BEFORE THE OHIO POWER SITING BOARD

In the Matter of the Application	**)**	
of Champaign Wind LLC for a	**)**	
Certificate to Install Electricity	**)**	**Case No. 12-0160-EL-BGN**
Generating Wind Turbines in	**)**	
Champaign County	**)**	

DIRECT TESTIMONY OF WILLIAM PALMER ON BEHALF OF INTERVENORS UNION NEIGHBORS UNITED, INC., ROBERT AND DIANE McCONNELL, AND JULIA F. JOHNSON

Q. Please state your name and business address.

A. My name is William K.G. Palmer. My address is TRI-LEA-EM RR 5, 76 Sideroad 33/34 Saugeen, Paisley, Ontario N0G 2N0 Canada.

Q. What is your occupation?

A. I have been a Professional Engineer in the Province of Ontario since 1973.

Q. What is your educational background?

A. The education that is relevant to this testimony includes:

- I am graduate of Stanstead College, Stanstead Quebec, holding the Governor General's Medal and the Spofforth Trophy for Excellence in Science and Mathematics;
- I graduated from the University of Toronto, with a B.A.Sc. degree in Electrical and Electronic Engineering (1971), (with Thesis work in Biomedical Engineering related to human health); and
- I have completed formal courses related to public safety and risk assessment at the Massachusetts Institute of Technology (MIT) (in 1995 and 2000).

Q. What professional licenses or certificates do you hold?

A. I am licensed by the Ontario regulatory body, Professional Engineers Ontario, as a Professional Engineer, and hold a Certificate of Authorization from Professional Engineers Ontario to provide Engineering Services to the public.

Q. Are you a member of any professional societies?

A. I am a Senior Member of the Institute of Electrical and Electronic Engineers (IEEE), a member of the Social Implications of Technology Subgroup of the IEEE, a member of the Canadian Nuclear Society, the Canadian Acoustical Association, and the Acoustical Society of America.

Q. Please describe your occupational experience with safety issues for industrial facilities, or with responsibility for public safety.

A. Experience directly related to presenting evidence in this review was initially derived from over 3 years engineering employment with Noranda Mines Limited, Geco Division, where I was employed as Electrical Project Engineer, which provided related opportunities:

- to deal with safety in industrial operations of an underground mine and an industrial plant,
- with responsibility for communication and control systems, involving the design, installation and commissioning of large industrial equipment;
- with responsibility for the design and commissioning of environmental systems.

Further directly applicable experience was derived during over 30 years employment with Ontario Hydro Nuclear and its successor companies, Ontario Power Generation, and Bruce Power. This provided many opportunities related to the area of public safety, industrial operation of a large electrical generating plant, and risk assessment in the following:

- commissioning gas turbine generators, standby power systems, and switchyard;
- writing emergency operating procedures;
- monitoring the performance of systems and reporting on system reliability;
- in authorization and experience as a Nuclear Shift Supervisor responsible for the on shift operation of a 3200 MW electrical nuclear generating station, requiring expert knowledge in subjects such as:
    - public safety;
    - radiation safety;
    - system operation;
    - report writing;
    - employee safety;
- as Training and Safety Superintendent I was responsible for:

- all employee conventional safety programs;
- all employee training programs, including safety training, and the training of subsequently authorized nuclear operators and shift supervisors;
- approval of all training documentation used for the authorization training program;
- development and personal delivery of training in Operating Policies and Principles to authorized staff, engineering staff, and executive staff;

- as Technical Superintendent responsible for Physics, Chemistry and Reliability, I was:
  - responsible for development of models for and the use of the models for the monitoring of reliability and public safety risk posed by systems;
  - responsible for the safety of refueling reactors, and all chemistry analyses;
- as Technical Superintendent for Reactor Safety, I was:
  - responsible for Operating Experience, and investigating the root causes of accidents and malfunctions;
  - responsible for the Bruce Safety Report, describing the public safety risk posed by system malfunctions, operating errors, and accidents;
  - responsible for assessing the implications of any changes on public safety;
  - chosen to deliver training for the International Atomic Energy Association (IAEA) related to public safety to international staff filling shift supervisor and senior positions at international nuclear facilities;
- as Assistant to the Station Director, I was responsible for preparing and making presentations related to public safety and plant refurbishment;
- as Section Manager responsible for Reactor Safety, I had ongoing responsibilities related to public safety and regulatory interface;
- as Section Manager responsible for Performance Assurance, I was:
  - responsible for public safety assessments at Bruce, Darlington, and Pickering Nuclear Generating Stations as a Peer Evaluator, chosen to evaluate the operation of other facilities for identification of improvements to operations performance. Qualified as a Performance Assurance Assessor and Peer Evaluator;

    - responsible for the risk assessment supporting the restart of Bruce Nuclear Units 3 and 4, chosen to train the contract staff performing the risk assessment, and supported development of the Public Safety sections of the environmental assessment supporting restart of Units 3 and 4.

Q. Please describe your professional experience with safety issues for wind turbines.

A. Since accepting early retirement from Bruce Power in 2004, the opportunity has presented itself to apply knowledge of public safety, operating experience, and reporting of public safety risk to the study of the impacts of wind turbines. I have contributed to the knowledge and understanding of the public safety risk posed by the installation of wind turbines in Ontario and the implications of noise emissions from wind turbines and their associated supporting equipment by undertaking the following activities:

- I provided input based on my professional experience and training to the Ontario Ministry of the Environment on a number of occasions:

    - related to reviews the Environmental Screening Reports of a number of wind turbine projects;

    - related to the public safety impact of wind turbine accidents;

    - as a participant with Ministry of Environment staff in Stakeholder Workshops; and

    - through direct submissions to the Minister of the Environment through correspondence, and submissions through the Environmental Registry.

- I also provided direct input to the Minister of Energy and Infrastructure through formal submission letters, face to face meeting, via the Ministry of Energy Website, and through input to the Environmental Registry.

- I have been a Participant or Party at a number of Ontario Municipal Board (OMB) hearings related to wind turbines, including giving input to the OMB hearing related to the CAW Wind Turbine in Port Elgin. I have presented evidence to the Environmental Review Tribunal (ERT) studying the impact on serious harm to human health posed by the Kent Breeze Wind Farm.

- I have had the opportunity to study at first hand setbacks from wind turbines to roads and residences at the majority of Ontario installations, in the province of Quebec, in several states of the United States, and at many international installations (including Denmark, Germany, France, the United Kingdom, Poland, Spain, Greece, Sweden, the Netherlands, Ireland, and New Zealand).

Q. Please identify some of your professional publications and presentations related to the topic of public safety, including wind turbine safety.

My publications and presentations related to this subject matter include:

- Directly responsible for issuance of Quarterly Technical Reports of Bruce Nuclear Generating Station A, which calculated the public safety impact of operation of the facility, using established engineering risk assessment methods;

- Directly responsible for audit reports related to operation of nuclear facilities;

- Presentation to Canadian Nuclear Society on the Bruce A Probabilistic Risk Assessment for Unit 3 and 4 Restart jointly with Mr. Peter Walsh of NNC Inc (UK), and Dr. Elisio Chan of Bruce Power representing the team effort;

- Submission to the Environmental Registry 011-1039, Re Kent Breezes Wind Project, Comment ID 128230, filed via Environmental Registry;

- Submission of Briefing File to Minister of Energy and Infrastructure on the concerns related to industrial wind turbines in Ontario, January 2009;

- Presentation to the Legislative Assembly Standing Committee for General Government investigating the Ontario Green Energy and Green Economy Act, April 2009;

- Submission to the Environmental Registry 010-6516 and 010-6708 related to the Proposed Regulations for Ministry of Environment Regulations for the Green Energy and Green Economy Act, 2009;

- Submission of "An Evidence Based Examination Of Factors Affecting Annoyance &Safety Concerns Related to Industrial Wind Turbines" using example of Clear Creek area, to the Minister of the Environment, Chief Medical Officer of Health, and Minister of Energy and Infrastructure, February 2010;

- Submission to the Minister of the Environment, "Working Together to Make Things Better" September 2010; and

- Submission to the Environmental Registry 011-0181 related to Proposed Amendments to OR 359/09 "Renewable Energy Approvals" November, 2010.

