NH OEP SB 99 Pre-Rulemaking Process
Health and Safety Work Group

Executive Summary

The objective of the Health and Safety was to consider safety criteria and standards for the proper siting of large-scale wind energy facilities and transmission.

Areas of focus included wind turbine noise emissions, safety setbacks and other mitigations for shadow flicker, ice throw, blade shear, turbine collapse and other catastrophic events. The group also looked at the question of high voltage transmission siting.

The topics discussed by the group were complex, each representing a significant body of experience and technical study that extends far beyond what could be addressed in the short time available. Experts were invited to participate in the meetings to help inform the group. This was particularly important on the topic of noise emissions.

The Health and Safety work group was made up a diverse group of participants representing industry, town officials, NGOs and members of the public. In total, there were nineteen members in the group. Roughly 15 attended each meeting.

The work group met via conference call on six separate occasions. Each call lasted ninety minutes and was well attended. In addition, members attended the April 30, May 16 and May 28 status meetings scheduled by the Advisory Council.

Work Summary by Topic

1. Key Findings - Wind Turbine Noise Emissions

During recent SEC dockets, in particular the Groton Wind and Antrim Wind proceedings, substantial time was spent examining and challenging the various sound studies prepared by the applicants in trying to arrive at a noise limit where the projects would operate without creating an unreasonable adverse effect on the community. Much of the time spent could have been avoided, and the process streamlined, had the SEC adopted standards defining the purpose of various studies and appropriate protocols needed to ensure reliable, repeatable post-construction results.

National (ANSI, ASA etc.) professional standards exist that clearly articulate the process of conducting these studies. The work group spent considerable time discussing the types of studies specified in the standards and the purpose of each study.

1.1. Areas of Agreement

The work group agreed on the following points pertaining to wind turbine noise:

- Professional standards should be utilized for conducting noise surveys[1];
- Three primary studies may be necessary in evaluating wind turbine noise emissions:
    - pre-construction baseline survey,
    - predictive modeling, and
    - post-construction compliance monitoring.

A brief description of each study is provided in Appendix C.1.

Beyond these two points, it was very difficult to fully assess areas where agreement could be reached (by the broader group) as much of the time spent in meetings involved moderated technical discussions among professional acousticians fluent in the topic of wind turbine noise, as well as the procedures required for conducting the studies successfully.

However, it was clear during these discussions that there is considerable agreement between the acousticians, and also some disagreement. Table 1.a lists the points of consensus between the acousticians.

[1] At the time of this writing, NH Senate Bill 281 addressing SEC rulemaking for wind energy systems passed both the Senate and the House. The bill requires the SEC to address "project-related sound impact assessment prepared in accordance with professional standards by an expert in the field."

Table 1.a

NOISE	
Pre-construction baseline survey	
1.	Adherence to the ANSI/ASA S12.9-2013 Part 3 standard, a standard that requires short-term *attended* measurements.
2.	Long-term *unattended* monitoring may be conducted in accordance with ANSI S12.9-1992/Part 2, provided audio recordings are taken in order to clearly identify and remove transient noises from the data. Frequencies above 1250 Hz 1/3 octave band are to be filtered out of the data.
3.	Measurement locations should be conducted at the nearest properties from proposed wind turbines representative of all non-participating residential properties within 2.0 miles.
4.	Sound measurements shall be omitted when the wind velocity is greater than 4 m/s (~9 mph) at the microphone position, when there is rain, and/or with temperatures below instrumentation minima. Following ANSI 12.9 Part 3 protocol, microphones shall be placed 1 to 2 meters above the ground, and at least 15 feet from any reflective surface. A windscreen of the type recommended by the monitoring instrument's manufacturer must be used for all data collection. Microphones should be field calibrated before and after measurements. An anemometer shall be located within close proximity to each microphone.
5.	Pre-construction sound reports shall include a map and/or diagram clearly showing the following: • layout of project area, including topography, project boundary lines, property lines; • locations of the Measurement Points (MPs); • distance between any MP and the nearest wind turbine(s); • location of significant local non-turbine sound and vibration sources; • distance between all MPs and significant local sound sources; • The location of all sensitive receptors including, but not limited to: schools, day-care centers, hospitals, residences, residential neighborhoods, places of worship, and elderly care facilities.
6.	Applicant will provide A weighted and C weighted sound levels for L10, L_{eq} and L90.
Preconstruction Predictive Modeling	
7.	Predictive modeling will be conducted in accordance with ISO 9613-2.
8.	An adjustment to the Leq produced by the model shall be applied in order to adjust for turbine manufacturer uncertainty. This adjustment shall be determined in accordance with the most recent release of the IEC 61400 Part 11 standard (Edition 3.0 2012-11). This standard anticipates that the analysis of wind turbine acoustical emissions will also consider sound power level and tonality for a batch of wind turbines as opposed to just one machine (IEC 61400 Part 14).
9.	Predictions shall be made at all properties within two (2) miles from the project turbines for the wind speed and operating mode that would result in the worst case wind turbine sound emissions at night.
10.	Other corrections for model's algorithm error shall be disclosed and accounted for in the model(s).
Post-Construction Compliance Monitoring	
11.	Adherence to the ANSI/ASA S12.9-2013 Part 3. This standard requires short-term attended measurements to ensure transient noises are removed from the data. Measurements will include at least one nighttime hour where turbines are operating at full sound power with winds less than 3 m/s (~6 mph) at the microphone.
12.	Unattended long-term monitoring can also be conducted.
13.	Sound measurements shall be omitted when there is rain, and/or with temperatures below

	instrumentation minima. Microphones shall be placed 1 to 2 meters above the ground and at least 15 feet from any reflective surface following ANSI 12.9 Part 3 protocol. Proper microphone screens are required. Microphones should be field calibrated before and after measurements. An anemometer shall be located within close proximity to each microphone.
14.	Monitoring will involve measurements being made with the turbines in both operating and non-operating modes. SCADA data will be used to record hub height wind speed and turbine power output.
15.	Locations to be pre-selected where noise measurements will be taken. Measurements will be performed at night with winds above 4.5 m/s (~10 mph) at hub height and less than 3 m/s (~6 mph) on the ground.
16.	All sound measurements during post-construction monitoring will be taken at 0.125-second intervals measuring both "fast" response and L_{eq} metrics..
17.	Post-construction monitoring surveys will be conducted once within three months of commissioning, and once each season thereafter for the first year. Additional surveys may be conducted at the request of the SEC. Reasonable adjustments to this schedule will be permitted subject to SEC review.
18.	Post-construction sound reports shall include a map and/or diagram clearly showing the following: • layout of project area, including topography, project boundary lines, property lines; • locations of the Measurement Points (MPs); • distance between any MP and the nearest wind turbine(s); For each measurement period during the post-construction monitoring, reports will include each of the following measurements: • LA_{eq}, LA10, and LA90; • LC_{eq} , LC10, and LC90
19.	Noise emissions shall be free of audible tones. If the presence of a pure tone frequency is detected, a 5 dB penalty shall be added to the measured dBA sound level.
20.	The SEC shall adopt a complaint resolution program. Validation of noise complaints shall require field sound surveys conducted under the same meteorological conditions as occurred at the time of the complaint.

