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May 9, 2022

SENT VIA EMAIL – maplevalleytownship@yahoo.com

Maple Valley Township Board
1977 Kohler Rd.
Trufant, MI 49347

Re: Regulation of Industrial Wind Turbines

Dear Maple Valley Township,

I am writing on behalf of my client and the hundreds of other similarly situated Maple Valley Township residents to respond to the April 5, 2022 correspondence from Montcalm Wind, as well as the April 7, 2022 correspondence from Nicholas J. Schrock concerning the proposed industrial wind turbine zoning ordinance recently approved by the Maple Valley Township Planning Commission (MVTPC). As you will see, the regulations approved by the MVTPC are rationally related to a legitimate governmental interest – the protection of the health, safety and welfare of Maple Valley Township residents, and as such, constitute a lawful exercise of the Township's authority under the Michigan Zoning Enabling Act.

When constructing your ordinance, it is helpful to understand how courts view a municipality's exercise of its authority. When a township creates a zoning ordinance, it is presumed to be valid.[1] Moreover, that zoning ordinance will be upheld by a court so long as the regulation in question is rationally related to a legitimate governmental interest.

> "Stated another way, the challenger must demonstrate that the ordinance is an arbitrary and unreasonable restriction upon the owner's use of his property. Under this standard, a zoning ordinance will be struck down only if it constitutes an arbitrary fiat, a whimsical *ipse dixit,* and... there is no room for a legitimate difference of opinion concerning its [un]reasonableness."[2]

Thus, contrary to statements you may have heard that Maple Valley Township "must let them in," Maple Valley Township actually holds a very strong position when drafting its zoning ordinance, so long as its proposed restrictions are rationally related to the protection of the health, safety and welfare of its residents. And wind energy companies

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[1] Dorman v. Clinton Township (Mich. Ct. App. 2006) 269 Mch App 638,650.

[2] *See* Kyser v. Kasson Township (Mich. 2010) 786 N.W.2d 543, 548.

recognize this fact, which is why they rarely ever file a lawsuit against a township that has enacted an industrial wind energy zoning ordinance.

Under Michigan law, "a zoning ordinance may not totally exclude a land use where (1) there is a demonstrated need for that land use in the township or surrounding area, (2) the use is appropriate for the location, and (3) the use is lawful."[3] To show demonstrated public need, the plaintiff must do more than show that "residents of the township benefit from" the excluded use."[4] However, as recognized by the U.S. District Court, Eastern District of Michigan, if a Township already has access to adequate energy, there is no "demonstrated need" for wind energy in that Township.[5] Therefore, if Maple Valley Township has access to adequate energy, and there is no indication it does not, it could arguably exclude wind energy entirely from Maple Valley Township. Thankfully, no such drastic actions are necessary if Maple Valley enacts the proposed industrial wind turbine zoning amendment.

A. Maple Valley Townships Setbacks Of Three (3) Times Height Are Reasonable And Rationally Related To The Protection of the Health, Safety And Welfare Of Its Residents.

The MVTPC has recommended a setback from non-participating property lines equal to three (3) times the height of the turbine. Mr. Schrock and Montcalm Wind have erroneously claimed that such a height limit is not rationally related to the protection of the health, safety and welfare of Township residents. However, such claims ignore the large body of evidence showing that blade debris and/or ice can be thrown well in excess of the One and one-half (1.5) times the height of the turbine (or approximately 750') that Montcalm Wind is requesting.

I have included an article documenting turbine blade debris throw in excess of 1,000' in Payne, Ohio.[6] This is a "real world" example of blade debris. However, there have been hundreds of other documented instances of blade and debris throw, many of which that were the subject of a study conducted by Texas State University, which concluded

> In the U.S. we currently have over 32,000 wind turbines in 38 different states with each of these wind turbines in each of these states having the potential for ice throw hazards. Previous studies have determined that wind turbines produce ice fragments on the turbine blades which are typically 1 kilogram in mass (2.2 pounds) and can be projected at 179 mph for up to 820 feet.
>
> The wind industry needs to implement ice throw risk information programs, adequate turbine setback criteria, and turbine icing safety procedures to address this

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[3] Eveline Twp. V. H & D Trucking Co. (Mich. Ct. App. 1989) 448 N.W.2d 727,730. See also, MCL § 125.3207.

[4] Tuscola Wind III, LLC v. Almer Charter Township (E.D.MI 2017), Case No. 17-CV-10497, attached hereto as Exhibit A.

[5] Id. at p. 45 – 46.

[6] See Exhibit B – Wind Action article entitled, "Vestas Turbine Blades Shredded in High Winds."

> of ice throw from wind turbines to better understand the perceived risk. The theoretical framework of the Protective Action Decision Model was used for studying community risk, vulnerability and response to the ice throw hazard.

In addition to the documented instances of blade throw identified above, a recent research article published in Wind Energy Journal highlights the finding of a peer-reviewed study of blade and ice throw from industrial wind turbines.[7] According to that peer-reviewed study:

> It is found that, **while at tip speeds of about 70 m/s (normal operating conditions), pieces of blade (with weights in the range of approximately 7-16 ton) would be thrown out less than 700 m** for the entire range of wind turbines, and **turbines operating at the extreme tip speed of 150 m/s may be subject to blade throw of up to 2 km from the turbine. For the ice throw cases, maximum distances of approximately 100 and 600 m are obtained for standstill and normal operating conditions** of the wind turbine, respectively, with the ice pieces weighting from 0.4 to 6.5 kg.

