STATE OF NEW HAMPSHIRE

BEFORE THE SITE EVALUATION COMMITTEE

Docket No. SEC 2015-02

<u>APPLICATION OF ANTRIM WIND ENERGY, LLC</u>
<u>FOR A CERTIFICATE OF SITE AND FACILITY</u>

PREFILED DIRECT TESTIMONY OF Dr. FRED WARD
ON BEHALF OF THE METEOROLOGICAL INTERVENORS

21 May 2016

Q. Please state your name, title and business address.

A. My name is Fred Ward. I am a meteorological consultant. My business address is P. O. Box 1529, E. Arlington, MA 02474.

Q Briefly summarize your educational background and business experience.

A. I have a Bachelor (1952), Master (1955), and a PhD (1957) in Meteorology from MIT. I was a research meteorologist for the Air Force Geophysics Laboratory (1952-79), including peer-reviewed papers in astronomy and astrophysics, TV meteorologist on Ch 7 in Boston (1963-69, 1972-79), founder and CEO of WSI Corporation (1977-83), Founder and CEO of Advertiming, Inc. (1983-88), and a meteorological consultant (1967 – date).

Q What is your role in the Antrim Wind Project SEC 2015-02?

A. I live about two miles SW of the proposed facility, and will see it every day. I am a meteorologist, with expertise in a wide range of meteorological areas and the data which describes the weather, and in particular, the meteorology of the visibility of distant objects, noise generation and propagation, the effect of sunshine on people and vehicles, the relationships between various meteorological variables at different locations and elevations, the variability of meteorology and its effects as a function of topography and height, the interactions between meteorology and energy production and distribution, and with the effects of natural and man-made influences on the earth's climate. I have substantial experience in the effects of weather on business and the advertising thereof, the frequency of occurrence of various meteorological events and their effects on the earth's surface, the astronomical factors affecting the weather and the earth's surface and am facile in geometry and trigonometry.

Q. What is the purpose of your testimony?

A. To explain the effects of the meteorology, astronomy, topography, and elevation and their interactions, and the totality of their effects on the proposed wind facility.

Q. What is your first example of their effects on the proposed facility?

A. My first example is the effect of the correlation of wind speeds over wide areas. Everyone knows that there are windy days, and there are breezy days and there are calm days. The average wind in New Hampshire is about 10 mph, but there are many days when the wind speed is 25-50 mph. Wind turbines are at the mercy of Mother nature, sometimes generating their maximum rated power, sometimes generating no power at all. Modern turbines, huge turbines one-tenth of a mile high, are about 1/3 efficient. When it's windy, these turbines generate their rated 3 Mw of electric power. At other times they hang still, not contributing a single watt of electricity. 1/3 efficiency means they will generate an AVERAGE of only 1 Mw of electric power. At any particular time, a 3 Mw turbine will actually produce somewhere between 0 Mw and 3 Mw.

A meaningful substitution of wind energy for fossil fuel energy requires enough wind turbines to generate a large fraction of the energy produced by a big nuclear, coal or hydro plant. Each of these plants generate about 1000 Mw, day and night, day in and day out. Simple arithmetic shows that replacing a single one of these plants, would require 1000 huge wind turbines, each rated at 3 Mw maximum, but averaging 1 Mw.

On a windy day, when the turbines generate their maximum rated power, 1000 3 Mw turbines will actually generate 3000 Mw. This 3000 Mw is however, equivalent to a large fraction of the ENTIRE electric generating capacity on the ISO-NE grid, and three times the generating capacity of any large generator currently on the grid, including Seabrook, Plymouth, Bow, etc. This is the generating power that wind turbines absolutely need to provide, in order to balance off the days with no wind, and no power. If the grid cannot, or will not, accept this power surge, the turbine efficiency craters, and wind power becomes moot. The only way the grid could handle such surges would be to shut off the power from their main nuke, coal and hydro sources, or to refuse to accept the wind power at just those times when the turbines are most efficient. Either route leads to a dead end, a short circuit!