Q. Have you reviewed any portions of the Application of Champaign Wind LLC and the Staff Report that have been filed in this proceeding?

A. Yes, I have reviewed the portions of the Application and Staff Report related to blade shear and ice throw.

Q. What was the purpose of your review of these documents?

A. I reviewed the Application and Staff Report to determine whether they contain safety precautions adequate to protect the public from the dangers of blade shear and ice throw.

Q. What is blade shear?

A. Blade shear, or the more appropriate term, "blade structural failure" is when a wind turbine blade loses its structural integrity due to either an internal fault, or an externally applied load, resulting in the blade breaking. Throughout this testimony, I will refer to this problem as "blade failure."

Q, Why is a wind turbine blade failure of concern?

A. Each of the three wind turbine blades for one of today's modern wind turbines, as proposed for the Buckeye II Wind Project, are between 46 and 51 meters (150 feet and 167 feet) in length (see Exhibit J), and weigh in the order of 20,000 pounds. Although the wind turbine rotation looks like a slow 17.8 rpm, the blade tips are actually traveling at a velocity of about 212 miles an hour. The blade tips are as high as 150 meters (492 feet) above the ground, and have considerable energy if a part breaks off.

Q. What causes blade failure on wind turbines?

A. A wind turbine blade may break from a number of reasons. A common cause of blade failure is a lightning strike, as the blades are far above the ground and trees, and are a target for the discharge of the energy in the lightning bolt. Modern blades do have a conductive strip to conduct the energy to the rotor from where it is grounded to earth, but the energy can result in the splitting of the blade, and the split blade no longer performs the same as the intact blade, and can fail, as happened for example in the photo in Exhibit A (photo of failed turbine blade at Port Burwell) – which broke, sending parts of the structural center member to the ground. A second cause of blade failure is overspeed, as can occur if the circuit breaker which connects the wind turbine to the electrical grid opens (as can happen during a lightning storm or electrical fault). The wind incoming to the blade will then accelerate the wind turbine blade, which then bends, and may contact the tower resulting in tower collapse and blade destruction. A third cause of blade failure is manufacturing defect, as discussed in Exhibit K and C (Sandia Labs paper, and the Wind Power International Magazine article) as the blades demand a very high precision of construction, and the papers indicate that this is pushing the limits of the manufacturers. Yet another cause of blade failure, as referred to in Exhibit D (NREL Paper) is the fact that due to what is called wind shear, the velocity at the top of a wind turbine rotor circle may be more than twice the velocity at the bottom of the blade circle. As the energy in the wind is a function of the cube of the wind velocity, this means that the energy pushing on the blade can vary by a factor of 4 to 8 from the top of the blade circle to the bottom (see exhibit E – Wind Shear Effects) resulting in the blade flexing back and forth as it rotates, fatiguing the blade. The NREL report identifies the concern this may be the cause of blade failures that are otherwise unexplained.

Q. What general principles apply to the identification of safety precautions that apply to industrial facilities?

A. Deterministic safety analysis assures public protection from adverse impacts of a project by placing appropriate safety barriers to prevent failure modes that have a non-negligible frequency of occurrence from impacting a member of the public. A fundamental premise of deterministic safety analysis is that unless a member of the public is prevented from accessing a risk / danger zone, then it is necessary to assume that a member of the public will be in the location where the impact can occur. The safety barrier must be effective in preventing access, such as a locked fence, signed to identify the risk / danger zone that prevents access. An example of a *totally ineffective* safety barrier is shown in Exhibit F, where a sign that is illegible from a passing vehicle is posted on the side of a public highway that cautions the public to stay back 305 meters (1000 feet) from wind turbines (operating or shutdown) during potential icing conditions – yet there is no control fence, and the roadway itself is closer than 305 meters (1000 feet) to the wind turbine.

Q. How do these safety principles apply to the persons who reside on or visit land that has been leased as wind turbine sites?

A. As a premise of safety analysis, one must consider the implications of signed "participant agreements" in which a landowner contractually accepts risk from a wind turbine on his/her property. Society may permit a person to accept a higher degree of personal risk than is normal to the general public, as for example the risk that is accepted by a firefighter (within acceptable limits of workplace safety.) However, the government should not allow the increased level of risk from the contractual agreement to be imposed on vulnerable members of society such as spouses, children, live in grandparents, visitors, delivery couriers, or workers who may be employed on the property.

Q. What information have you used to identify the safety threats from wind turbines?

A. I have been personally tracking industrial wind turbine performance since the mid 1990's when the prototype industrial wind turbine in Ontario, a Tacke 600 kW wind generator with a 50-meter tower and 21-meter blades, was installed by Ontario Hydro at the Bruce Information Centre which I passed on a daily basis en route to work. I had taken part in a workshop on the design of wind generators on my own volition, knew the technician who was involved in the installation of the Tacke generator and communicated regularly with him discussing the machine performance. You might say that, like many other energy professionals, I found this wind generator to be fascinating, and from my background responsibility of reporting the performance of the Bruce Nuclear reactors, it was of professional interest and relevance. Shortly after Ontario Hydro was restructured in 1999 the wind turbine was allocated to a different branch of the company than the nuclear generators, and our routine communications stopped. Performance of the wind generator became commercially confidential information – and could no longer be shared. This was indeed foreign to those of us in the nuclear field where the industry had learned that sharing operational information through organizations such as the Institute of Nuclear Power Operators (INPO) and the World Association of Nuclear Operators (WANO) had been determined to be critical to ensure plant safety, so we all learned from each other. The wind business is different though, and information of failures has not been shared with other wind companies or with the public.

As a professional knowing the importance of sharing operational information, I have pursued other avenues to satisfy my quest for information about wind turbine safety. For years I have tracked publicly available information from citizen groups such as the National Wind Watch and the Industrial Wind Alert of the Wind action organization in the United States, and the Country Guardian Group in the United Kingdom. Additionally, I have tracked the industry information as available from the Wind Energy Weekly of the American Wind Energy Association (AWEA), and from the website of the Canadian Wind Energy Association (CANWEA).

Any assessment of public safety must determine the types of interactions with the public that could result in harm and to calculate the frequency of these events happening in a wind farm, and to those who may be impacted. Early public reports about wind turbine accidents have identified blade failures, tower collapse, and collapse of the nacelle (the enclosure at the top of the tower containing the generator and gearbox, if used), or having the entire rotor fall off as significant accidents.

I started to create my own listing of accidents replicating the sort of operational information tracked by the nuclear industry. In addition, several citizen groups track failures of wind turbine components, and I use that information to identify wind turbine failures. One of the best sources of information is the database of wind turbine accidents compiled by the Caithness Windfarm Information Forum[i] at www.caithnesswindfarm.co.uk, which is attached as Exhibit G. The Caithness group issues a comprehensive listing of failures quarterly, with the most current list issued for data ending September 2012. As a matter of fact, I have provided information about the details of wind turbine accidents that occurred in Canada to the Caithness Windfarm Information Forum, and am a supporting member of that group as it performs this valuable service. My assistance to Caithness assists the group in the regular updating of its database. I have excerpted information about some of the accidents on the Caithness database on a separate list, attached as Exhibit H to make it easier to identify the sort of accidents than can harm persons. However, my review of the Caithness database for purposes of preparing my testimony was not limited to the incidents in Exhibit H.