Therefore, according to this peer-reviewed study from an entity that partners with the American Wind Energy Association (AWEA), blade debris can travel in excess of 2,000 feet under normal operating conditions and up to 6,500 feet at extreme tip speeds. Moreover, ice throw can be expected to travel between 300 feet and 1,900 feet, rendering MVTPC's recommended setback rationally related to the protection of health, safety and welfare

Montcalm Wind and Mr. Schrock erroneously allege that a property line setback does not protect health, safety and welfare. However, this argument ignores two things: (a) the rights of existing residents to use all portions of their property without the burden of an uncompensated safety easement to their neighbors and (b) their right to future development of their own land.

If setbacks were measured from an existing residence, Maple Valley Township residents would effectively be halting all development in the township by granting an uncompensated safety easement to their neighbors over their own property. Residents could not section off five (5) acres in a corner of their own land to allow their children or grandchildren to build a home, as any such home would be located too close to the neighbor's turbines.

Moreover, residents could not let their children play in the yard or have a family cookout without concerns about ice or blade debris being thrown at them. They could not build a barn or a garden on a corner of their own property without fear that either will be

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[7] See Exhibit C – "Analysis of throw distances of detached objects from horizontal-axis wind turbines," Hamid Sarlak and Jens N. Sorensen, Technical University of Denmark, published February 19, 2015 (*emphasis added*).

harmed by ice or blade debris. Those rights can only be preserved if turbine setbacks are measured from property lines, the same way every other setback in the Maple Valley Township Zoning Ordinance is measured.

We must also consider what turbine manufacturers themselves have said about this issue in the past. Although Montcalm Wind has provided a purported recommendation from a turbine manufacturer with a recommended setback of 1.1 times height, that is not what they recommend to their own employees. As you can see from the attached excerpt from the Nordex Safety Manual, they advise employees to "keep a safety distance of 500m around the turbine" in the event of a fire because parts may come off of the turbine.[8] Obviously, one cannot move a home or building in the event of a fire, nor should non-participants be required to reside within this 500 meter (approx. 1,640') evacuation zone.

In light of the foregoing, there is ample evidence that the recommended setback of three (3) times turbine height from a non-participating property line is rationally related to the protection of the health, safety and welfare of Maple Valley Township residents.

B. Maple Valley Township's Proposed Shadow Flicker Regulation is Rationally Related To The Protection Of Health, Safety and Welfare.

Montcalm Wind and Mr. Schrock complain that MVTPC's proposed shadow flicker regulations are unreasonable. However, Mr. Schrock himself acknowledges that "prolonged shadow flicker for more than thirty minutes can cause annoyance and stress" and that "there has been some concern that flicker from wind turbines could cause seizures in individuals with photosensitive epilepsy ..." That alone grants the Township the authority to take reasonable steps to limit residents' exposure to shadow flicker, as it is rationally related to the protection of health, safety and welfare.

While Montcalm Wind and Schrock argue that total ban on shadow flicker is unreasonable, they ignore the fact that technology exists that will allow them to stop the turbine blade from turning when the turbine would generate impermissible shadow flicker, then resume when the sun changes position, such as the Vestas Shadow Detection System.[9] Since Montcalm Wind is confident that shadow flicker will not be a frequent occurrence, the installation of this Shadow Detection System will have minimal impact upon its operations. And since this equipment can be installed on a turbine in any location, MVTPC's proposed shadow flicker regulation will not have any impact on Montcalm Wind's ability to site turbines within the Township.

One must also consider the difficulty in enforcing the 30 hour shadow flicker limit proposed by Montcalm Wind. Under the currently proposed language, it is a relatively simple matter to address a resident's concern about shadow flicker. It is either occurring or not. Under Montcalm Wind's proposed language, a resident must track the amount of

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[8] See Exhibit D – Nordex Safety Manual excerpt – p. 47.

[9] See Exhibit E – Vestas Shadow Detection System.

shadow flicker they are incurring each day until they reach their 30 hour maximum. Presumably, they would need to video record these events to support their claims. And then some poor soul from the Township is going to have to watch 30 hours of shadow flicker video to confirm the allegations? Montcalm Wind knows that this standard is simply unenforceable whereas the proposed regulation makes it easier for the Maple Valley Township residents AND Board to enforce.

Considering the relatively low impact that MVTPC's proposed shadow flicker regulation would have on the project, and the admitted benefits it would provide to the protection of the health, safety and welfare of Maple Valley Township residents, it is clear that this regulation is rationally related to a legitimate governmental interest.

C. Maple Valley Township's Proposed Height Regulation Is Reasonable.

Montcalm Wind and Schrock both object to the 500' height limit recommended by MVTPC and seek an ordinance with no restrictions whatsoever. However, it is well within the Township's authority to place a height limit on any structure erected in the Township.

An example of the deference shown to restrictive zoning regulations can be found in the case of Johnecheck v. Bay township. In that matter, a township board rejected a request to amend its zoning ordinance to separately regulate industrial wind turbines and to exempt them from a general thirty (30') foot height limit. Instead, the township determined that allowing 300' tall industrial wind turbines "would be contrary to the stated goals of the Township Land Use Plan." Landowners who wanted to have industrial wind turbines on their property sued on the grounds that such a regulation was "exclusionary." In granting summary judgment to Bay Township, the Court noted that "the law recognizes that aesthetic concerns are a reasonable government interest" and that although aesthetic concerns alone may not justify a total exclusion of a legitimate land use, "aesthetic concerns are a legitimate governmental interest sufficient in themselves to support restriction of wind turbine generators in the Township.[10]

D. Maple Valley Township's Proposed Noise Limit Is Reasonable And Rationally Related To The Protection Of Health, Safety And Welfare.