1.2. Areas Without Agreement

Disagreements between the acousticians were technical in nature and related to how field sound surveys and predictive modeling should be conducted. The points of disagreement are detailed in Table 1.b.

Table 1.b

NOISE - Areas without agreement	
Question of need	Mike Novello argued that pre-construction baseline studies should be focused on informing the SEC about the applicant's ability to meet post-construction compliance criteria. As those criteria were not established by the work group, he questioned whether pre-construction baseline studies were necessary.
Adherence to the standards	There is disagreement regarding how closely the standards are to be followed.
Uncertainty factor	Additional uncertainty factor relating to wind shear or other meteorology that is not adequately addressed by the model.

Ground absorption factor	Ground absorption factor to be applied in the predictive modeling.
Unattended v. attended monitoring	Disagreement on whether both methods are required when conducting post-construction compliance measurements.
Location of monitors	Location of where measurements should be taken.
Project layout and noise	Minimum distance between turbines, measured in rotor diameters
Noise limits	All work group members and acousticians agreed the SEC should establish a noise limit against which a project is judged as unreasonably adverse. There was disagreement on what that limit should be.

1.3. Alternative Proposals for Areas Without Agreement

Table 1.c details the alternative positions offered by the expert acousticians as well as the work group participants on areas where agreement could not be reached.

Table 1.c

NOISE - Alternative Proposals For Areas Without Agreement	
Pre-construction Predictive Modeling	
Adherence to standards	• Rick James argued that adherence to the ANSI/ASA S12.9-2013 Parts 2 and 3 protocols is important and there is no justification for following some portions of the standards and not others. • Ken Kaliski argued that monitoring be conducted consistent with the relevant portions of ANSI/ASA S12.9-2013 Parts 2 and 3.
Uncertainty factor	• Rick James argued that the added factor should be +3 dB. • Ken Kaliski argued that the factor should be between 0 to +3 dB. • Fred Ward argued models are only used when there are many of a kind with similar characteristics. "Just as there are (allegedly) no two snowflakes alike, there are no two hills or ridges alike, and the differences are major. The whole concept of modeling hills or ridges should give any reputable scientist or engineer the shakes. Given the enormous differences in the topography and meteorology from one hill to the next, any 'hill' model, or a flat land model adapted for hills, must have a very large factor of uncertainty."
Ground absorption factor	• Rick James argued that a ground factor of G=0 would more accurately reflect NH terrain. • Ken Kaliski argued a mixed ground factor of G=0.5 would be adequate, with G=0 on in areas of hard, non-porous ground. • Fred Ward supported a ground absorption factor of G=0 given the likelihood of many months where NH ridgelines are covered in ice.
Post-Construction Compliance Monitoring	
Adherence to standard	• Rick James argued that adherence to the ANSI/ASA S12.9-2013 Parts 2 and 3 protocols is important and there is no justification for following some portions of the standards and not others. • Ken Kaliski argued that monitoring be conducted consistent with the relevant portions of ANSI/ASA S12.9-2013 Parts 2 and 3.
Unattended v. attended monitoring	• Rick James argued that short-term attended studies were more accurate and better able to assess the sound levels emitted by the turbines. Long-term attended studies

	could be conducted, but not to the exclusion of attended studies. • Ken Kaliski argued that long-term unattended surveys gave a greater opportunity to evaluate worse-case conditions and that attended surveys were not needed. • Both agreed that there was no problem conducting both types of sound surveys
Location of monitors	• Rick James argued that noise measurements be conducted at the property lines. • Ken Kaliski argued that nighttime measurements be taken within 200 feet of a residence or the property line, whichever is closest. If a separate daytime noise limit is adopted then monitoring could be at the property line to assess that limit. • Members of the group who voiced a concern argued that noise limits be specified at non-participants' property lines.
Project design and noise	• Rick James argued that wind turbines spaced less than 5-7 rotor diameter widths apart could introduce wake turbulence that would increase project noise emissions. • Ken Kaliski argued there was no basis for this claim, especially in a noise standard.

1.4. Other General Comments

One area of interest that the work group did not have time to fully explore was the discussion of noise limits against which projects would be judged as unreasonably adverse.

While each wind application before the SEC has included an examination of project noise emissions, there has been very little consistency in the noise conditions imposed by the Committee. Table 1.d lists the limits set by the SEC in each wind project decision.

Table 1.d

SEC Noise Limits by Project	
Lempster Wind	• Town agreement differed from the SEC standard. Measured 300 feet from existing, occupied buildings. Different standard for the Goshen/Lempster school. • SEC standard triggered mitigation measures including installing Energy Star air-conditioners in bedrooms of non-participating homeowners if in-door noise levels exceeded the greater of 30 dBA or 5dBA above ambient.
Granite Reliable	• No noise standards
Groton Wind	• Daytime: Not to exceed 55 dBA or 5 dBA above ambient, whichever is greater. • Nighttime: Not to exceed 45 dBA or 5 dBA above ambient, whichever is greater. • Campground: Not to exceed 40 dBA or 5 dBA above ambient, whichever is greater.
Antrim Wind	• Daytime: Not to exceed 45 dBA or 5 dBA above ambient • Nighttime: Not to exceed 40 dBA or 5 dBA above ambient

Rick James has recommended that the SEC adopt a relative noise limit of 10 decibels above the background level with a noise cap not to exceed 45 $dB(A)_{(fast).}$ The overall cap is to account for a possible cumulative impact of multiple projects sited near each other. In contrast, Ken Kaliski recommended an absolute sound limit (for example an overall turbine cap of 40 dB(A) or 45 dB(A) Leq 1-hour). Others within the group argued that a 'not to exceed' limit be established and measured at the property lines.

The question of low-frequency noise and infrasound was briefly discussed. In general, the group recognized that the topic of audible sound is more defined and an area where rules could more readily be developed.