This leads to the obvious meteorological question, how often will the winds conspire to get 1000 turbines scattered over the hills of New Hampshire or New England, operating at or near their maximum capacity? An analysis of the National Weather Service stations over New England shows the answer is OFTEN, maybe once or twice each week. When the winds at one Industrial Wind facility (IWF) in New Hampshire are strong, the winds at all the other IWFs will be strong too. This means that the cumulative effect of authorizing IWFs in New Hampshire will rapidly choke the ISO-NE grid. This choke point depends on how many turbines are authorized in each facility, but it is certainly less than 100 huge turbines. Worse, IWFs generate their electric power predominantly at night when demand is at a minimum. An interesting facet of turbine operation is that the turbines generate maximum (rated) power with winds at about 18-20 mph, and higher wind speeds add no additional power. This characteristic means that the correlation between the power output from one wind facility in New England to another will be much higher than the already high correlation of the measured wind speeds. The intensity and frequency of these grid-blowing surges will be substantial.

In order to generate a significant amount of clean(?) power, say 10-20% of the average power in New England, many hundreds of large turbines are required. Generating 10%-20% of our average power means that these (1/3 efficient) turbines will actually generate between 0% and 60% of the average power from all other sources. No system can accept even a fraction of this 30%-60% of the AVERAGE system power.

Q. What is another effect that this proposed facility will have on its neighborhood?

A. The Visual Impact of a facility, a mile long and one-tenth of a mile high is simply not comprehensible in a simple picture, and only comprehensible in real life from a very few locations, none close by. Parts of it will be visible from many different points, with each view different from all the others, and each view, even from the same place, different each time.

Since much testimony has been given on the subject of VISUAL IMPACT, it is proper to consider the factors which affect that impact. There are actually two separate sets of factors and they interact. There are factors which affect how impressive the facility will be when it is viewed, and equally important, there are additional factors that will affect the tendency for passers-by to actually turn to view the facility? These questions become especially relevant since the SEC rules imply that a simple picture, taken under specific conditions, will not only suffice, but will convey the two sets of issues listed above. To demonstrate the absurdity of the SEC rules, I suggest treating IWFs as advertising billboards. REFERENCE (a)

What might an advertiser consider if planning to buy space on a particular billboard? And what might the billboard owner charge for such an ad? Let's consider the possibilities. The placement of the billboard in a prominent location would certainly be at the top of the list. Would an isolated hill be preferable to the bottom of a swamp? Would a huge billboard be preferable to a tiny one? Would a colorful display lure more than black and white? Would lighting be seductive? Maybe flashing lights? How about some motion? Maybe Eine Kleine Nachtmusik, or other sound effects? How about one with constant motion, maybe even one where the motion is different from day-to-day? I have the North Carolina Valuation Guide for Billboard Structures for 2015. It lists all the factors which go into how valuable a billboard actually is. Among those factors are the size, with large more valuable than small, display position, illumination or no, electronic/digital face or no, and height above ground level.

This omits the constantly changing and never reproducible perspective! It also omits the "attraction" that music or noise has on the decision to look. Trying to judge the visual impact from a simple (still, silent) picture is madness.

Q. How does meteorology factor into noise production and its propagation to its neighborhood?

A. The question of noise separates into two parts, the amount of noise generated by the turbine itself, and the extent and volume of its broadcast to the neighborhood. Both are functions of the meteorology of the hill/ridge and its surrounding area. Wind speed and wind shear seem to be the main factors determining the noise of the turbines, while the low-level temperature structure is an added factor determining the area and intensity of the noise.

An important, partly meteorological factor, is the nocturnal maximum in the wind speeds over elevated ridges and hilltops, leading to the nighttime surges in power output from the turbines. This nighttime maximum is apparently due to the decoupling of the winds near the surface from those a thousand or more feet above the ground. This nocturnal behavior in the wind speed is likely to be coupled with changes in the wind direction also.