Montcalm Wind argues that use of an LMax sound pressure level is "not at all appropriate." However, a review of the recommendations of the World Health Organization ("WHO"), as well as the conclusions of the a Michigan federal court, reveal otherwise.

First, it should be noted that the WHO's 2009 Night Noise Guidelines specifically references LMax (aka - LaMax) as a proper sound metric and recommends a night time indoor noise limit of 35 – 42 dB(A).[11]

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[10] See Johnecheck v. Bay Township (W.D. Mich. 2003), Case No. 02-CV-71.

[11] http://www.euro.who.int/__data/assets/pdf_file/0017/43316/E92845.pdf

Second, it should be noted that a Michigan federal court has already upheld the use of an LMax sound limit for industrial wind turbines. In Tuscola Wind III v. Almer Township, an industrial wind turbine developer argued that the Township's "shall not exceed 45 dB(A)" noise limit had to be interpreted as 45 dB(A) Leq (aka - hourly average) because it did not provide a specific metric for how often sound should be measured. The U.S. District Court of Michigan, Eastern District, Northern Division soundly rejected that claim, relying heavily on the expert testimony of acoustician Kerrie Standlee who stated:

> **Model noise ordinances written over the past 50 years have shown that noise ordinances can be written with a maximum noise level limit or they can be written with some other noise metric limit.** However, in each case where a metric other than the maximum noise level is included, the noise metric was specified in the ordinance. When a noise limit is specified in an ordinance without reference to any specific noise metric, it is generally understood by acousticians that the limit is intended to be a "maximum" noise level limit and not a limit for a noise descriptor other than the maximum noise level. (Emphasis added).

Mr. Standlee then went on to note, "**I'm on the City of Portland Noise Review Board and we have an Lmax standard.** It's not specified as the Lmax it's just – like yours it says it shall not exceed this level. And that is an absolute level, not – not an equivalent energy level." (Emphasis added.)[12] Thus, contrary to Montcalm Wind's erroneous claim, use of an LMax standard is completely appropriate and has in fact been upheld in litigation by a Michigan federal court.

Similar to the proposed shadow flicker regulation, an LMax standard also makes it considerably easier for residents and the Township to enforce the noise limits. An Leq standard requires a measurement over some period of time to determine compliance. An LMax standard is much easier to enforce – the turbine is either exceeding the noise limit or it is not. Moreover, a resident whom is awoken multiple times per night by short term spikes in turbine noise will find little solace in the fact that the hourly average is still within the limits.

Montcalm Wind and Schrock also complain that placing sound limits and setbacks at the property line rather than an occupied structure is not protective of the public health because, in essence, people only need protection from noise inside their homes. However, this argument ignores that fact that Maple Valley Township residents have the right to build other lawful structures on their properties that may not currently exist and to conduct activities on portions of their property that are not contained within their home. While there may not be a house in the corner of a section now, that landowner has, and should continue to have, the right to construct a house or other structure there in the future. These future development rights should not be curtailed because a neighboring landowner built an industrial wind turbine too close to the property line to contain the noise, flicker, blade debris or ice throw coming from that turbine on their own property.

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[12] A copy of the Almer Township decision is attached hereto as Exhibit A.

No other land use measures setbacks from the neighbor's home. Instead, we measure those setbacks from the property line so as to not interfere with the neighbor's right to use all portions of their property in a lawful manner. There is no logical reason to treat industrial wind turbines any differently. Measurement of setbacks and sound limits at the property line of a non-participating parcel is a valid exercise of the Township's authority to regulate potential nuisance issues and proposed 45 dBA LMax noise limit is rationally related to protecting the health, safety and welfare of Maple Valley Township residents.

E. Maple Valley Township Has No Obligation To Implement Recommendations From Montcalm County.

The Montcalm County Planning Commission has completed their review and recommended several changes that would negate the protections requested by Maple Valley Township residents. If Maple Valley Township were to make the changes in question, the proposed industrial wind turbine zoning ordinance amendment would essentially revert back to the same regulations that were put up for referendum in 2020. Thankfully, the Montcalm County Planning Commission is only an advisory board and has no authority to require Maple Valley Township to change the regulations in question.

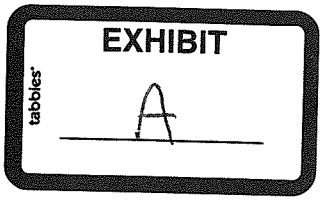
F. Conclusion

The positions taken by Montcalm Wind are all based upon a turbine height that will maximize their profitability from this project, not to protect the health, safety and welfare of Maple Valley Township residents. And each of these positions ignores the fact that Montcalm Wind can easily comply with the setbacks and noise limits if they were to construct a smaller turbine, a fact that was recognized by the Court in Tuscola Wind III v. Almer Township.

The MVTPC is charged with creating regulations to protect the health, safety and welfare of Maple Valley Township residents and they have done an admirable job in identifying potential issues and creating regulations to address those concerns. For all the reasons set forth herein, my client and hundreds of other similarly situated Maple Valley Township residents respectfully request that the Township Board adopt the proposed industrial wind turbine zoning ordinance amendment recommended by the Maple Valley Township Planning Commission.