I augmented the information from this database by adding information about other turbine failures learned from other sources. For example, as I monitor the news of wind turbine performance, I make notes of accidents noted on news broadcasts, and I learned that when other persons discovered my interest, they too send me information sources they run across, which I verify before adding to my listing.

Q. Have you had the opportunity to learn about any new blade failure during the preparation of your testimony?

A. In the preparation for this hearing, I had the opportunity to review the report of the Vestas wind turbine failure at the EDP Renewables Timber Road II wind development in Ohio as reported to the Ohio Power Siting Board, available on the Board's web site and attached as Exhibit I. It was remarkable to read that, after one broken blade (determined to be due to a manufacturing defect) hit the wind turbine tower at 12:48 PM, a technician then remotely restarted the turbine. This resulted in the breaking of a second blade. The turbine continued to rotate until a technician arrived at 1:20 PM, over 30 minutes after the first alarm, and called the control center to put the failed machine into the pause state. This sequence of events offers little assurance that the control system responded correctly to either blade failure, since it should have shut down and prevented the restarting of the turbine after both failures. As one who has been responsible for preparing and assessing many reports of equipment malfunctions over my career in the nuclear power industry, it was incredible to read of the casual restart of the machine after failure, and to see how the control system failed to take the appropriate action to protect the public. It was also informative to learn in the report about the displacement of parts from the turbine over 3 kg (6.6 pounds) at a distance of 233 meters from the turbine. The report stated that the largest piece of turbine debris (called "Section J") was recovered at a distance of 233 meters (764 feet) but did not reveal how large this piece actually was. The report also failed to note how far pieces of blade debris smaller than 3 kg in weight traveled from the turbine.

As I mulled over the missing information, I was able to review the written testimony of Mr. Milo Schaffner in this case, in which Mr. Schaffner provides testimony that he found debris one foot by one foot in size at 1158 feet (over 350 meters) from the turbine tower, and blade pieces along the public road at a distance of 1561 feet (476 meters) from the turbine tower along the side of the road. The testimony of Mr. Schaffner provides detailed information about how he calculated the distance to the debris He reported debris at distances over twice the distance reported by the report filed by EDP Resources. This is a troubling example of the wind industry's reluctance to publicly report the actual impact of its accidents.

The Timber Road II blade failure reminded me of one of the first blade failures about which I was able to collect accurate information, a failure of a blade at the Port Burwell Wind Power development in Ontario. See Exhibit A. The local television news reporter filmed himself standing behind debris on the field at a distance from the wind turbine after a blade failed the night before. It was clear from the video on the news (photographed in Exhibit A) that the material on the ground was indeed a significant size. Yet, the next day, the Chief Executive Officer of the wind operator reported that the wind turbine blade had performed exactly as designed. He represented that the turbine had taken a lightning strike and had buckled, but had not separated from the tower. Yet, the news photograph clearly showed that the inner blade support structure had been thrown a distance from the tower.

Q. Do you consider the Caithness survey to be a reliable source of information about accidents at wind projects?

A. Yes. Routinely, during each quarter, I compare the list of accidents I maintain with the listing provided by Caithness, both to verify my list, and to ensure that Caithness has not missed any events. I will admit that it is rare that I identify an event that it has not identified, and I have never found an event on the Caithness list that was not actually publicly reported. They do an exemplary job of listing the source information for the events they list.

Q. Do you have any information showing that the publicly available records on wind turbine accidents, such as ice throw and blade shear, do not identify all of the accidents that have occurred at wind projects?

A. A problem noted by the Caithness Windfarm Information Forum and by Sandia National Laboratories Report SAND2006-1100[ii] (See Exhibit K) is that the wind industry does not maintain a comprehensive equipment failure database that is available for public (or government agency) assessment. The Sandia Laboratory report summarized the concern in this manner,

> The uncertainty associated with component life has direct bearing on the risk associated with a wind turbine project. The factors that affect the level of certainty are numerous and to some extent unique to the wind industry. First and foremost is the lack of data relating to component reliability. Turbine manufacturers maintain records of failures and wind farm operators maintain records of warranty claims and associated downtime, but this information is proprietary and is not accessible to the public.

Thus, while the information in the Caithness Windfarm Information Forum is carefully prepared based on available information from publicly available sources, and information in the database has been independently verified, it cannot be considered to include all failures, but only known failures that have been noted by the public press and some technical papers. One of my experiences illustrates this reality. At the Environmental Review Tribunal hearings in Ontario, I presented a report including two known failures of General Electric Wind Turbines in Canada in April 2007 and January 2008 based on known information, as reported in the Caithness Windfarm Information Forum.[iii] In his Supplementary Statement in response, William Holley, Chief Consulting Engineer, Wind Systems of GE Energy, noted[iv] that two additional wind turbine blade failures of GE wind turbines had occurred in Canada. These events were not in the Caithness listing, as they had not been reported in the public media.

As a professional who was responsible for the calculation of system reliability performance in the energy industry, I am very clear that to properly calculate the reliability of a system, one has to correctly count the actual number of failures in a period of time, to be able to calculate the number of failures per component year in service. A significant problem with the wind industry because of the lack of sharing of failure data as I note earlier, is that while the total number of failures is not publicly made available, or even shared among manufacturers, the industry is very forward in identifying the total number of MW of capacity installed, so the total number of turbines in operation can be calculated. As a result it is important when performing a reliability calculation for the evaluator to correctly assess the number of failures divided by the number of turbine years in operation to accurately determine a failure rate. Even as it is, examples as shown in the case of the GE wind turbines in Canada show that not all failures in locations where turbines are remote from people are counted. One can suspect that areas like Texas; home of the largest number of wind turbines in the United States suffers a similar fate, as turbines are quite a distance from people.

Compounding this problem is that while the fastest growth in wind turbine installations in recent years is in the countries of China and India, who between them at the end of 2011 constituted over 30% of the turbine capacity in service, there are no agencies routinely reporting turbine blade failure as there are in Europe, North America, and the Pacific region of Australia, New Zealand, and Japan. Thus when calculating wind turbine failure rates it is important that if one is not counting the failures, then one must not count the number of turbines for which failures are not regularly reported.

Q. Based on the publicly available information in your possession, how many accidents are known to have resulted in turbine blades falling from the turbine nacelle to the ground?

A. See the chart below.

Q. Based on publicly available information, has the rate of turbine blade failures decreased in recent years?

A. No, the rate of blade failures has stayed relatively constant. To illustrate this fact, I have counted the number of times that turbine accidents have caused blades to fall on the ground from the Caithness database of known accidents for the most recent months from January 2008 to September 2012. See the list in Exhibit L entitled Industrial Wind Turbine Failures.

Briefly summarizing, Exhibit G shows the following occurrences of failures that are known to have put full or parts of wind turbines on the ground from 2008 to September 2012.

	Year 2008	Year 2009	Year 2010	Year 2011	Year 2012
# Failures of Blades dropping 1 blade to ground at a distance from the turbine	9	8	9	6	11
Number of Fires resulting in burning parts of blade or nacelle dropping to ground at a distance from the turbine	8	7	7	6	7

From the number of blade failures and the number of wind turbine years in service for each year, I calculated the rough failure rate of wind turbine blade, in Exhibit M. The failure rate can be seen to be very similar over the last five years. (The Caithness database simply observes that the number of blade failures is increasing as the number of turbines in service increases, which is a similar way of saying the same thing.)