The SEC requires the applicants use the ISO publication 9613-2 to determine the extent and intensity of the noise broadcast. However, the publication requires the user to be aware of its limitations, and adjust for them. The adjustments however are hard to determine, and the formulae in the publication do not apply to the worst case meteorological situations. These limitations are clearly stated in the publication, so there is no reason to slavishly follow them when they are demonstrably inapplicable. The applicant is required to determine the "worst case", and ISO 9613-2 does not yield the "worst case" result. This requires manipulation of ISO 9613-2 to convert its numbers to those required by the SEC.

There is another meteorological factor which is critical to any analysis of noise, and which ISO 9613-2 defines as G. It is the reflective value of the ground between the turbine and its neighbors. Sound waves travel out from the turbines like an expanding sphere, up, down and sideways. The meteorology of the atmosphere in the lower 1-2 thousand feet can seriously limit the upward spread. The temperature inversions on most nights in NH will form a "duct" keeping sound from going upward. The reflectivity of the ground can either absorb the sound as it travels, or reflect it and send it along unabsorbed. Water and ice surfaces are excellent reflectors of both light and sound, like mirrors. This means that there are many meteorological factors to be considered, all are listed in ISO 9613-2, and all are required in order to determine the worst case sound generation and broadcast to the neighborhood. A cursory inspection of the official meteorological data publications shows that the Antrim area has a snow cover every day for many months of every year. A further perusal of these same publications shows that on many of these days, the snowpack will have an ice frosting.

These days follow either significant melting/refreezing or some rain and refreezing. This means that the G factor is close to zero on many days of winter in Antrim, substantially extending the area over which turbine noise will be a problem and increasing the noise level at all surrounding neighborhoods. REFERENCE (b)

Q. What is another effect this proposed facility will have on its neighborhood?

A. There will be an effect called "shadow flicker", which is a misnomer. The effect would be more accurately labeled "shadow vibration", since it is a regular, timed flashing. I will explain.

The shadow of a backlit object is projected in front of the object (e. g. a wind turbine) for a distance which is determined by the geometry of the object, its (back)lighting and the placement of the observer in front. Shadow flicker requires that the motion of the turbine blades pass in front of a fraction of the solar disk, with the motion of the blades regularly causing a diminution of the sunlight reaching the observer. This alternating diminution occurs only when the sun is at a low angle, just rising, or setting, over the hill on which the turbine is located. Its elevation with respect to the observer depends on the difference in elevation between the observer and the turbine. Both the cloudiness obscuring the sun and the solar intensity are functions of this elevation, and require accurate correction factors. The secrecy surrounding the model which calculates these corrections makes their evaluation difficult.

The alternating shadows and light appear to move with the motion of the blades, their velocity determined by blade motion, multiplied by a factor related to the distance between the turbine and the observer (the sun's distance is a negligible factor at 93 million miles). As the distance between the obscuring turbine and the observer increases the shadow remains, moving ever more rapidly, and the outline of the shadow becomes larger and more diffuse. The shadow velocity and its diffuseness continue to increase until the circle of the turbine appears smaller than the solar disk, approximately ten miles distant. At that point the turbine obscuration diminishes steadily as the turbine appears smaller and smaller compared to the (one-half degree) solar disk.

As the distance from the turbine to the observer increases, and the turbine shadow becomes larger, its shadow and its motion are still apparent, but observation of the shadow edges requires that they be observed from longer distances. The shadow of a cloud for instance, including its edges, can be seen from a distance, moving across the landscape, but an observer out on that landscape will experience only a gradual diminution and brightening, and will not be able to distinguish a sharp edge to the shadow. SEC Site 102.48 requires only "alternating changes in light intensity" and "cast moving shadows on the ground..." Both of these requirements are met many miles from the facility.