Sincerely,

Joshua J. Nolan



UNITED STATES DISTRICT COURT
EASTERN DISTRICT OF MICHIGAN
NORTHERN DIVISION

TUSCOLA WIND III, LLC,

Plaintiffs,

Case No. 17-cv-10497

v

Honorable Thomas L. Ludington

ALMER CHARTER TOWNSHIP, et al,

Defendants.
_____/

OPINION AND ORDER AFFIRMING THE DECISION OF THE ALMER CHARTER TOWNSHIP BOARD OF TRUSTEES

On February 15, 2017, Plaintiff Tuscola Wind III, LLC, ("Tuscola") filed a complaint naming the Almer Charter Township and that Township's Board of Trustees as Defendants. ECF No. 1. Count One of the Complaint is the "Claim of Appeal." Compl. at ¶¶ 100–124. Tuscola Wind's claims arise out of Defendants' denial of a Special Land Use Permit ("SLUP") that would have permitted Tuscola Wind to construct the "Tuscola III Wind Energy Center" in Tuscola County, Michigan. Compl. at 6. Oral argument on the claim of appeal was held on October 5, 2017. For the following reasons, the Board of Trustee's denial of the SLUP will be affirmed.

I.

Tuscola Wind III, LLC, is a Delaware limited liability company, which is indirectly wholly owned by NextEra Energy Resources, LLC. Tuscola Wind SLUP App. at 1, ECF No. 30, Ex. B. Tuscola is attempting to build the "Tuscola Wind III Energy Center" in Tuscola County, Michigan. *Id.* The project, if completed, would include 55 wind turbines in Fairgrove, Almer, and Ellington Townships, and would produce enough energy to supply 50,000 homes with wind energy. *Id.* In its SLUP application, Tuscola explained that "[t]he Project facilities are to occupy 15.2 acres of land, and will be serviced by 6.6 miles of access roads, occupying 12.9 acres of land." *Id.* at 2.

Prior to submitting the SLUP application, Tuscola had entered into agreements with 87 landowners (representing 192 parcels of land) for the use of their property for the project. *Id.* Those individuals are described as "participating landowners." *Id.* Thus, at the time the SLUP application was submitted, Tuscola had already identified the ideal number of and locations for wind turbines in Almer Township, categorized parcels of land as necessary or unneeded, and secured access to the parcels it believed were required for the proposed project. The present dispute centers on Tuscola's attempt to secure SLUP approval for the 19 wind turbines that Tuscola wishes to build in Almer Township.

A.

The Almer Township Zoning Ordinance characterizes wind energy systems as special land uses. As such, Tuscola was required to seek a Special Land Use Permit ("SLUP") from the Township for the project. *See* Almer Zoning Ord. Art. 24, ECF No. 30, Ex. A. Pursuant to Section 2401 of the Zoning Ordinance, the first step in receiving approval for a wind energy system is to submit a SLUP application to the Township's Planning Commission. *Id.* at § 2401. Upon receipt of the application, the Planning Commission is required to hold a public hearing within 45 days. *Id.* After the public hearing, the Planning Commission recommends either granting or denying the application to the Township Board and must state its reasons for the decision. *Id.* Once the Planning Commission issues its recommendation, the Township Board will render a decision on the SLUP application. *Id.*

Section 1522 of the Almer Township Zoning Ordinance provides special requirements for SLUP applications involving a wind energy system. *Id.* at § 1522. Among other things, the applicant must provide an escrow account to cover the Township's costs and expenses associated with the SLUP zoning review and approval process. *Id.* at § 1522(C)(1). Likewise, the applicant

must fund and submit environmental and economic impact studies (if requested by the Township). *Id.* at § 1522(C)(2)–(3). The application must include a site plan which specifies the design characteristics of the turbines, safety features, security measures, and a lighting plan. *Id.* at § 1522(C)(4).

The Zoning Ordinance also addresses noise emissions from the turbines:

> Noise emissions from the operations of a [Wind Energy Conversion System] shall not exceed forty-five (45) decibels on the DBA scale as measured at the nearest property line of a non-participating property owner or road. A baseline noise emission study of the proposed site and impact upon all areas within one mile of the proposed WECS location must be done (at the applicant's cost) prior to any placement of a WECS and submitted to the Township. The applicant must also provide estimated noise levels to property lines at the time of a Special Use application.

Id. at § 1522(C)(14).

Similarly, "[a]ll efforts shall be made not to affect any resident with any strobe effect or shadow flicker." *Id.* at § 1522(C)(20).

And the Zoning Ordinance provides the general admonishment that "[t]he wind energy conversion system shall not be unreasonably injurious to the public health and safety or to the health and safety of occupants of nearby properties." *Id.* at § 1522(C)(7).

B.

On September 23, 2016, Tuscola submitted its SLUP application to the Almer Township Planning Commission. Several portions of the application became points of contention between Tuscola and the Planning Commission. Those sections will be summarized.

In the SLUP application, Tuscola referenced three studies which analyzed the "impact wind farms have on property values." SLUP App. at 10. Each study found no evidence that wind farms have a statistically significant impact on nearby property values. One study, conducted by the Lawrence Berkeley National Laboratory, analyzed home sales near 67 wind facilities across nine

states. *Id.* Another study, conducted by the University of Rhode Island, analyzed 48,000 home sales that occurred within 5 miles of wind turbines in Rhode Island. *Id.* at 11. The third study, jointly prepared by the Lawrence Berkeley National Laboratory and the University of Connecticut, reviewed 122,000 home sales within 1 mile of operating turbines in Massachusetts. *Id.* Besides summarizing these three studies, Tuscola did not include any information or analysis regarding the possible impact of the proposed wind farm project on Tuscola County property values, specifically.