Q. What safety risks result from blade failure?

A. A breaking blade results in free pieces that have an initial kinetic energy due to the turbine rotation, are subject to the acceleration of gravity as they fall, and are subject to the lateral displacement of the wind. All three forces can result in the broken blade part traveling a distance from the turbine.

Review of the blade failure data reveals the following information showing that dropping pieces of turbine on the ground at a distance may well injure or kill a person.

- Blade Failures
    - Very large pieces of blade (10% of the blade length landed up to 660 feet (200 meters) from the base of the turbine
    - Piece of blade large enough to inflict fatality (> 3 kg or 6.6 pound) landed 1 mile (5280 feet or 1610 meters from turbine base) in severe storm.
    - Piece of blade > 3kg (6.6 pounds) landed 764 feet (233 meters) from turbine during normal operating conditions.
    - Smaller pieces up to 1 kg (2.2 pounds) landed 1607 feet (490 meters) from turbine base during normal operating conditions.

I have made an assessment to determine the impact of falling objects of the size of those shown in the turbine data when falling to the ground. The results of my analysis are provided in Exhibit N. If the outer 10% of a wind turbine blade falls to the ground, it hits with the same impact as a Ford Crown Victoria falls over two and a half times the height of Niagara Falls. This does not take into consideration the additional kinetic energy of a moving blade part due to rotational velocity. Without getting too technical, it is pretty clear that this will result in injury or death if it hits a person, even if protected in a house or an automobile.

Similarly, an assessment was carried out to determine if a three-kilogram sized piece of a wind turbine blade (6.6 pounds) would have an adverse effect if it hit a person. Exhibit O shows that the energy contained in the falling turbine blade bit is equivalent to dropping an 18-kilogram (40 pound) concrete block from an 8-story window on a person below. Again, without getting too technical, it is pretty clear that this will result in injury or death if it hits a person A blade piece of that size also may well result in serious injury if it hits a moving vehicle, as illustrated by the photograph in Exhibit P showing the impact of a 1 kg brick that had been dropped on a car's windshield from an overpass above.

My assessment determined that people protected in a vehicle will be at risk of serious injury or death at distances of at least 1000 feet (305 meters) and if unprotected by a vehicle, as for example mowing a lawn out of doors, or working on the fence line of a rural property, will be at risk of serious injury or death at distances of at least 1640 feet (500 meters).

Q. Why are falling pieces from burning blades a problem?

A. Falling pieces of burning blades pose a two-fold problem. First, of course, is the risk of being hit by the falling debris, which is similar to that for blade parts falling from the height of the turbine. Even if the turbine is shutdown, these parts can be projected at a distance from the turbine by the wind.

The second, and perhaps more serious problem is that burning debris (including blades, burning oil, and nacelle components) falling to the ground – excluding electrical fires in transformers at base of turbine, or arc fires that injured/killed workers

- The falling burning debris may well cause additional injury due to ignition of fires in combustibles on the ground. See exhibit Q for examples showing the projection of burning debris streaming quite some distance from a turbine due to wind. The falling burning bits are often bits of resin impregnated or oil soaked material and sustain combustion for a time, permitting ignition of material on the ground.

- Actual experience shows subsequent ground fires from burning debris from a wind turbine fire burned up to 367 acres in one case – had this been fully rectangular, the area would be that filled by a square 4000 feet on a side, however, in actual practice, the burned area would be longer in the direction of prevailing winds, so greater than 4000 feet in the windward direction. (Fires in earlier years resulting from turbine fires have burned up to 950 acres – more than 2 ½ times bigger yet.)

- Turbine fires cannot be fought due to the elevation, and the lack of fire suppression of large items like burning blades. The generally used practice in the event of a turbine fire is to evacuate all people in the direction the fire is blowing, and let it burn itself out while trying to fight fires created on the ground, while the risk of being under the burning turbine means that the firefighters too are outside the exclusion zone.

Q. You have provided some illustrations showing the impact of blades and blade pieces that fall downward off the turbines. How does that impact compare to that of blades or blade pieces that become airborne?

A. A wind turbine is a special case. Not only are the parts that can break and fall at a considerable height overhead, (up to three times the height of Niagara Falls) the detached part is subject to a wind speed considerably higher than at the ground level. At nighttime, the wind speed at the top of a wind turbine may easily be 3 or 4 times higher than the wind speed 10 meters above the ground due to a phenomenon known as wind shear. The wind speed may be 3 m/s at 10 meters above the ground and greater than 10 or 12 m/s at the top of the wind turbine. If a part breaks off the wind turbine it can be subject to three sources of energy, the kinetic energy due to rotation of the turbine blade, the lateral force from the wind that wants to displace the broken part, and the force of gravity pulling the broken bit downward. While I'm not going to get into the math here, I will say that all three forces add together to act on the broken bit. Up to now, I've done some very simplistic examples using only the kinetic energy from rotation and the force of gravity to determine the force that the object can hit the ground to help you to understand the situation. In the most simplistic way of putting it, wind can make the broken bit travel quite a bit further. As an example previously cited, in Kansas during severe weather, a piece of broken blade fell to ground over 1 mile, (5280 feet or 1610 meters) from the wind turbine.

Next one must consider the orientation of the broken part as it falls. As most know, if one throws a "Frisbee" where one adds kinetic energy of rotation to the object in the plane of the disc, it tends to soar, traveling a distance, while if one throws the "Frisbee" flat, towards the receiver, the "Frisbee" will travel almost no distance. Falling objects tend to fall in the orientation of least resistance, which is with their largest plane parallel to the direction of travel, which tends to make the distance traveled greater particularly if the object becomes supported by a wind current. This explains how the wind will tend to displace the object further than if it was simply falling under the forces of gravity or the kinetic energy in the object.

Q. Can turbine blade pieces smaller than 3 kilograms (6.6 pounds) coming into contact with a person or vehicle cause damage to that person or vehicle?

A. Absolutely. In Exhibit P, I give an example of the damage done to a car by someone dropping a brick, weighing about 1 kg, from an overpass only 5 to 10 meters above the road below. The brick went through the windshield injuring the passenger in the car. I do not think it is necessary for me to elaborate that a 1 kg object falling (with the additional kinetic energy from the rotation of the blade, and the additional displacement energy of the wind, as noted in my last answer) falling from a much higher elevation than an overpass would be far more serious.

Q. Based on publicly available information, are you aware of any incidents in which blade failure or fires have resulted in property damage?

A. If I go back five years through the Caithness Windfarm Information listing, and exclude the numerous events documenting property damage to the wind turbine itself (which is a business issue for the investors in the company, which I'll gloss over) I note:

- Incident 1182 – Jan 2012 - UK - Farmer upset after a nearby wind turbine was ripped apart by gales and casing from the turbine landed on his land, damaging fencing.

- Incident 1120 – Oct 2011 – USA - Wind turbine catches fire near Rep. Susan King's home" The turbine fire spread and burned 2 acres of Rep. Susan King's private ranch. Fire crews managed to put out the ground fire. King is quoted: "I'm watching a turbine…on fire, throwing fire balls on my property".

- Incident 1110 – Sept 2011 – India - "Gamesa starts probe after blade breaks off wind turbine in India" Blade "fell off" a 5-year old 850kW turbine. The blade hit a transmission line, knocking out power.