Appendix C.4 provides some references on noise limits including infrasound.

2. Key Findings - Shadow Flicker

Wind turbines can create a visual phenomenon known as shadow flicker which is defined as the alternating change in light intensity or shadows created by the moving turbine blades when back-lit by the sun. The location and occurrence of the shadowing effect depends on the time of year, time of day and the position of the sun in the sky[2]. The frequency of shadow flicker is related to the rotational speed of the blades. See Appendix C.2 for background information on shadow flicker.

The State of New Hampshire has not adopted any rules regarding shadow flicker, however, international standards do exist which are often cited.

German Limit[3] -

- Shadow flicker at residences, learning spaces, workplaces, and health care settings cannot exceed 30 minutes/day or 30 hours/year for **astronomical maximum** shading duration;

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[2] There was some discussion within the work group on whether moon light could create the same shadowing effect. No formal evidence was available to suggest moon flicker is a problem.

[3] Minnesota Department of Commerce: Energy Facility Permitting (2011) International Review of Policies and Recommendations for Wind Turbine Setbacks from Residences: Setbacks, Noise, Shadow Flicker, and Other Concerns. Retrieved from http://mn.gov/commerce/energyfacilities/documents/International_Review_of_Wind_Policies_and_Recommendations.pdf.

- Actual permitted amounts of shadow flicker at sensitive locations cannot exceed 8 hours/year;
- If setback distances are not sufficient in meeting these limits, mitigation methods are required which may include curtailing turbine operation until the flicker period ends.

Danish limit[4] -

- actual limits: 10 hours per year.
- If shadow flicker exceeds the maximum recommended amount, project owner may be required to curtail operation when shadow flicker might occur.

The best opportunity for avoiding and minimizing shadow flicker is during project design. But if this is not possible, or if the problem of shadow flicker arises after the project is operational, technology is available that can sense when the problem will occur, (turbine by turbine) and automatically curtail the unit until the sun moves out of position.

2.1. Areas of Agreement

The work group members generally agreed that shadow flicker could prove to result in an unreasonable adverse effect if not limited. It is difficult to fully assess the areas where agreement was reached since much of the time spent in meetings involved understanding the nature of the problem. Table 2.a provides an initial level of agreement.

Table 2.a

SHADOW FLICKER	
1.	Applications for wind energy facilities shall include shadow flicker assessments.
2.	Shadow flicker assessments shall identify the astronomical maximum (worst case) and anticipated hours per year of shadow flicker for each residence, learning space, workplace, health care setting, public gathering area (outdoor and indoor), and roadway that falls within the study area.
3.	Shadow flicker at residences, learning spaces, workplaces, health care settings, public gathering areas (outdoor and indoor) shall be limited.
4.	If Shadow Flicker limits cited under rule 3 cannot be met via project layout and setback distances, curtailment technology or other mitigation tools may be considered.

[4] Danish Energy Agency. (2009). Wind turbines in Denmark. Retrieved from http://www.ens.dk/da-dk/Sider/forside.aspx

2.2. Areas Without Agreement

Although the work group members generally agreed that shadow flicker could prove to be an issue, we did not reach consensus on the number of hours per year or minutes per day that a non-participating property owner could be subject to shadow flicker before the project would create an unreasonable adverse effect.

At least one member argued that since no known complaints of shadow flicker have been reported in New Hampshire, a 30-hour per year threshold, which is the limit most often seen at projects throughout the United States, would be appropriate (see discussion on Appendix C.2 to understand the origin of the 30-hour limit). Others made the case that even though complaints have not been filed, we should be planning for future applications.

There was also no agreement within the group regarding the distance at which turbine shadow flicker posed a problem.

2.3. Alternative Proposals for Areas Without Agreement

Table 2.b provides alternative positions offered by the work group participants on areas where agreement could not be reached.

Table 2.b

SHADOW FLICKER - Alternative Proposals for Areas Without Agreement	
Distance at which Shadow Flicker is a problem	• 10x rotor diameter width • One mile (5280 feet) • 6200 feet as recorded in Mason County Michigan • Do not establish any distance. Assume SF it is a problem at any distance.
Maximum hours per year of SF at residences, learning spaces, workplaces, health care settings, public gathering areas (outdoor and indoor), and roadways.	• 30 hours per year with a limit of 30-minutes per day • German standard of 30-hour astronomical maximum per year with an actual number of 8 hours per year; limit of 30-minutes per day • 0 hours per year. Given that technology exists that can eliminate shadow flicker by curtailing turbine operation, there seems no reason to permit even one minute of flicker beyond the project site. • Whatever the limit, it should not apply to roadways.

2.4. Other General Comments

Table 2.c shows the results of the shadow flicker modeling submitted with the four wind energy applications reviewed by the SEC.

Table 2.c

Project	Maximum hours of flicker per year at nearby properties
Lempster	More than 30 hours/year for properties close to the turbines 10-20 hours per year for residential properties nearby
GRP	Turbines remote - no shadow flicker
Groton	1-3 hours per year for properties near the turbines
Antrim	10-22 hours per year for properties near the turbines

3. Key Findings - Safety setbacks Ice/Blade Throw, Turbine Collapse

Safety setbacks from turbines are established to minimize the risk of property damage or injury resulting from ice throw or component failure. Setbacks are often defined as multiples of total turbine height (tower base to the upper tip of the blade in the 12 o'clock position) and measured from different points including property lines, occupied buildings, roads or public gathering areas.

The separate concept of a 'safety zone' around a turbine establishes an area of risk that is measured as the radius from the turbine base. Safety zones are appropriate when the turbines are sited long distances from buildings and roads, but in areas where the public might gather such as ski and hiking trails, hunting areas etc.

The State of New Hampshire has not adopted any rules regarding safety setback distances from turbines. See Appendix C.3 for more information on this issue.

3.1. Areas of Agreement

The work group members generally agreed that setback distances, or safety zones, were necessary to ensure the public is not placed at risk when in the vicinity of an operating turbine. Table 3.a lists the areas of agreement.

Table 3.a

SAFETY ZONES - Ice/Blade Throw, Other Catastrophic Failure	
1.	Turbines shall be curtailed during periods of ice accretion.
2.	Turbine technology shall be implemented which will prevent ice accretion or operation during periods of ice accretion.
3.	The use of warning signs is required to alert anyone in the area of risk.
4.	Operational staff should be aware of the conditions likely to lead to ice accretion on the turbine and conduct visual inspections to ensure the turbines are not operating with ice on the rotor unit.
5.	A safety zone or setback distance shall be defined for each turbine.
6.	The SEC may reconsideration the size of the safety zone if the applicant submits a risk assessment that includes project-specific information and mitigations that will adequately protect the public.
7.	In no case shall safety zones encompass portions of non-participating properties, public roads or public gathering areas.