Tuscola attached a Sound Modeling Report as Appendix "D" to the SLUP application. Sound Modeling Rep, ECF No. 30, Ex. B. The report begins by quoting the Zoning Ordinance requirement (reproduced above) which provides that "[n]oise emissions from the operation of a WECS . . . shall not exceed forty-five (45) decibels on the DBA scale as measured at the nearest property line of a non-participating property owner or road." § 1522(C)(14). In the report, Tuscola asserts that "[n]o metric is specified for this ordinance, so we have assumed a 45 dBA 1-hour L_{EQ}." Sound Modeling Rep. at 4.

Later in the report, Tuscola expanded on its decision to construe the ordinance as involving 45 dBA 1-hour L_{EQ}. Tuscola explained: "Sound pressure levels are constantly changing. It is for this reason that it makes sense to describe sound levels over time." *Id.* at 5. The report then defined various ways of measuring sound levels: "L_{min} and L_{max} are simply the minimum and maximum sound level, respectively, monitored over a period of time." *Id.* But more sophisticated measures of sound levels over time exist:

> Ln is the sound level exceeded n percent of the time. . . . For example, the L_{10} is the sound level that is exceeded 10 percent of the time, while L_{90} is the sound level exceeded 90 percent of the time. The L_{50} is the median and is exceeded half the time. The L_{90} is often described as the "residual" level, describing a condition when most short-term contaminating sources are removed.

Id.

Finally, Tuscola defined its preferred metric: "One of the most common ways of describing noise levels is in terms of the continuous equivalent sound (L_{EQ}). The L_{EQ} is the average of the sound *pressure* over an entire monitoring period." *Id.* (emphasis in original). Tuscola goes on:

> The monitoring period . . . can be for any amount of time. It could be one second ($L_{EQ\ 1\text{-}sec}$), one hour ($L_{EQ(1)}$), or 24 hours ($L_{EQ(24)}$). Because L_{EQ} is a logarithmic function of the average pressure, loud and infrequent sounds have a greater effect on the resulting L_{EQ} than quieter and more frequent sounds. . . . Because it tends to weight the higher sound levels and is representative of sound that takes place over time, the L_{EQ} is the most commonly used descriptor in noise standards and regulations.

Id. at 6.

Next, Tuscola discussed metrics for frequency weighting:

> [S]ound pressure levels are expressed in terms of decibels. Since the human ear is not sensitive to all frequencies equally, some frequencies, despite being the same decibel level, seem louder than others. For example, a 500 Hz tone at 80 dB sounds louder than a 63 Hz tone at 80 dB. For this reason, frequency weightings are applied to sound levels . . . . The most common weighting scale used in environmental noise analysis in the A-weight, which more accurately represents the sensitivity of the human ear at low to moderate sound energy. An A-weighted sound level is usually denoted with the unit dBA or dB(A).

Id.

Thus, the Zoning Ordinance specifies the metric for use in frequency weighting (dBA), but does not expressly identify the metric for measuring sound pressure levels. Applying its preferred metric of L_{EQ} 1-hour, Tuscola found that "the highest modeled sound level at any non-participating property line, or road adjacent to a non-participating property line within the Township of Almer is 45 dBA and the highest sound level at any residence is 44 dBA." *Id.* at 9.

The SLUP application additionally proposed that the "electrical power collection system," which would transport the energy produced by the turbines, include aboveground power lines. SLUP App. at 13. The Zoning Ordinance requires all electrical connection systems and power

lines from wind turbines to be located below ground, but permits the Planning Commission to waive that requirement. *See* Zoning Ord., at § 1522(C)(15).

C.

To assist in its consideration of the application, the Township retained the Spicer Group, Inc., an engineering consulting firm. On October 25, 2016, the Spicer Group sent Tuscola an email requesting clarification and/or additional information regarding several aspects of the application. Spicer Oct. 25 Email, ECF No. 30, Ex. C. Three of the Spicer Group's concerns are relevant. First, Spicer questioned several aspects of the sound emissions report, including how Tuscola chose the 1-hour L_{EQ} as the proper metric. *Id.* at 2. The Spicer Group further asked when Tuscola would be submitting an economic impact study, indicating concern that "the property value information provided on pages 10 through 11 of the TW3 SUP Application is not local and not pertinent to Almer Township." *Id.* Finally, the Spicer Group indicated that Tuscola's proposal to place the power lines above the ground did not conform with the Zoning Ordinance requirement that all electrical connection systems and lines from a wind farm be placed underground. *Id.* at 3. The Spicer Group acknowledged that the Planning Commission has discretion to waive that requirement, but suggested that Tuscola had not yet sought that waiver. *Id.*

Tuscola responded to the Spicer Group's inquiries on October 31, 2016. Oct. 31, 2016, Resp, ECF No. 30, Ex. D. Tuscola defended its use of the 1-hour L_{EQ} metric by asserting that international standards for measuring sound in the wind turbine context use that metric. *Id.* at 4. Tuscola further noted that the Akron, Ellington, and Columbia Townships use the 1-hour L_{EQ} metric and that past wind power projects in the area were assessed under that metric. *Id.* Tuscola explained that it did not provide an economic study specific to Almer Township because the Township had not requested one. Finally, Tuscola defended its proposal to place the power lines

from the wind turbines above ground. Tuscola explained that construction, maintenance, and repair are all more difficult and costly for underground lines. *Id.* at 6. Similarly, underground power lines require more cables and have a shorter life expectancy. *Id.*

D.