- Incident 1106 – Sept 2011 – UK - "Six-foot blade flies off new Lister turbine". A six-foot blade flew off after only a week's operation, and landed on a car, damaging its roof. The turbine is on the roof of a brand new Hospital car park. (a smaller turbine).

- Incident 1110 – Aug 2011 – USA - "Blade gets splintered during ferocious storm". Blade was struck by lightning, shattering it and throwing debris over trucks parked nearby. The blade tip was blown off.

- Incident 1074 – June 2011 – USA - "Wind turbine tumbles onto Toledo man's roof" A 25 foot turbine collapsed in a gust of wind and crashed onto the roof of the neighboring property, damaging the roof. (a smaller turbine).

- Incident 976 – Sept 2010 – USA - "Suit says wind turbine blade came off, hit employee vehicle". Court case in April 2011 regarding wind turbine blades which sheared off in September 2010. One blade struck a vehicle causing "substantial damage".

- Incident 867 – Dec 2009 – UK - "Wind turbine topples over on high school field" Stunned students watched as a 40ft wind turbine crashed to earth during its installation on Fakenham High School playing field this lunchtime. The field was evacuated after the giant turbine toppled over, crushing a contractor's van. (a smaller turbine).

- Incident 681 – June 2008 – UK - "Farmhouse horror as (16-ft) turbine blade smashes through roof" A farmer has described the shocking moment a 16-foot wind turbine blade smashed through the roof of his home as his family slept inside. "It was like a bomb hitting the roof of the house. (a smaller turbine).

Q. Robert Poore's written direct testimony for Champaign Wind represents that he has "never known a blade throw to injure anyone." How do you respond to this statement?

A. I have to say that my first response as one who spent many years calculating safety performance for a utility generator is a chill down my spine. I'll use a personal close example. Last year in Ontario the Bruce A Generating station had 1600 MW of generation in service, while at year end Ontario had about 1600 MW of wind turbines in operation. Had anyone I managed told me that they had never heard of anyone being injured in over 30 years of operation, inferring it as an excuse to say that adequate safety was provide without ensuring safe barriers were in place, they would have been dismissed on the spot. Not having an accident harming a person is not an acceptable excuse to say that protection is not needed. Had the utility offered that excuse to the regulator, the operating licence would have been immediately pulled due to the demonstration of an inadequate safety culture. I'm professionally troubled that anyone would use this as a justification for any generating system because of the safety culture it demonstrates. If an accident can harm someone, the public deserves to be protected.

Over the last 6 years as I said earlier I've had the opportunity to look at a great many wind turbine installations in many nations, to examine how the nations treat setbacks to homes. Denmark is often the example used as a nation with a large number of wind turbines for the size of the country. We traveled the length of Denmark from Copenhagen to Aarlborg and looked at every wind turbine installation we passed. There were many. In no case did we see an example of turbines as close to homes and roads as is proposed by the Buckeye II project. I will not say there are none, only that we did not see one. What we consistently saw were arrays of 3 or 4 turbines with neither roads nor homes within the vicinity of the turbines.

The problem is that the failure rate is relatively low as human experience dictates, and while one is no doubt more likely to be killed in an automobile accident, that is not justification to add a new method of killing people so that if we place wind turbines close enough to roads and homes that there is the potential to kill or injure someone, that in a few years, not only will most people know someone killed by a car accident, but they will also know of families who have lost someone, or had someone injured by a wind turbine accident.

The Caithness summary does identify the following incidents that may be considered to show the safety of the public was challenged if setbacks were inadequate:

Incident #	Incident Description
22	A one-ton piece of blade hurled 1312 or 1640 feet[1] (industrial sized turbine)
39	Blade parts landed in a garden (industrial sized turbine)
42	Blade pieces landed on a road and damaged adjacent turbine (shows distance traveled) (Industrial Sized turbine)
49	Blade parts flew over 984 feet across a road (industrial sized turbine)
50	Blade parts traveled between 1312 and 1640 feet, some landing in a summer house (industrial sized turbine)
71	Blade pieces flew 1640 feet (industrial sized turbine)
78	At least 30 blade parts up to 3.28 ft in length blown more than 984 feet (industrial sized turbine)
99	60 residents living within 1640 feet of turbines evacuated from area while blades rotated four times faster than normal speed (industrial sized turbine)
114	One blade piece traveled 1968 feet; another one went 656 feet and landed in a swimming pool
128	Blade piece traveled between 328-492 feet, landing on a factory and private home, and piercing a 9-inch thick stone wall, timber floor, and roof of the house
169	Blade pieces covered an area within 1312 feet from the tower

[1] The metric distances documented in the compilation have been converted to feet in this summary.

(industrial sized turbine)

428	Blade parts found 4265 feet (1.3 km) from turbine (industrial sized turbine)
472	Farmer on whose land a turbine had been erected three days earlier watched as blades flew over his house. One blade landed in the yard where he had been standing shortly before the incident. (smaller turbine)
477	Blade pieces "scattered well outside owner's property" (smaller turbine)
681	Four turbines on a wind farm threw their blades due to manufacturing defects. One 16-foot long blade smashed through the roof of farmhouse as the family slept inside. The farmer reported that it "was like a bomb hitting the roof of the house." (smaller turbines)
772	A blade on a small turbine at Perkins High School in Ohio "fell apart," throwing a piece of the blade into the student parking lot (smaller turbine)
773	An eight-foot long piece of blade crashed through the roof of a neighbor's home (smaller turbine)
853	Blade ripped off the tower and landed on a hiking path (industrial sized turbine)
854	Article reports that Denmark experienced 27 incidents of blades coming loose between 2000 and 2009 (industrial sized turbines)
989	Another blade throw incident at Perkins High School in Ohio (smaller turbine)
1047	Three blades flew off a turbine on a New Jersey farm, flying 215 feet and narrowly missing a 17-year old youth (smaller turbines)
1223	Two wind tubine blades break, debris of parts over 3 kg seen at 748 feet, other parts at 1561 feet (industrial sized turbine)

1241	Violent storm destroys 5 turbines, parts travel p to 1 mile (industrial sized turbines)
1243	Blade comes off turbine close to highway, lands beside highway (industrial sized turbine)
1255	Blade fails on turbine, large part falls close by, smaller parts scattered over wide area (industrial sized turbine)
1257	Blade falls over 328 feet from turbine (industrial sized turbine)

Q. Are you familiar with the turbine models that are identified on page 10 of the Application as being suitable for the Buckeye Wind II project?

A. Yes, I have reviewed the manufacturer's literature for all, and have personally seen many of the earlier turbine models of those manufacturers in the field, in Europe and North America. I have also tracked failure information for all of these manufacturers. None are remarkably different in safety risk, and all have demonstrated blade failures for example.

Q. Is the information in the Caithness database about the blade failures of turbine models other than those listed in the Application pertinent to your evaluation of the setbacks in the Application and Staff Report?

A. Yes. All of these turbines are very similar upwind, three bladed machines, with gearboxes, with very similar hub height, rotor diameter, and rotation speeds. Fundamentally they all have similar blade profiles with long, narrow blades (as opposed for example to the Enercon machines, which have a different blade profile, and operate without a gearbox.)

Q. Do you understand that Champaign Wind has withdrawn the Vestas V100 turbine model from consideration for the Buckeye Wind II project?

A. Yes, I have read that fact.

Q. In light of that withdrawal, do the facts about the blade throw from the Vestas V100 model at the Timber Road II Wind Farm provide you with information that is pertinent to the Buckeye Wind II project?