3.2. Areas Without Agreement

There were two areas of disagreement: the size of any setback distance or safety zone and whether visual inspections of the turbines shall be regularly conducted to ensure the turbines are not operating with ice on the units.

3.3. Alternative Proposals for Areas Without Agreement

Simple math describing motion shows that ice or debris from a 100-foot long blade can be thrown nearly 1700 feet from the base of the turbine. Distance is dependent on the length of the blade, the angle of the blade at the time of the incident, the speed of rotation and the vertical distance from the ground.

Several alternatives can be considered in establishing the size of a safety zone or setback distance as follows:

- Establish a fixed size safety zone as a multiple of rotor diameter widths (for example 5x the rotor diameter) that accounts for the larger turbines and the maximum mathematical distances that objects can be thrown.

- Determine the maximum mathematical distance that objects can be thrown from a spinning blade.
- Consider previous setback distances adopted by the SEC on prior decisions involving wind projects. See appendix C.3 for a table of setback distances at the Lempster, Granite Reliable and Groton Wind facilities.

3.4. Other General Comments

The SEC must, by statute, make a determination as to whether a project presents an unreasonable adverse effect on public safety, however, determining the level of risk to the public where a project becomes unsafe is not an easy problem to solve. One member noted that establishing setback distances could result in significant land areas in the vicinity of a wind project being off-limits for safe public use.

4. Key Findings - Transmission Setbacks

Magnetic fields are created from the flow of current through wires or electrical devices. As the current increases, so does the strength of the magnetic field as measured in units of milligauss (mG). The magnetic field level at 300 feet or more from a transmission line centerline should be similar to local ambient, or background levels.

There are no known causal links between power-line magnetic field (MF) exposure and demonstrated health effects, in particular with regard to some forms of childhood cancers. However, some studies show a weak association. Since science cannot prove a negative, magnetic fields cannot be proven to be entirely safe. At the same time, science has been unable to prove the positive either. It's for this reason that the debate persists.

The State of New Hampshire does not have specific rules regarding EMF levels at the edge of transmission rights-of-way (ROW) nor are there federal standards for limiting transmission line EMF. Other states, however, have tackled this issue beginning in the 1980's and 90's at a time when utilities were undertaking substantial power line build-out. Several states enforce firm limits on EMF while others have adopted siting constraints and/or reporting rules around EMF levels. A policy of 'Prudent Avoidance' crops up frequently in the literature. Under this policy, state agencies seek a reasonable balance between avoiding potential harm to humans and the associated costs and risks. See Appendix C.4 for a review of how different states are treating this matter when siting high voltage (HV) transmission lines.

4.1. Areas of Agreement

The topic of safety setbacks for HV transmission lines was the most contentious within the Health/Safety work group. Several participants held firm that human exposure to electromagnetic fields (EMF) emanating from HV power lines is a concern, particularly for children, while others insisted that numerous studies have repeatedly demonstrated that EMF is not a public health risk. The dispute within the group was representative of the broader debate nationwide where, after more than three decades of research, concerns still remain[5].

4.2. Areas Without Agreement

It is difficult to assess the level of agreement on this topic but some in the group at least agreed that the SEC consider requiring applicants to provide pre- construction and estimated post-construction EMF readings as part of the application process. In addition, there was some agreement that the number and types of buildings at specific distance categories be included in the application.

4.3. Alternative Proposals for Areas Without Agreement

Since the extent of agreement on this topic is uncertain, proposed rules are listed in Table 4.a. An alternative is to take no action relative to EMF.

Table 4.a

TRANSMISSION LINE SAFETY (EMF) - Application requirements[6]	
1.	The number and type of each building within the following distance categories – as estimated from the centerline: 0-25 feet, 26-50 feet, 51-100 feet, 101-150 feet, and 151-300 feet. Types of buildings include homes, apartments, schools, daycare centers, hospitals, and commercial/ industrial buildings.
2.	Detailed magnetic field profiles for each unique structure type or circuit configuration (new and existing) with the exception of dead-end structures adjacent to substations.
3.	For routes that would affect existing electric lines, provide magnetic field profiles for the existing lines and a post-construction scenario that incorporates the new and the existing lines.
4.	For routes that would have multiple adjacent underground circuits, provide magnetic field profiles for each set of circuit configurations.

[5] California Department of Health Services and the Public Health Institute, Electric and Magnetic Fields retrieved at http://www.ehib.org/emf/longfactsheet.PDF

[6] Application rules derived from the State of Wisconsin PSC requirements. The State of Wisconsin has not established any limits on EMF levels or setback distances.

5.	Estimated magnetic field data which includes: • estimate for proposed lines at 80 percent and at 100 percent of peak load for one year post-construction and 10 years post-construction. For existing lines, use present day loadings to estimate the magnetic fields levels. • provide expected current levels for 80 and 100 percent of peak load at one and ten years post-construction.
6.	Provide all assumptions used to model magnetic field levels including: • Pole design diagram that includes the dimensions of pole arms, dimensions of conductor locations, horizontal distance from the pole to the conductors, and the distance of conductors from the ground at the pole. • Height of lowest conductor(s) at mid-span. • Depth from ground surface to circuits, for underground construction.
7.	The Application shall propose and implement where practicable, low-cost efforts to reduce EMF without compromising safety. Suggested mitigations may include but not be limited to: • increase distance between the transmission line and the public's exposure to the magnetic fields; • Increase height of transmission structures which would lower resulting exposure levels; • bring lines closer together *(magnetic fields interfere with one another, producing a lower overall magnetic field level, too close could cause arcing between the lines);* • bury transmission lines to reduce magnetic fields. *(Underground lines can be installed closer together and insulated with rubber, plastic, or oil.)*

4.4. Other General Comments

Appendix C.4 provides a brief summary of the rules adopted by other states on the topic of HV transmission siting and EMF. In addition to the EMF discussion, additional information was provided to the group covering the following transmission setback concerns:

- FERC recommendations[7] on setbacks for new transmission to the outside of the ROW.
- HUD guidelines[8] precluding buildings from being constructed within the "engineered" fall distance of a high voltage tower. HUD is tightening its lending and is requiring verification that the building is not within this fall distance.