1.

On November 8, 2016, the Spicer Group submitted a report to the Planning Commission analyzing Tuscola's SLUP application. Spicer Rep., ECF No. 30, EX. F. In the report, the Spicer Group concluded that Tuscola had complied with many, indeed most, of the Zoning Ordinance's requirements. But the Spicer Group did identify a number of outstanding issues. Among other recommendations, the Spicer Group suggested that the Planning Commission should require Tuscola to commission or identify an economic impact study for the proposed Almer Township project. *Id.* at 5. The Spicer Group also noted that Tuscola had not provided information confirming that the proposed turbines had a braking device which complied with the Zoning Ordinance.[1] The Spicer Group explained that Tuscola was seeking an exception to certain Zoning Ordinance requirements: first, instead of building an 8-foot fence around the turbines, Tuscola was requesting leave to keep the structures locked at all times[2]; and, second, Tuscola was seeking leave to build aboveground transmission lines. Finally, the Spicer Group indicated that Tuscola's noise emissions report left several questions unanswered, including whether the 45 dBA limit was measured to the closest road, or simply to the closest road adjacent to a *non-participating property*. *Id.* at 7.

[1] § 1522(C)(11) requires each wind turbine to be "equipped with a braking device capable of stopping the [turbine's] operation in high winds."

[2] *See* § 1522(C)(8).

On November 10, 2016, the Planning Commission held a public hearing to discuss the SLUP application. Nov. 10, 2016, Hearing Tr., ECF No. 30, Ex. I. At the hearing, a representative from Tuscola discussed the project. Among other things, the Tuscola representative explained why he believed that 45 dBA 1-hour L_{EQ} was the appropriate metric to use in determining the sound emissions produced by the turbines. *See id.* at 29–35. First, the representative explained that the 1-hour L_{EQ} metric was used by certain international standards and was the metric used by the manufacturer to model probable sound emissions. *Id.* at 31. The representative also explained that the 1-hour L_{EQ} metric was more practical: L_{EQ} is used in many noise emission standards, regulations, and guidelines (including neighboring townships).[3] More importantly, the 1-hour L_{EQ} metric is not "susceptible to wind gusts or other extraneous non-wind turbine events," unlike the L_{max} metric. *Id.* at 32.

For the rest of the hearing, members of the community expressed their opinions on the proposals. Most speakers communicated objections to various aspects of the application (if not the project as a whole), but some expressed support for the wind energy project. Two sound engineers testified at the hearing. The first engineer, Rick James, is an employee of e-Coustic Solutions and was hired by concerned citizens. *Id.* at 107. First, Mr. James opined that Tuscola's noise emissions report likely understated the dBA level at several property lines. *Id.* at 108–09. Second, Mr. James challenged Tuscola's assertion that the noise emissions provision in the Zoning Ordinance allowed for an averaged sound level measurement, as opposed to a maximum level: "[T]he words are very explicit, they say, 'Shall not exceed 45 dBA.' When you read law you can't read into it when the words aren't there. It doesn't say 45 dBA Leq, it does not say 45 dBA average, it says not exceed

[3] The Tuscola representative specifically mentioned one New Hampshire regulation which stated that the noise emissions "shall not exceed" 45 dBA and where that language was interpreted as involving the L_{EQ} metric.

45 dBA." *Id.* at 109. Ms. Kerrie Standlee, the principle engineer for Acoustics by Design, also testified.[4] *Id.* at 130. Ms. Standlee concurred with Mr. James's interpretation of the ordinance:

> [T]he limit is stated in there that the level shall not exceed 45 dBA. It doesn't give any descriptor, is it supposed to be the Lmax or – and as was mentioned, an L90 or an L10 at 50, an Leq, it doesn't specify. Mr. James is correct in that when something is not specified, you take the normal interpretation, which would be Lmax. I'm with – I'm on the City of Portland Noise Review Board and we have an Lmax standard. It's not specified as the Lmax it's just – like yours it says it shall not exceed this level. And that is an absolute level, not – not an equivalent energy level.

Id. at 131.

Ultimately, the Planning Commission concluded that additional information was necessary before the SLUP application could be ruled upon. Accordingly, the public hearing was adjourned.

2.

The day after the public hearing, Tuscola sent the Planning Commission a response addressing several of the concerns raised by the Spicer Group. Nov. 11, 2016, Prop. Conditions, ECF No. 30, Ex. J. Tuscola offered to provide a copy of GE's safety manual and technical documentation to confirm that the turbines were equipped with a braking device, but indicated that the documents could be provided only if the Township entered into a "commercially reasonable non-disclosure agreement." *Id.* at 4. Tuscola also committed to providing a "baseline noise emission study" prior to site plan approval. *Id.*

Several days later, Tuscola sent another communication to the Planning Commission further addressing several of the issues identified by the Spicer Group. Nov. 15, 2016, Resp., ECF No. 30, Ex. K. The response included an economic impact report. *See* Economic Impact Rep., ECR No. 30, Ex. K. That economic impact report discussed the project's probable financial impact on local jobs, tax revenue, and lease payments. The report did not specifically identify the impact

[4] Acoustics by Design was retained by the Township to assist in reviewing the application.

the project would have on local property values, but summarized the studies (previously mentioned in the original SLUP application) which found no evidence in other states that existing wind farms lowered nearby property values. Tuscola also addressed the Spicer Group's concern regarding security at the turbines. Rather than placing a fence around the turbines as contemplated by the ordinance, Tuscola proposed "an alternate means of access control at the turbines: a locked access door built into the turbine." Nov. 15, 2016, Rep. at 5. Tuscola reiterated its request for permission to construct aboveground power lines.