A. Yes. As I said, the Vestas V100 has very similar characteristics as the other machines. All have a similar narrow blade profile, use gearboxes, and have similar hub heights and rotational speeds. All will be operating in similar conditions of wind shear, and will be exposed to similar operating conditions of lightening, and icing. All will be operated by the same operator, and thus maintenance issues (good or less so) would apply to each.

Q. What did you do to determine whether Champaign Wind's application and the recommended conditions of the Staff Report contain safety precautions adequate to protect the public from the dangers of blade failure and ice throw?

A. I did an assessment to determine if the proposed wind turbine setbacks are adequate to protect the public from blade throw and ice throw. Using Figure 05-4: Site Layout, of the application, I measured the distances between the proposed turbine sites and neighboring homes and roads. I also measured the distances between proposed turbine sites and the homes and property lines of the members of Union Neighbors United (UNU). These measurements are accurate to 100 feet, and the bearings are accurate to 10 degrees. I used these measurements to create the table presented in Exhibit R entitled "Public Safety Assessment." I also created the attached table entitled "Physical Safety Setbacks," marked as Exhibit S, which shows the setbacks between proposed turbine sites and the homes and property lines of UNU's members.

Q. What standard are you using to determine whether a turbine site poses an unacceptable safety risk to residences from blade throw, and what is the basis of that standard?

A. I consider that society expects that at persons' homes, they have a reasonable expectation that they can be safe, and free from intrusion from external stressors, such as objects, or noxious substances that may adversely affect their health, safety, and well being. A person justifiably expects to spend hours at home, venture out of doors, enjoy recreational activities, or do agricultural work, such as mending fence lines or working fields without external threats. From a deterministic point of view, this means putting in place a safety barrier to prevent being impacted from outside. The only effective barrier for wind turbine blade throw is distance. We know of cases of significant parts of wind turbines being thrown up to 476 meters (1561 feet) from wind turbines, and smaller parts that would still injure at 1561 feet, even in Ohio from turbines of the same operator, in Prince Edward Island where parts traveled up to 1607 feet, and in Denmark where parts traveled up to 1640 feet I consider that a 500 meter (1640 foot) setback is the minimum that can be justified. I note that the 1561 feet blade throw in Ohio occurred from a wind turbine that was not operating in an overspeed condition, nor did it occur during unusual weather conditions. I am aware that under such conditions, the throw distance may be even higher such as the blade pieces found over 1 mile from turbines damaged during severe weather in Kansas in May 2012. (See exhibit T photo).

As supporting analysis by others, I note a letter received from Ontario Hydro Networks (see Exhibit U) showing that they have a technical directive preferring that wind turbines be separated 500 meters (1640 feet) from their 500 kV power corridors, where an impact could result in significant upset. While Ontario Hydro consider that a smaller setback might be acceptable for lover voltage corridors, considered to be more of a loss of redundancy, I would not want to be the one explaining to a family that their loved one was not to be protected at their home or on the highway because they are considered "redundant."

Q. Are you applying this blade throw standard to the residences of landowners who are leasing their land for turbine sites, and if so, why?

A. Yes. I consider that the individuals who lease their land do so on the understanding that they are giving up use of their land, and perhaps accepting some inconvenience, but I do not accept that any landowner can sign a document that places at risk his or her spouse, children, live in grandparents, delivery couriers who come to the home, visitors, or workers on the property . I am aware for example that child protection agencies would in fact step in if they felt parents were depriving their child of basic safety and security of life. As a professional who has an appreciation of the risk that these individuals are placing on their families, I feel obligated to treat them the same, even if they did not fully appreciate the effect of signing the lease agreement.

Q. What standard are you using to determine whether a turbine site poses an unacceptable safety risk of blade throw to roadways, and what is the basis of that standard?

A. A good argument could be made to apply the same 500 meter (1640 foot) standard to roadways as applies at homes. The same blade part that could hit persons outside their home could hit the unprotected person on the roadway if walking, or cycling. Similarly, if a person is operating a motor vehicle and a falling wind turbine blade bit hits the vehicle, then the driver might well swerve and run off the road or into another vehicle. Yet, somewhat reluctantly, I would consider the risk to be acceptable if the turbines are more than 1000 feet from public roads. It is difficult rationalization, but I consider there indeed are differences. In some cases, a motor vehicle will provide some protection. I acknowledge that the time persons spend driving by the wind turbine where they may be at risk may be less than the time spent at one's home, where one can expect to spend hours.

Q. Are you applying this blade throw standard to all roads, and if so, why?

A. I've applied the same standard to all public roadways that a member of the public can reasonable expect to be safe driving on. I have not applied this standard to private driveways.

Q. What are the results of your evaluation of the setbacks proposed in the Application for protection from blade throw?

A. The table in Exhibit R shows that the location of 10 turbines are an unacceptable safety risk due to their proximity to BOTH roadways and buildings. An additional 25 turbine locations are an unacceptable safety risk due to their proximity to either roadways or buildings. Thus, 35 of the turbine locations pose an unacceptable safety risk due to their locations. As shown by Exhibit S, turbine 131 is too close to the residence of the Gordon family, who are UNU members.

Q. Some of the turbines you listed in your prior answer are shown by Exhibit # to be within 1000 feet of a road or within 1500 feet of a residence. Why do you regard those setbacks to pose an unacceptable safety risk?

A. As I stated, the accuracy that I was able to determine the distances to is about 100 feet. I'm consider distances less than or equal to 1000 feet to roads or less than 1640 feet to homes to be a cause for concern that should be addressed, so distances of 1000 feet to roads and 1500 feet to homes are a serious concern. Even beyond these distances, blade debris can seriously harm motorists and persons who are outside.

Q. How do the distances between the Application's turbines sites and neighboring homes and roads compare to the minimum setback recommended by the Staff Report?

A. The Staff Report, at pages 31-32, recommends that turbines 87 and 91 should be relocated or resized to meet the minimum setback distance of 150 percent of the sum of the turbines' anticipated hub height and rotor diameter. For the GE Energy turbine model referenced in the Staff's discussion, that setback would be approximately 302 meters (991 feet) from any occupied structure or heavily traveled road. However, my review of the entire layout for the wind project shows that turbines 81, 85, 91, 101, 105, 106, 107, 118, 122, 123, 127, and 130 are ALL within 1000 feet (nominally 991 feet) of nearby identified roadways, and turbines 79 and 85 appear to be closer than 1000 feet to buildings that may be occupied. The setbacks for all of these turbines should be increased for the safety of the public.

Q. What standard are you using to determine whether a turbine site poses an unacceptable safety risk from blade throw to the land of neighbors who are not leasing their land to the wind project, and what is the basis of that standard?

A. I consider that property owners deserve adequate protection on all of their property. I can find no justification in depriving property owners of the safe usage of their own property.

Q. Is the 541-foot or 561-foot setback between turbines sites and neighboring property boundaries proposed by the Application and Staff Report adequate to protect the public against blade throw?

A. No. I've explained that there is demonstrated evidence that wind turbine blade parts have traveled over 1500 feet and on impact could injure or kill a person. A shorter setback simply does not protect a person on that property, and as a result the enjoyment that the person has of their property would be taken away. Society sometimes might make a decision that it is necessary to expropriate the property of a landowner for a project with a common good value such as making a road safer by smoothing out a sharp curve, however in that case the landowner is appropriately compensated before the property is expropriated.

Q. Are you aware of any turbines that are 1000 feet or closer to the property lines of non-participating landowners?

A. Yes. Turbines 131 and 90 are too close to the property line of UNU members Linda and Larry Gordon. See Exhibit #. The application does not reveal what other turbines are 1000 feet or closer to the properties of other non-participating landowners.