Turning to the "corrections" for cloudiness and the orientation of the turbine blades with respect to the observer, there are a number of meteorological factors which need to be considered. The "prevailing" winds at, and above, 2000' will be much more westerly that the wind roses at the ground level weather stations at airports, guaranteeing that there will be neighbors west, southwest and northwest of the facility who will experience the orthogonal orientation, which is optimal for shadows, much more often than the surface wind roses indicate. Moreover, since cloudiness is minimal with westerly winds, there will be a high correlation between the orientation produced by these westerly winds and clear skies, also guaranteeing that the shadow flicker "correction" substantially overstates the diminution by clouds. This means that morning observers to the west, southwest and northwest of the facility will experience a much increased frequency of flicker, and the distance (in that direction) at which flicker will violate the standard will also be much longer. This requires the "shadow flicker" model be run out many miles, and the "correction" for clouds and orientation be extended as well.

There is an additional potential shadow flicker problem which has not been addressed to date. Since Site 102.48 says "cast moving shadows on the ground", there is an issue resulting from the total reflection of shadows from ice-covered ground, and water bodies. These shadows will be reflected, with little diminution in intensity, far and wide, and cause flicker problems very similar to those shadows which travel directly. There will be lots of ice-covered, and reflective, ground available in the Antrim area for many months, every year.

I have been retained as an expert to testify in court on the effect of low sun angle radiation in the eyes of car and truck drivers. This problem is also noted by "warning solar glare" signs on our highways. Solar glare is a significant traffic safety problem. I have not yet been asked to testify on solar glare which was exacerbated by shadow flicker from a wind turbine. Driver adaption would be almost impossible. REFERENCE (c)

Q. Are there other meteorological factors which should be better addressed?

A. Yes. Icing and Sun Glint.

Icing on the turbine blades may or may not be an issue depending on its frequency, and the meteorological conditions that cause the icing, and its subsequent melting and throwoff. There will be preferable meteorological conditions, especially wind direction and speed, which will be associated with icing, both its intensity, its frequency of occurrence and its throwoff. That means that there will be preferential areas around the turbines which will experience frequent ice throwoff. Depending on the association of wind directions and speeds with these occurrences of ice throwoff, certain neighbors will experience substantially more frequent, and significantly more dangerous ice throwoff from the turbines.

The question of sun glint arises because wet or icy blades are almost perfect reflectors of sunlight shining on them at low incidence angles. If all the blade surfaces are flat, and remain in a non-feathered state, these reflections could be calculated straightforwardly. However, since the operator claims to be able to feather them, and since pictures of these blades show definite curvature, the reflections are more difficult to determine, are not restricted to low sun angles, and can occur any time during the day. These reflections might even be concentrated by concave surfaces. The safety concerns for drivers on nearby roads would be similar to, but much more difficult to adapt to, the usual low sun-angle reflections on many roads, and be much less predictable. Low sun-angle light is difficult in any case, sun glint is bound to occur at these same low sun angles.

Q. Does this conclude your pre-filed testimony?

A. Yes

REFERENCES:

(a) Billboard Structures Valuation Guide, North Carolina Department of Revenue, 2015.
This lists many factors which affect the value of a billboard, and hence the value of the messages contained thereon.

(b) Environmental Review Tribunal, Case No. 15-068/15-069, Reply Witness Statement of Dr. Paul Schomer
A detailed description of the meteorological and topographical factors which substantially affect the generation and broadcast of noise to the surrounding neighborhood. It also demonstrates the inapplicability of ISO 9613-2, and the many factors which the AWE proposal ignores. It shows that the "worst case" noise problem is highly dependent on meteorological and topographical descriptors, and can vary significantly from any ISO 9613-2 calculations.

(c) Letter to Chair Honigberg, 15 September 2015
An interesting comment on shadow flicker problems and their possible amelioration, at the expense however of overall efficiency.