Finally, Tuscola turned to the noise emissions issue. First, Tuscola discussed whether the 45 dBA limit is measured to the nearest road, even if the property owners adjacent to the road are participating in the wind project:

> Where a non-participant is adjacent to a participant and the two are separated by a road, it is logical that the 45 dBA limit applies at the non-participating property line, which is also the road center. But where two participating properties are adjacent but separated by a road, it is also logical that the 45 dBA limitation does not apply. The purpose of this subsection is to protect non-participants from the potential effects of wind turbine sound at the property line. From a policy standpoint, it makes no sense to protect those using the road (typically in an automobile) from wind turbine sound.

Id. at 6.

Next, Tuscola addressed the appropriate sound metric by which to measure the sound level:

> A specific sound level metric is not specified in this ordinance. The ordinance says that noise emissions from a WECS "shall not exceed" 45 dBA at a non-participating property line, but "shall not exceed" is not a metric; it simply means that, whatever metric is reasonably applied, that number shall not exceed 45 dBA. Therefore, an interpretation must be made on what is the most appropriate metric to apply to evaluate this ordinance.

Id.

Tuscola explained that its preferred metric, L_{EQ}, is the "sound metric commonly used in community sound surveys, guidelines, regulations (including those in neighboring communities), and standards, and is appropriate for use here." *Id.* at 7

In further support of its proposed metric, Tuscola explained that "[t]he standard for measuring the wind turbine sound power, IEC 61400-11, requires L_{eq} sound level measurements" and thus "[an] L_{eq} sound level limit allows for an appropriate and reasonable 'apples to apples' comparison.'" *Id.* (emphasis omitted). Tuscola further emphasized that most public health studies use L_{EQ} to define their findings. *Id.* Perhaps most importantly, Tuscola explained that nearby Ellington and Columbia Townships use a 1-hour L_{EQ} metric to regulate sound emissions and that the same metric governed "compliance evaluations for [previous wind farm projects] in neighboring townships, including Akron (L_{eq} specified), Fairgrove (no metric specified in the ordinance), and Gilford (no metric specific in the ordinance)." *Id.* Tuscola additionally noted that the Huron County and Akron Township ordinances couple "shall not exceed" language with an L_{EQ} metric. *Id.*

Finally, Tuscola articulated why it believed an L_{EQ} metric was more suited for measuring the true impact of wind farm noise emissions:

> A L_{eq} metric makes more sense here than a short-duration metric such as an L_{max}, which is susceptible to wind gusts and other extraneous events that result in elevated sound levels unrelated to the operation of the wind turbine. In addition, it is not reasonable to determine that a facility is out of compliance based on a 1-second reading above a particular limit. The intent of a sound ordinance is typically to allow for the continued use and enjoyment of the property and/or residence. For sounds that are of a short duration and dramatic, such as gun shots, mine blasts, or pile driving, an L_{max} metric could make sense, and is analogous to a speed limit infraction where an instantaneous level is necessary to protect the safety of drivers on the roadway. But for sound sources that are continuous in nature and do not include dramatic spikes, such as a wind turbine, using L_{eq} over a given time period is more appropriate. Even then, as noted above, the measurement will be primarily determined by any louder noises during the time period.

Id. at 8.

E.

On November 17, 2016, the Almer Township Board approved a "Wind Energy Conversion Systems Moratorium Ordinance." Moratorium, ECF No. 30, Ex. M.[5] In the moratorium, the Board indicated that applications for "Wind Energy Conversion Systems may be proliferating" and so "[t]he Township Board requires sufficient time for enactment of amendments to its Zoning Ordinance to establish reasonable regulations pertaining to the establishment, placement, construction, enlargement, and/or erection of Wind Energy Conversion System." *Id.* at 2. Thus, the Board enacted a

> moratorium, on a temporary basis, on the establishment, placement, construction, enlargement, and/or erection of Wind Energy Conversion Systems within the Township and on the issuance of any and all permits, licenses or approvals for any property subject to the Township's Zoning Ordinance for the establishment or use of Wind Energy Conversion Systems. . . . [T]his Ordinance shall apply to any applications pending before any Township board or commission, including the Township Board, Planning Commission or Zoning Board of Appeals.

Id. at 3.

F.

On December 6, 2016, Acoustics by Design, the sound engineering firm retained by the Township to aid in reviewing the SLUP application, submitted a memorandum to the Planning Commission addressing the Zoning Ordinance's 45 dBA limit. Acoustics by Design Memo, ECF No. 30, Ex. O. The memorandum, prepared by Kerrie Standlee, addressed the proper interpretation of the "shall not exceed" language:

> Ordinance 1522 states that the noise radiating from a wind energy facility cannot exceed a level of 45 dBA at the nearest property line of a non-participating property

[5] Although independent corroboration of this fact is not present in the record, Tuscola alleges that four new Board members were elected on November 8. According to Tuscola, each of these new Board members were part of an anti-wind citizen advocacy group. One of the newly elected Board members, Jim Tussey, was designated as the Board's Planning Commission representative. Defendants do not contest these assertions.