Q. Page 83 of the Application states that "modern utility-scale turbines are certified according to international standards" and go through audits, testing, and other quality control procedures. Page 31 of the Staff Report states that the turbine models under

consideration "are certified to international engineering standards." Do these representations persuade you that the setbacks you recommend are unnecessary?

A. No, manufacturing flaws have continued to cause blade failures. A further clue to wind turbine blade failures is given in the report issued by Douglas Cairns, Trey Riddle, and Jared Nelson of Sandia National Laboratories (operated for the US Department of Energy)[v] This paper (Exhibit V) states:

> Wind turbine blades have near aerospace quality demands at commodity prices; often two orders of magnitude less cost than a comparable aerospace structure. Blade failures are currently as the second most critical concern for wind turbine reliability. Early blade failures typically occur at manufacturing defects.

The report goes on to note:

> While the design and manufacturing of blades has improved, it is not clear that it has done so at a rate necessary to ensure a 20 year design life. Many of the blade suppliers are using technologies and techniques that were developed for structures with much lower design loads and criteria. While these methods are inexpensive, they are thought to offer questionable reliability.

The wind industry itself recognizes that blade failures are widespread problem. The journal "WindPowerMonthly" issue of 1 September 2008 reported on "Blade Failure and Load Monitoring." Exhibit C. The article elaborates on the issue as follows: "Defective manufacturing, however, is only one part of the blade story. Industry understanding of more fundamental issues, such as how best to measure loads and their impact, is far from complete." Compounding the issue is the reluctance of the industry to share information, as noted earlier. Failure to divulge failures is working against the industry, while it hides the actual magnitude of the problems faced.

Literature supports the fact that wind turbine blade failures are an issue that the Buckeye II wind Project can expect to face. The Caithness database, even though it is probably not a complete set of failures, shows that when the events that put blades, significant pieces of blades, or burning debris on the ground based on all failures reported for Europe, North America, and the Pacific region (Australia, New Zealand, Japan, and the Philippines) the failure rate is remaining stubbornly high. A failure rate in the order of 125 failures per million turbine years which have been identified as potentially able to injure or cause death if setbacks are inadequate, is in the order of a decade times higher than the failure rate that is permitted for other conventional generating systems, which target failure rates less than 10 failures per million years – or for nuclear plants less than 1 failure per million years. Clearly, the high (for generating systems) stubbornly persistent failure rate demands that safe setbacks are established to protect citizens.

The EDP's report to the Board about the Timber Road failure blamed a blade manufacturing defect for the blade failure. However, this blade failure occurred in 2012, after blade manufacturing supposedly had improved. The articles in Exhibits W and X suggest that the high tolerance demanded for wind turbine blades is simply difficult to achieve in the setting of wind turbine blade construction. Recognize that the construction of wind turbine blades involves a lot of close contact with highly noxious chemical resins, and it is not a desirable employment for many workers who can find a different job. Expectations for the quality demanded are difficult to achieve under these conditions.

Note that the statement in the Application, that "the reduction in blade failures coincides with the widespread introduction of wind turbine design certification and type approval." However, the Caithness database report shows that the blade failure rate is not reducing significantly, but is continuing at an unacceptable level.

The failure rates observed are certainly not consistent with the statement in the application that "Risk of catastrophic blade failure is minimal." In the generating industry, a minimal failure rate is understood to be a failure rate less than 1 in 10 million years, and the observed blade failure rate is well higher than that (about 1250 times higher).

Q. Even if a turbine blade is manufactured properly, are there other causes of blade failure that can result in blade throw and necessitate safe setbacks?

A. Yes. A common cause of wind turbine blade failure is a lightning strike, as noted earlier. Additionally, literature shows that blades have failed due to operating error, in which the brakes were taken off a turbine that is disconnected from the grid, and the blades put into the operating position. A failure of this nature resulted in a turbine destruction in Oregon and resulted in the death of a maintainer. Blade failures have also been attributed to be due to blade wear from abrasion over time if not adequately maintained, and due to the cause of wind shear. A number of the wind turbine blade failures identified in the Caithness database were unexplained. The review reports for these incidents revealed that the winds were within rated limits, there was no blade icing or abnormal vibration, and in many cases the investigation of the failed blade showed no manufacturing abnormality. Yet these blades failed.

A clue to some of these failures can be found in a report issued by Neil Kelley and Brian Smith of the National Renewable Energy Laboratory (a division of the US Department of Energy)[vi] This report examines the situation of high night time wind shear detected at wind farms, stating:

> Wind shear is quantified as the exponent in the Power Law equation that relates wind speeds at two different heights. At some projects, the annual average shear peaks above 0.5 during early morning hours, with 10-minute and hourly average shear measurements frequently exceeding 0.75.
>
> <u>These high nighttime shear values are of concern due to the potential for high stresses across the rotor as the wind speeds are significantly different across the blades, particularly for newer turbines with large rotor diameters. The resulting loads on turbine components could result in failures.</u> A significant number of nighttime faults have been observed at some TVP projects. The assumed causes of these faults have included high wind speeds and the lack of

> on-site nighttime operators to resolve problems, but incidences of some fault types also appear to be more frequent during periods of high wind shear." (Emphasis added.)

Stated simply, increased nighttime wind shear is a situation in which the wind is blowing much harder at higher altitudes than it is simultaneously at lower altitudes. This means that the wind is blowing harder against the turbine blades at the top of the rotor's rotation than at the bottom. [reword if you wish]

The wind turbine models suggested for the Buckeye II Wind Project all have large rotor diameters of 93.5 to 103 meters, and hub heights of 95 to 100 meters. Typical nighttime wind shears at locations such as the Buckeye II Wind Project are 0.42 as demonstrated by projects north of Lake Erie in Ontario. Nightime windshears in Ohio at the Buckeye Project location will be similar as the proximity to Lake Erie is similar, and the general climatic conditions north and south of the lake are very close. In Ontario, developers must identify average nighttime wind shear and accordingly adjust the acoustic emission data for the wind turbine. Exhibit E shows that with a wind shear of 0.42, the forces on the wind turbine blades are 4 times higher at the top of the rotor than they are at the bottom of the rotor. An average wind shear of 0.42 means that the forces are different than a factor of 4 during any times the wind shear is greater than 0.42. This means that there are considerable flexing forces operating on the wind turbine blades that fatigue the material. Page 6 of the Kelley report for NREL indicates that nighttime wind shears and may be subject to wind shear as high as 1.0 for short periods (which places 10 times as much pressure on the top of the rotor as the bottom). This stress on the blades makes them more prone to breakage.

Q. Are you familiar with the safety procedures and equipment for preventing blade throw that are described on page 83 of the Application and on page 31 of the Staff Report?