[7] http://www.nh.gov/oep/energy/programs/documents/sb99-setbacks-transmission-ferc.pdf

[8] http://www.hud.gov/offices/adm/hudclips/handbooks/hsgh/4150.2/41502c2HSGH.doc

Acknowledgements

We are grateful for the tireless contributions of all of the work group members. Significant time was dedicated to this process on topics that turned out to be more complicated and more controversial than many expected. Special thanks to our invited experts who donated freely of their time to educate us and offer their advice. Thanks also go to meteorologist Dr. Fred Ward (and NH resident) who provided valuable insight and comment on something we all live with but few understand -- NH weather. Finally, thank you to the Advisory Council and Navigant for providing us the opportunity to be part of this important effort.

References

Appendix A: Group Members

Name (First, Last)	Role (Member/ Moderator)	Affiliation (Town Resident, Company, Organization, Industry, etc.)
Lisa Linowes	Member/Moderator	Windaction.org
Tripp Blair	Member	Bridgewater resident
Edward Dekker	Member	New Ipswich resident
Elizabeth Freeman	Member	New Ipswich resident
Larry Goodman	Member	Hebron resident
Jack Kenworthy	Member	Eolian Renewables
Lori Lerner	Member	Bridgewater resident
Campbell McLaren	Member	Easton resident, MD
Tom Mullen	Member	Campton resident
Mike Novello	Member	Wagner Forestry
Donald Pfundstein	Member	Gallagher, Callahan & Gartrell
Francis Pullaro	Member	Renew NE
Derek Rieman	Member	EDP Renewables
Susan Schibanoff	Member	Easton resident
Stuart Smith	Member	Grafton Energy
Ken Sullivan	Member	Temple resident
Fred Ward	Member	Meteorologist
Ric Werme	Member	Resident
Joe Wilkas	Member	Resident

Appendix B: Group Meeting/Conference Call Dates & Notes

Date	Focus	Guest Attendees
April 25*	Noise emissions	Acoustician Richard James
May 5*	Noise emissions	Acousticians Richard James, Stephen Ambrose and Edward Duncan
May 9*	Shadow Flicker, Debris throw, Transmission	Cary Shineldecker and William Palmer
May 13	Predictive modeling for noise	Acousticians Richard James, Stephen Ambrose and Ken Kaliski
May 23	Shadow Flicker, Debris throw, Transmission	Cary Shineldecker and William Palmer
June 3*	Noise emissions, Transmission	Acousticians Richard James, Ken Kaliski and Edward Duncan
* = call was recorded		

Appendix C: Relevant Documents and Materials

C.1 Wind Turbine Noise Studies

Pre-construction baseline or background noise survey: The purpose of the baseline sound survey is to quantify the existing background sound levels at surrounding land uses to define the existing soundscape around the project area. The existing soundscape is not adequately described by one acoustical metric, but by a number of acoustical metrics including: the equivalent continuous sound pressure level (Leq), statistical sound levels (e.g. L90, L50, L10), and maximum and minimum levels. The baseline sound survey should also include descriptions of the types of natural and anthropogenic sounds that are present in the existing environment.

Predictive modeling: The purpose of predictive modeling as defined under ISO 9613-2 specifies the engineering method for calculating the attenuation of sound during propagation outdoors in order to predict the levels of environmental noise that will be introduced into a community after a wind project is constructed. The model is suitable for predicting propagation under well- developed moderate ground-based temperature inversions, such as commonly occurs on clear, calm nights or under moderate downwind conditions. Inversion conditions over water surfaces are not covered and may result in higher sound pressure levels than predicted with the model.

Post-construction compliance monitoring: The purpose of compliance monitoring is determine whether noise emissions from the operating project are within permitted limits.

C.2 Background information on Shadow Flicker

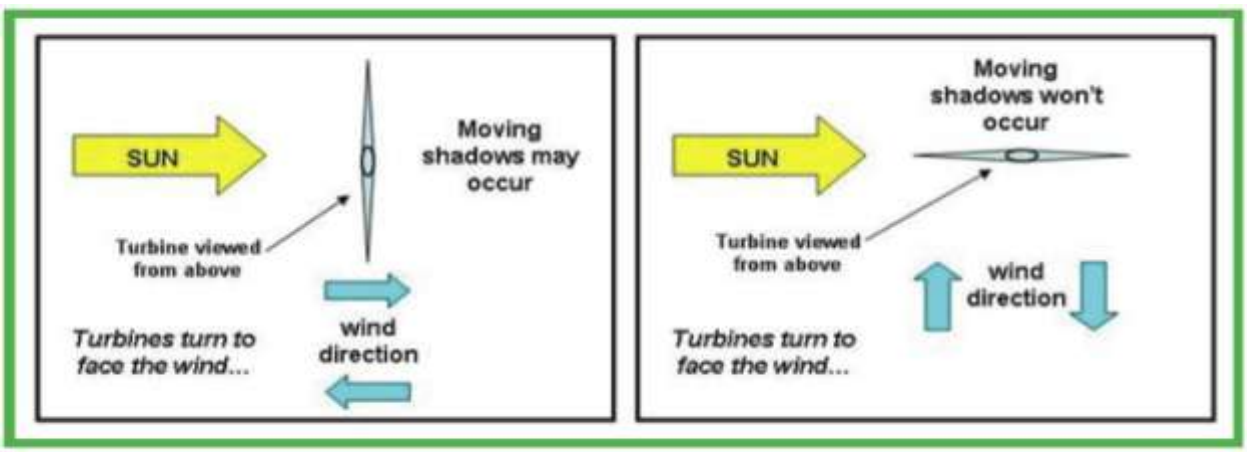
Shadow flicker occurs at all times when the turbines are rotating and there is a visible solar disk.

As the sun moves in the sky, the direction the shadows are cast and how far they are cast changes constantly. When the sun is high in the sky the area being flickered is very close to the turbine, but when the sun is lower in the sky, which is most of the daytime, the flickered area extends out many times the total height of the turbine.

The intensity of the flicker depends on the intensity of the sun and the amount of the (apparent) solar disk which the blade covers as it rotates in front of the disk.

Commercial products are available that can model the number of hours per year of shadow flicker an operating wind energy facility will produce at various locations based on the placement of the turbines. The three products most commonly cited are WindPRO, WindFarm and Windfarmer. The output of these packages does not vary significantly. All computer models produce the worst conditions referred to as the "astronomic worst case scenario". The worse case is the theoretical maximum number of hours that shadow flicker will be produced at a location assuming:

1. The sun is shining all day from sunrise to sunset;
2. The rotor-plane of the turbine is always perpendicular to the sun;
3. The turbine is always operating.



