequency Noise and Vibration	[grey]	2f
Pedersen,E et al	2004	Perception + annoyance due to wind turbine noise- a dose-response relationship	Journal of the Acoustical Society of America	[black]	2d
Pedersen,E et al	2010	Can road traffic mask sound from wind turbines - response to wind turbine sound at different levels of road traffic sound	Energy Policy	[black]	2d
Pedersen,E et al	2009	Response to noise from modern wind farms in the Netherlands	Journal of the Acoustical Society of America	[black]	2d
Pedersen,E et al	2009	Wind turbine sound – how often is it heard by residents living nearby?	Euronoise	[grey]	2e
Pedersen,E et al	2007	Wind turbine noise, annoyance and self-reported health and well-being in different living environments.	Occupational and Environmental Medicine	[black]	2d
Pedersen,E et al	2005	Human response to wind turbine noise – annoyance and moderating factors	International Meeting on Wind Turbine Noise	[grey]	2d
Persson Waye, K	2004	Effects of low-frequency noise on sleep	Noise and Health	[black]	2f
Persson Waye, K et al	2002	Psycho-acoustic characters of relevance for annoyance of wind turbine noise	Journal of Sound and Vibration	[black]	2a
Persson Waye, K et al	2001	The prevalence of annoyance + effects after long-term exposure to low-frequency noise	Journal of Sound and Vibration	[black]	2e
Renewable UK	2013	Template planning condition on amplitude modulation	Independent report	[grey]	2f
Renewable UK	2013	Development of a penalty scheme for amplitude modulated wind farm noise	Independent report	[grey]	1

AUTHOR	YEAR	TITLE	PUBLICATION	STATUS	CATEGORY
Rennies,J et al	2015	Spectro-temporal characteristics affecting the loudness of technical sounds-data + model predictions	Acta Acustica united with Acustica	[black]	2c
Roberts, M et al	2009	Evaluation of the scientific literature on the health effects associated with wind turbines and low frequency sound	Independent report	[grey]	2d
RSG et al	2016	Massachusetts study on wind turbine acoustics	Independent report	[grey]	2a
Salt, AN et al	2010	Responses of the ear to low frequency sounds, infrasound + wind turbines	Hearing Research	[black]	2e
Schmidt, JH et al	2014	Health Effects Related to Wind Turbine Noise Exposure: A Systematic Review	PLOS One	[black]	2d
Seong,Y et al	2013	An experimental study on rating scale for annoyance due to wind turbine noise	Inter-noise	[grey]	1
Seong,Y et al	2013	An experimental study on annoyance scale for assessment of wind turbine noise	Journal of Renewable and Sustainable Energy	[black]	1
Shepherd, D et al	2011	Evaluating the impact of wind turbine noise on health-related quality of life.	Noise and Health	[black]	2d
Sherman,T	2015	INWG Work Package 3.1 - Study of Noise and Amplitude Modulation Complaints Received by Local Planning Authorities in England	Independent report	[grey]	2e
SRL & Hoare Lea	2015	Wind farm impacts study	Independent report	[grey]	2a
Stelling,K	2015	Infrasound-low frequency noise and wind turbines	Independent report	[grey]	2e
Stigwood,M et al	2013	Audible amplitude modulation - results of field measurements and investigations compared to psychoacoustical assessment and theoretical research	International Conference on Wind Turbine Noise	[grey]	2e

AUTHOR	YEAR	TITLE	PUBLICATION	STATUS	CATEGORY
Stigwood,M et al	2014	Initial findings of the UK Cotton Farm Wind Farm long term community noise monitoring project	Inter-noise	[grey]	2b
Tachibana,H et al	2014	Outcome of systematic research on wind turbine noise in Japan	Inter-noise	[grey]	2a
Tachibana,H et al	2014	Nationwide field measurements of wind turbine noise in Japan	Noise Control Engineering Journal	[black]	1
Takahashi,Y	2013	Present situation + research task on the assessment of psychological effects caused by low-frequency noise	Japanese Journal of Hygiene	[black]	2e
Thorne,R	2014	The perception and effect of wind farm noise at two Victorian wind farms	Independent report	[grey]	2d
Thorne,R	2007	Assessing intrusive noise and low amplitude sound	Independent report	[black]	2e
van den Berg,F	2011	Wind Turbine Noise Chapter 6 - Effects of sound on People	Wind Farm Noise Book	[grey]	2a
van den Berg,F	2013	Wind turbine noise- an overview of acoustical performance + effects on residents	Acoustics 2013	[grey]	2a
van den Berg,F	2009	Why is wind turbine noise noisier than other noise?	Euronoise	[grey]	2a
van den Berg,GP	2004	Do wind turbines produce significant low frequency sound levels	International Meeting on Low Frequency Noise and Vibration	[grey]	2e
van den Berg,GP	2004	The beat is getting stronger - the effect of atmospheric stability on low frequency modulated sound of wind turbines	Noise Notes	[grey]	2a

AUTHOR	YEAR	TITLE	PUBLICATION	STATUS	CATEGORY
van den Berg,GP	2005	The beat is getting stronger - the effect of atmospheric stability on low frequency modulated sound of wind turbines	Journal of Low Frequency Noise, Vibration and Active Control	[grey]	2a
van Renterghem,T et al	2013	Annoyance, detection and recognition of wind turbine noise	Science of the Total Environment	[black]	2d
von Hünerbein et al	2015	Affective Response to Amplitude Modulated Wind Turbine Noise	International Meeting on Wind Turbine Noise	[grey]	1
von Hünerbein et al	2013	Wind Turbine Amplitude Modulation- Research to Improve Understanding as to its Cause & Effect. Work Package B(2)- Development of an AM Dose-Response Relationship	Independent report	[grey]	1
Vos,J et al	2010	Analysis of wind turbine sound recordings	Independent report	[grey]	2a
Vos,J et al	2010	Annoyance caused by low frequency sounds- spectral + temporal effects	Inter-noise	[grey]	2c
Yano et al	2013	Dose-response relationships for wind turbine noise in Japan	Inter-noise	[grey]	2d
Yano, T et al	1990	Assessing intrusive noise and low amplitude sound	Environment International	[black]	2c
Yelland,J	2015	INWG Work Package 1 – The Fundamentals of Amplitude Modulation of Wind Turbine Noise	Independent report	[grey]	2e
Yokoyama et al	2015	Subjective experiments on the auditory impression of the amplitude modulation sound contained in wind turbine noise	International Meeting on Wind Turbine Noise	[grey]	1
Yokoyama et al	2014	Perception of low frequency components in wind turbine noise	Noise Control Engineering Journal	[black]	1
Yokoyama et al	2014	Audibility of low frequency components in wind turbine noise	Forum Acusticum	[grey]	1