A. Yes.

Q. Do these safety procedures and equipment obviate the need for the setbacks you have recommended for blade throw?

A. No. The Application and Staff Report speak of two fully independent braking systems that have greatly reduced the risk of blade throw. The two braking systems of wind turbines are blade pitch (in which all three blades must pitch to stop the turbine rotation, not any one) and the friction brake system. However, like the parking brake on a car, the latter system is capable only of holding a slowly rotating or stopped rotor, and is not capable of stopping a rotor that has blades still in the operating manner, if wind speeds are at typical operating levels accelerating the turbine which has no restraining forces from the generator as it is disconnected from the grid. The systems are independent, but are not both capable of braking the turbine if the generator breaks synchronization with the grid (as on a lightning strike) when wind conditions are at operating levels. The primary system, in which three cylinders pitch the three blades to the furled position to stop the turbine rotation depends on all three cylinders receiving the stop signal and operating correctly. This is not what is usually described as a redundant system in which either of 2 systems could work to be effective, it is a system demanding all three to work correctly, which is not an ideal sort of a safety system. Even with one blade in the operating position a wind turbine will still continue to rotate and accelerate on a windy day. An accelerating wind turbine has been demonstrated numerous times to result in turbine destruction as the blades hit the tower, often shattering the blade, sending parts traveling long distances (due to the increased kinetic energy at the higher speed) and resulting in the collapse of the cylindrical tower. A cylinder is strong only if not “kinked” as when hit by a blade. A simplistic example is the fact that a wrapping paper tube seems strong, and is often used for impromptu family fun duels, yet if the tube is kinked, the tube immediately collapses. Effectively a cylindrical wind turbine tower is a large wrapping tube, and is subject to the same failure mode if kinked by a blade hit.

The same systems did not prevent blade throw at the Timber II wind turbine, as documented on the Ohio Siting Board web site.

Page 83 of Champaign Wind’s application and pages 91-92 of the application for the Timber Road II Wind Farm proposed the same safety procedures and equipment to prevent blade throw. See Exhibit W Page 37 of the Staff Report for Timber Road II Wind Farm and page 18 of the Certificate for Timber Road II Wind Farm which predicted that these measures would adequately address blade throw at that wind farm. Timber Road II Wind Farm experienced this blade throw after it had been operational for less than a year. Exhibit W. These documents for the Timber Road II Wind Farm are available on the Ohio Power Siting Board web site.

Q. What is ice throw as related to wind turbines?

A. A wind turbine at an elevation of 50 to 150 meters (164 to 492 feet above ground) is subject to icing due to the drop in temperature with elevation, if the air is moist, and temperature is near freezing. This can occur on days with freezing rain ice can form as wind turbine blades rotate. The ice builds up evenly on all 3 blades, keeping them in balance, although if ice then breaks off, the wind turbine instrumentation can detect an imbalance and shut the turbine down after the ice breaks off. See Exhibit Y (photo of wind turbines with ice broken off, still rotating)

Q. What causes ice throw from wind turbines?

A. The ice can break off if it builds up due to the velocity on the blades, and the loads exceeding the “gluing energy” of the ice, particularly if the turbine keeps rotating. Additionally, if the turbine shuts down, as the ice starts to melt, wind can carry the pieces of ice from the blades at a distance from the turbine. (See Exhibit Z) School bus and turbines.

Q. What standard are you using to determine whether a turbine site poses an unacceptable safety risk to residences from ice throw, and what is the basis of that standard?

A. The staff report agrees with the manufacturer’s recommendation of a setback of 1.5 x hub height + rotor diameter for ice throw, Generally my work shown in Exhibit Y supports this for ice throw, bit it is not sufficient to protect for blade throw as demonstrated by experience.

Q. Are any of the turbine sites proposed in the Application closer than this recommended setback?

A. My measurements show that the following roads appear to be within the limit of the 991 foot (nominally 1000 setback by my measurements with their accuracy of 100 feet):

- turbine 81 – 1000 feet to road TWHY 223
- turbine 85 – 600 feet to road TWHY 168
- turbine 91 – 800 feet to road TWHY 205
- turbine 101 – 800 feet to TWHY 205
- turbine 105 – 900 feet to Evans Road
- turbine 106 – 800 feet to CR167
- turbine 107 – 1000 feet to Swisher Road
- turbine 123 – 800 feet to Dolly Varden Road
- turbine 127 – 850 feet to road TWHY 205
- turbine 130 – 850 feet to State Hy 161

Q. Are you familiar with the safety procedures and equipment described on page 82 of the Application and in recommended Condition 45 of the Staff Report?

A. Yes, Condition 45 requires an ice warning system for the turbines that may include ice detection equipment or ice sensor alarms to trigger automatic shutdown. Page 82 of the Application describes those types of equipment, as well as vibration monitors to shut down the turbines or equipment to shut down the turbines when the wind speed to power output ratio becomes too high.

Q. Do these safety procedures and equipment make the setback you have recommended for ice throw unnecessary?

A. No. See my Exhibit Y & Z. Even with the ice detection systems, ice has been shown to be thrown from turbines. Vibration monitors are only effective after the ice is thrown. Manufacturers information suggests that ice detection equipment is not fail proof.

Q. Do you hold all of the opinions you have expressed in this testimony to a reasonable degree of engineering certainty?

A. Yes.

Q. Does that conclude your direct testimony?

A. Yes.

---

[i] *Accident Statistics*, Caithness Windfarm Information Forum, September 2012, http://www.caithnesswindfarms.co.uk/

[ii] *Wind Turbine Reliability: Understanding and Minimizing Wind Turbine Operation and Maintenance Costs,* Walford C., Sandia National Laboratory Report SAND2006-1100, March 2006.

[iii] *Assessment of Kent Breeze Renewable Energy (Wind) Project Impact on Serious Harm to Human Health,* Palmer W.K.G. January 2011, Prepared for Submission to Hearing of Ontario Environmental Review Tribunal Case No. 10-121 / 10-122 With Respect to Renewable Energy Approval Granted by Ontario Ministry of the Environment to
Kent Breeze Corp. and MacLeod Windmill Project.

[iv] *Supplementary Witness Statement to January 14 Witness Statement,* Holley, W.E., February 23, 2011, Prepared for Submission to Hearing of Ontario Environmental Review Tribunal Case No. 10-121 / 10-122 With Respect to Renewable Energy Approval Granted by Ontario Ministry of the Environment to Kent Breeze Corp. and MacLeod Windmill Project.

[v] *Wind Turbine Composite Blade Manufacturing: The Need for Understanding Defect Origins, Prevalence, Implications and Reliability,* Cairns, D., Riddle, T., Nelson, J., February 2011 issued as Sandia Report SAND2011-1094.
[vi] *Evaluation of Wind Shear Patters at Midwest Wind Energy Facilities,* Keeley N., Smith B, National Renewable Energy Laboratories, and Smith K., Randall G., Malcolm D., Global Energy Concepts, May 2002, Report NREL/CP-500-32492

<u>Exhibits</u>:
Exhibit A Photo of failed turbine blade at Port Burwell
Exhibit B Sandia Labs paper
Exhibit C Wind Power International Magazine article
Exhibit D NREL Paper
Exhibit E Wind Shear Effects
Exhibit F An Ineffective Safety Barrier
Exhibit G Caithness Windfarm Information Group Database to Sept 2012
Exhibit H Extract from Caithness Windfarm Database
Exhibit I EDP Renewables Report on Timber II Failure
Exhibit J Wind Turbine Blade
Exhibit K Sandia Report SAND 2006-1100
Exhibit L Industrial Wind Turbine Failures
Exhibit M Wind Turbine Blade Failure Rate
Exhibit N Consequences of Falling Wind Turbine Blade Part
Exhibit O Consequences of Falling 3 kg Part of Blade
Exhibit P Dropping 1 kg brick from overpass
Exhibit Q Turbine Fires
Exhibit R Public Safety Assessment
Exhibit S Setbacks to UNO Members
Exhibit T Object thrown 1 mile in Kansas
Exhibit U Letter from Hydro One Networks

Exhibit V Sandia Labs Paper
Exhibit W
Exhibit X
Exhibit Y Wind Turbines Rotating Ice Broken Off
Exhibit Z Ice Throw From Turbines