Upon determining the worst case scenario, average meteorological conditions for the project site are applied in order to model a more realistic estimate for the number of hours of flicker.

When the sun is close to the horizon (3-degree angle) or as distance increases between an observer and the turbine, it's expected that light diffuses thereby reducing the appearance of the harsh shadows cast by the blades. There is also a greater potential for obstruction by trees, topography, buildings. However, the density and length of the shadows may be more pronounced when the turbine is situated on a ridgeline several hundred feet above the impacted properties. In this scenario, the sun may be high in the sky but still be positioned behind the spinning blades.

Shadow flicker modeling, in general, assumes a maximum impact distance of 10-rotor diameters which for a 100-meter (328 feet) rotor diameter, shadows would be expected to fully dissipate after 3280 feet.

The work group heard from Cary Shineldecker of Mason County, Michigan. Mr. Shineldecker's home is located within Consumers Energy's Lake Winds Energy Park, a 100.8 megawatt facility consisting of 56 Vestas V100 1.8-megawatt turbines each standing 476 feet tall and with a 100-meter rotor diameter. Five turbines are within ½ mile of his home, 13 turbines within 1 mile and 26 turbines within 1.5 miles. *(see photo on this page)*

Consumers Energy conducted a shadow flicker analysis prior to construction. The study predicted an astronomical worst case of 48.8 hours of flicker per year on Shineldecker's home. Using average weather patterns and anticipated cloud cover, this figure was further refined to a more realistic limit of 6.8 hours per year. The project went online Thanksgiving weekend, 2012. Within 4 weeks shadow flicker at his home exceeded the 6.8 hours and shortly after exceeded the 10 hour/year limit set in the county ordinance.

The inaccuracies in the modeled results, in part, were tied to the assumption that shadows would not cast beyond 10-rotor diameter widths. This standard may have been appropriate for shorter blades, however, the longer, wider blades on today's machines and different shadow profiles for different blade shapes (manufacturer dependent) suggest the 10-rotor limit may not be appropriate. Shineldecker recorded substantial flicker on, and in, his home from a turbine located 5400' away. Mason County's Zoning and Building department independently measured flicker at distances beyond 6000 feet or 18+ rotor diameters[9] away.

The table below shows the results of the shadow flicker modeling submitted with the four wind energy applications reviewed by the SEC.

Project	**Maximum hours of flicker per year at nearby properties**
Lempster	More than 30 hours/year for properties close to the turbines 10-20 hours per year for residential properties nearby
GRP	Turbines remote - no buildings nearby
Groton	1-3 hours per year for properties near the turbines

[9] Reilly, Mary, Mason County Zoning and Building Director. Shadow Flicker Monitoring http://www.masoncounty.net/userfiles/filemanager/414/

Antrim	10-22 hours per year for properties near the turbines

International Standards

The State of New Hampshire has not adopted any rules regarding shadow flicker, however, there are international standards that provide important guidance.

Germany's shadow flicker limits are referred to in a large number of government and wind energy association documents worldwide, however, there is considerable confusion about the actual regulations. It is common to see the 30-hour limit codified in ordinances across the United States. However, Germany's 30-hour limit, again, refers to the astronomical maximum figure while the more realistic maximum of 8 hours per year is permitted at homes and places where people work, learn, and gather.

Mitigating for Shadow Flicker

The best opportunity for avoiding and minimizing shadow flicker is during project design. But if this is not possible, or if the problem of shadow flicker arises after the project is operational, as was the case in Mason County, technology is available that can sense when the problem will occur, (turbine by turbine) and automatically curtail the unit until the sun moves out of position.

In Mason County, the Zoning and Building Director initiated an enforcement proceeding after Cary Shineldecker was able to demonstrate that his home was subject to shadow flicker in excess of the 10-hours permitted by law. According to Shineldecker, the turbines operating out of compliance were later equipped with the Vestas Shadow Detection System (VSDS)[10], developed by Vestas and the problem of shadow flicker has been eliminated.

VSDS consists of two light intensity sensors mounted on the east and west sides of the offending turbine. A difference in the light intensity readings at each sensor acts as an indicator that shadowing will occur *(see figure below).* A controller integrated into the unit tracks the shadow flicker conditions at each impacted property. If the controller determines that a turbine is encroaching on the annual hour limit allowed, which for Mason County would be 10 hours per

10 http://www.lakewindsenergypark.com/Uploadedfiles/Lakewinds/SHADOW%20FLICKER%20MONITORING%20AND%20MITIGATION%20INFORMATION.pdf

year at a residence, the turbine is stopped and remains off until the period of shadow flicker is over.

C.3 Background information on Safety Setbacks (Ice/Debris/Blade Throw)

Ice throw, blade failures, and turbine collapse can result in turbine debris being flung considerable distances from the turbine base, especially on hills and ridges with updrafts.

Ice Throw: Project developers often represent that operating wind turbines are equipped to sense any imbalance in the system due to ice build-up and shut-down, however, this is not always the case. According to Seifert et.al[11]:

> *"There is significant evidence that rime ice continues to form when the turbine is operating and is not shaken off by blade flexing, even though this may be the case for other types of ice formation. Also, rime ice formation appears to occur with remarkable symmetry on all turbine blades with the result that no imbalance occurs and the turbine continues to operate."*

GE Wind[12] states that rotating turbine blades may propel ice fragments up to several hundred meters if conditions are right depending on turbine dimensions, rotational speed and many other potential factors.

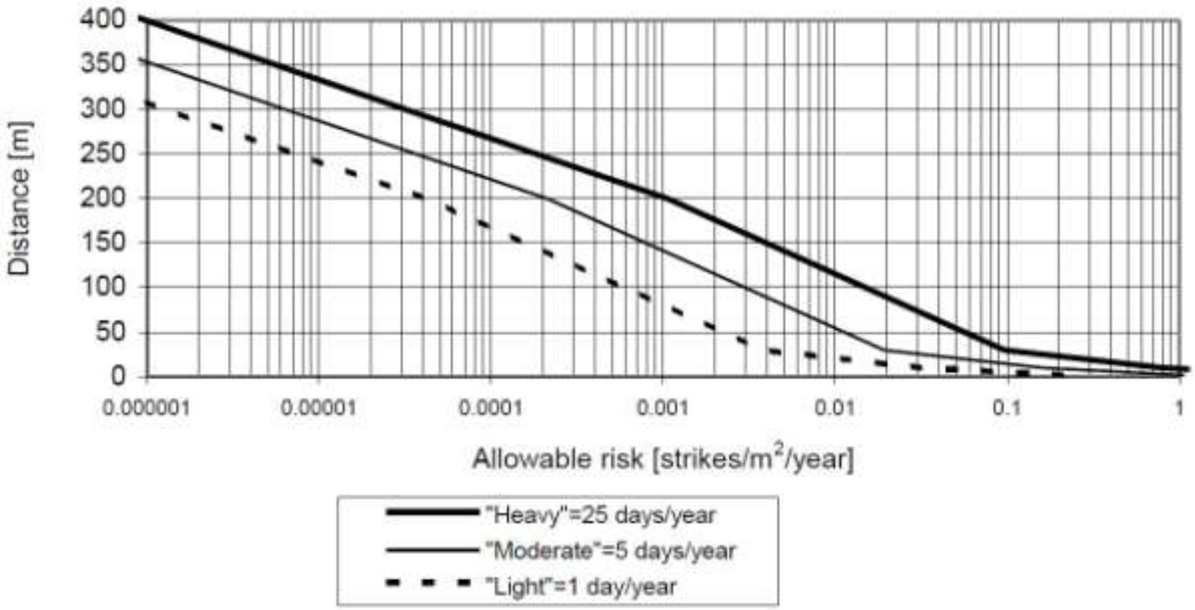
Estimates of icing risk are also reliant on the number of days in a year when ice events might occur. In colder climates, icing can occur during non-winter months.

According to meteorologist Fred Ward, there is a lack of icing data for elevated structures on hills and ridges in New Hampshire other than for Mount Washington. Rime icing is elevation dependent and there may be additional effects due to wind flow over isolated peaks. As more turbines are sited in cold climates, the wind industry has considered safety distances based on the level of allowable risk. The figure below maps safety distances from the turbines based on

[11] Morgan C., Bossanyi E., Seifert H., "Assessment of Safety Risks Arising From Wind Turbine Icing" 31 March - 2 April 1998, Hetta, Finland http://arcticwind.vtt.fi/boreasiv/assessment_of_safety.pdf

[12] http://site.ge-energy.com/prod_serv/products/tech_docs/en/downloads/ger4262.pdf

the estimated annual icing events at the project site and degree of risk.



Very little public information is available that documents the frequency of ices throw and the distances flung from the turbines. Surveys have been conducted of large project operators in an effort to track the size and distance of ice fragments being thrown but the results are inconclusive as there is no way to assess how well the area around the turbines was searched, especially at great distances from the towers.

Component Failure: Turbines are complex machines that can fail. Total collapse and blade shred/shear are two examples. In any case, components of the turbine can be thrown a distance from the turbine base. It is more difficult to assess the problem as it depends on the type of failure. Turbine manufacture, Vestas, has reported debris thrown from its V90 turbine 1,600 feet[13].

Simple math[14] describing motion shows that ice or debris from a 100-foot long blade can be thrown nearly 1700 feet from the base of the turbine. Distance is dependent on the length of the blade, the angle of the blade at the time of the incident, the speed of rotation and the vertical distance from the ground.

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[13] Jensen, Chris NHPR *Expanding Balsams Ski Resort Money Jobs And Regulatory Challenge* retrieved at http://nhpr.org/post/expanding-balsams-ski-resort-money-jobs-and-regulatory-challenge

[14] Matilsky, Dr. Terry Windmills: Basic Kinematics retrieved at http://xray.rutgers.edu/~matilsky/windmills/throw.html

The certificates for the three operating wind facilities in New Hampshire, Lempster Wind, Granite Reliable Power (GRP) and Groton Wind, impose different safety distances. In the case of GRP, the SEC defined a safety zone around the turbines. For Lempster Wind and Groton Wind, actual setback distances were defined in the respective town agreements and subsumed into the certificate.

Project	Distance to property line	Distance to occupied building	Distance to public roads	Notes
Lempster	1.1x height	3x height	1.5x height	Town agreement
GRP	--	--	--	1300-foot[15] safety zone around the turbines; public discouraged
Groton	1.1x height	3x height	1.5x height	Town agreement; 524-foot safety zone for Iberdrola employees

Mr. William K. Palmer, a utility reliability engineer responsible for analyzing the impact on public safety at a nuclear facility in Ontario Canada explained to the work group the importance of assessing risk of injury/damage from a deterministic perspective. As a general rule, deterministic risk assessments require the analyst to assume that a person is permanently standing at the limit of risk (edge of the safety zone), and is considered to be there during the accident. Thus, a deterministic risk assessment for a wind turbine will determine an effective mitigation safety zone that prevents a member of the public from wandering into the zone of accident impact.

C.4 Background information on Transmission Siting and EMF

Different states have taken different approaches regarding EMF when siting large transmission projects. The following paragraphs briefly detail how some address EMF exposure when siting lines greater than 69kV[16].

[15] *Mechanical Operating and Maintenance Manual* for the Vestas V90 3.0MW turbine which defines a "radius of 400m (1300 ft) from the turbine" as necessary to ensure safety. Vestas has since removed this reference in the manual. The company now states that responsibility for public safety lies with the permitting bodies.

Massachusetts

The Commonwealth of Massachusetts has defined an edge-of-ROW level of 85 mG as a benchmark for comparing different design alternatives. Although a ROW-edge level in excess of this value is not prohibited, it may trigger a more extensive review of alternatives.

New York[17]

New York has a policy that requires transmission lines to be designed, constructed and operated so that magnetic fields at the edges of the ROW will not exceed 200 mG.

Florida[18]

Florida limits magnetic fields at the edge of the ROW to 150 mG for transmission lines with voltages of 69 kV through 230 kV. For lines greater than 250 kV, the limit is 200 mG. Double-circuited 500 kV lines and lines greater than 500 kV may not exceed 250 mG, also at the edge of the ROW.

Wisconsin[19]

Wisconsin has not set hard limits on EMF levels but the state has taken the position that the public has a right to know details about EMF levels. The application process requires project proponents to provide the following information:

a) number and type of each building within the following distance categories – as estimated from the centerline: 0-25 feet, 26-50 feet, 51-100 feet, 101-150 feet, and 151-300 feet. Types of buildings include homes, apartments, schools, daycare centers, hospitals, and commercial/ industrial buildings.

b) detailed magnetic field profiles for each unique structure type or circuit configuration (new and existing) with the exception of dead-end structures adjacent to substations.

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[16] It's important to note that EMF is directly tied to the amount of current flowing through a line. Lower capacity lines (69 kV) can show high levels of EMF while some 115kV lines may have lower levels of EMF.

[17] State of New York Public Service Commission, *Statement of Interim Policy on Magnetic Fields of Major Electric Transmission Facilities, Cases 26529 and 26559*, Issued and Effective September 11, 1990.

[18] Florida Administrative Code 62-814.450.

[19] http://psc.wi.gov/utilityinfo/electric/construction/documents/transmissionLineAFR.pdf

c) for routes that would affect existing electric lines, provide magnetic field profiles for the existing lines and a post-construction scenario that incorporates the new and the existing lines.

d) for routes that would have multiple adjacent underground circuits, provide magnetic field profiles for each set of circuit configurations.

e) estimated magnetic field data which includes:

- estimate for proposed lines at 80 percent and at 100 percent of peak load for one year post-construction and 10 years post-construction. For existing lines, use present day loadings to estimate the magnetic fields levels.
- provide expected current levels for 80 and 100 percent of peak load at one and ten years post-construction.

f) Provide all assumptions used to model magnetic field levels including:

- Phase ID and angles.
- Pole design diagram that includes the dimensions of pole arms, dimensions of conductor locations, horizontal distance from the pole to the conductors, and the distance of conductors from the ground at the pole.
- Height of lowest conductor(s) at mid-span.
- Depth from ground surface to circuits, for underground construction.

This information is then available to the public and considered by the Commission in its route selection decisions. In some respects, EMF exposure has become a proxy for property value impact. [20]

California[21, 22]

The California Department of Education requires minimum distances between new schools and the edge of transmission line rights-of-way. The setback guidelines are: 100 feet for 50-133 kV

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[20] Kenneth Rineer, personal communication with L. Linowes June 2, 2014).

[21] Electric And Magnetic Fields Measurements And Possible Effect On Human Health — What We Know And What We Don't Know In 2000 http://www.ehib.org/emf/longfactsheet.PDF

[22] California Department of Education Power Line Setback Exemption Guidance, May 2006. http://www.cde.ca.gov/ls/fa/sf/powerlinesetback.asp

lines, 150 feet for 220-230 kV lines, and 350 feet for 500-550 kV lines. These limits are not based on specific biological evidence, but on the rationale that the electric field drops to background levels at the specified distances.

The California Public Utilities Commission (CPUC), recommends that state investor owned utilities carry out “no and low cost EMF avoidance measures” in construction of new and upgraded utility projects. This means that 4% of the total project cost is allocated to mitigation measures if these measures will reduce magnetic field strength by at least 15%.

Connecticut[23]

The Connecticut Siting Council adopted a precautionary policy, in place since 1993, which includes establishing a standard method to allocate funds for MF mitigation. The Council follows California’s cost allotment strategy for no-cost/low-cost MF mitigation of 4% total project cost is to help reduce magnetic field strength by at least 15%.

As part of the application process, proponents are required to provide design alternatives and calculations of MF for pre-project and post-project conditions, under 1) peak load conditions at the time of the application filing, and 2) projected seasonal maximum 24-hour average current load on the line anticipated within five years after the line is placed into operation.

MF values are to be calculated from the ROW centerline out to a distance of 300 feet on each side of the centerline, at intervals of 25 feet, including at the edge of the ROW at 1 meter above ground level. Calculations shall assume “all lines in” and projected load growth five years beyond the time the lines are expected to be placed into operation, and shall include changes to the electric system approved by the Siting Council and the ISO-NE.

The applicant must also provide the locations of, and anticipated MF levels encompassing, residential areas, private or public schools, licensed child day care facilities, licensed youth camps, or public playgrounds within 300 feet of the proposed transmission line.

Vermont[24]

[23] Electric and Magnetic Field Best Management Practices For the Construction of Electric Transmission Lines in Connecticut December 14, 2007 http://www.ct.gov/csc/lib/csc/emf_bmp/emf_bmp_12-14-07.doc

[24] Position Paper On Electric And Magnetic Power Frequency Fields And The Velco Northwest Vermont Reliability Project. Vermont Department Of Health December 15, 2003

The State of Vermont[25] Department of Health has adopted the policy of prudent avoidance as initially outlined in the state's Twenty Year Electric Plan (1994) in order to mitigate EMF exposure. Taking no action, according to the department, would not be commensurate with the evidence that some risk may exist.

World Health Organization[26]

The World Health Organization position on EMF resembles that of states which have adopted a no-cost/low-cost MF mitigation policy. The following text is taken from the WHO's guidance on EMF:

- Government and industry should monitor science and promote research programmes to further reduce the uncertainty of the scientific evidence on the health effects of ELF field exposure. Through the ELF [extremely low frequency] risk assessment process, gaps in knowledge have been identified and these form the basis of a new research agenda.
- Member States are encouraged to establish effective and open communication programmes with all stakeholders to enable informed decision-making. These may include improving coordination and consultation among industry, local government, and citizens in the planning process for ELF EMF-emitting facilities.
- When constructing new facilities and designing new equipment, including appliances, low-cost ways of reducing exposures may be explored. Appropriate exposure reduction measures will vary from one country to another. However, policies based on the adoption of arbitrary low exposure limits are not warranted.

Aside from the public health question, establishing siting rules regarding EMF levels may limit undue delay when considering transmission applications before the SEC.

Consider SEC docket DSF 85-155[27] from September, 1986 where the SEC reviewed Hydro Quebec's application to construct a 140-mile DC transmission line through the state. After seventeen days of hearings and extensive cross-examination of five expert witnesses on the

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[25] http://healthvermont.gov/enviro/rad/documents/VELCOtestimony.pdf

[26] Electromagnetic fields and public health. World Health Organization (June 2007) http://www.who.int/peh-emf/publications/facts/fs322/en/

[27] http://www.nhsec.nh.gov/1985/documents/091686_findings.pdf - Hydro Quebec's application to construct a 140-mile DC transmission line through the state

topic of public health, the SEC found that no health impact but also agreed to the stipulations prepared by the parties which included, in part:

- New England Hydro shall conduct studies related to existing ambient static electric and magnetic fields and ion level monitoring shall be performed for a period equal to at least 1 full year prior to energizing of the line; Studies of ambient air ion levels and static electric and magnetic field concentrations shall be conducted for a period of no less than 2 consecutive years;
- New England Hydro shall undertake an investigation of the feasibility of a long-term epidemiological study. The Company is obligate to conduct the human epidemiological study should it be deemed feasible by the Site Evaluation Committee and the Public Utilities Commission upon such terms and conditions as they deem advisable.

C.5 Other References

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