> owner or road. It does not however say anything about a noise metric that is associated with the limit. Because noise can be quantified in several ways, the omission of that detail has resulted in some of the Commissioners asking if the limit was intended to be what is referred to as a "maximum" noise level limit or if it was intended to be a limit associated with some other noise metric such as a statistical noise level limit (for instance, the L_{01}, L_{10}, L_{50}, or L_{90} noise level – defined as the level exceeded 1%, 10%, 50% and 90% of a specified time period) or an energy equivalent noise level (the Leq noise level – the noise level, which if present continuously, that would have the same acoustic energy as the time-varying sound level present during a specified time period).

Id. at 3.

Ultimately, Mr. Standlee opined that the ordinance established a maximum noise level limit:

> Without having access to any information regarding the ordinance author's intentions relative to the wording used in the ordinance, I would conclude that the 45 dBA limit specified in the ordinance is addressing a "maximum" noise level limit and not a limit associated with some other noise descriptor. Model noise ordinances written over the past 50 years have shown that noise ordinances can be written with a maximum noise level limit or they can be written with some other noise metric limit. However, in each case where a metric other than the maximum noise level is included, the noise metric was specified in the ordinance. When a noise limit is specified in an ordinance without reference to any specific noise metric, it is generally understood by acousticians that the limit is intended to be a "maximum" noise level limit and not a limit for a noise descriptor other than the maximum noise level.

Id.

The memorandum further explained that, even if a L_{EQ} metric were adopted, Tuscola's proposed 1-hour L_{EQ} metric was unreasonable:

> While I can agree that it might be reasonable to conclude that the 45 dBA noise limit in the wind energy facility noise ordinance could be considered an Leq noise metric limit and not an absolute maximum noise level limit, I cannot agree with the consultant that the limit could be a one-hour L_{eq} noise level limit. . . . Given the relatively short amount of time required to quantify the turbine sound level, it would be more reasonable to consider the noise limit in the ordinance is [sic] related to an L_{eq} metric associated with a time period that is much shorter than a one-hour time period.

Id.

G.

On December 7, 2016, the Planning Commission held a second public hearing. Dec. 7, 2016, Tr., ECF No. 30, Ex. Q. A Tuscola representative opened the hearing by addressing the concerns previously raised by the community and the Planning Commission. In large part, the Tuscola representative summarized the company's November 15, 2016, submission to the Planning Commission. A representative of the Spicer Group was also present. After Tuscola's presentation, members of the Planning Commission began asking questions of both the Tuscola representatives and the Spicer Group. One Planning Commission member, Jim Tussey, appeared to lead the discussion (the relevant aspects of which will be summarized here).

First, Mr. Tussey addressed the noise emission metric dispute, asking whether the L_{max} metric is equivalent to the L_{EQ} metric. *Id.* at 43. Tuscola's representative said it was not. *Id.* at 44. The Planning Commission then addressed the economic impact study. Chairman Braem was concerned about the lack of local studies:

> I appreciate the studies from other areas and looked at them, but in my opinion the ordinance has stated property values and I would say the assumption is Almer Township or at the least, you know, in possibly the townships where we already have turbines, and what were the property increases, whatever. . . . Could they supplement with an assessment of their opinions of the property-value impact a little closer to home?

Id. at 58–59.

In response, a Tuscola representative explained that any study of only Almer Township would be statistically suspect:

> A study specific to Almer Township I think would be too -- too minute and specific to really have, you know, statistically significant results, and so that's why we relied on those larger studies that covered a lot more areas over a much -- a much longer period of time. So we didn't find any more specific info specific to this area, but I can look in to see what more specific info can be provided to you.
>
> The closest that I found is Tuscola controller presentation [sic] to the county that he indicated since wind turbines came through Tuscola County property values in those particular areas have climbed and have climbed higher than the overall

> increase in property values that has been occurring since 2009. . . . And I want to point out that the national level studies that cover multiple states, I used an analysis method that, yes, it included some houses that were farther away from turbines, and fewer houses that were near turbines, but the way that the model weighted it is the nearer the house to a turbine, the exponentially higher that data point was weighted.

Id. at 59–60.

Eventually, the discussion returned to the proper noise emission metric. First, the Spicer Group representative explained his understanding of the ordinance: "[The Acoustics by Design sound engineer is] saying without any qualifier in your ordinance he thinks that it would be -- that you would interpret it as an Lmax, meaning 45 aren't at the property line . . . . The sound produced by the turbine itself, a hard line at the property line that would not exceed 45 decibels." *Id.* at 65. Mr. Tussey then articulated his understanding of the ambiguity in the ordinance: "That seems very reasonable, but just for everyone here to hear that there's ambiguity in the specification, and isn't the ambiguity caused because the first part of it uses an abbreviation of dBA? It doesn't spell out the words decibels space A weighted, it just says dBA?" *Id.* at 66. After the Spicer Group representative agreed, Mr. Tussey continued:

> And the second part it says not to exceed when it could have used the engineering term Lmax in replacement of the text not to exceed. So we kind of have a little bit of a mixture, on one part we use an engineering unit, metric as it's called, and on the other side we use a text form or a written form of the method Lmax. Now, couldn't we have written the whole part out in English and couldn't we have written the whole part out using metric?

Id.

The Spicer Group representative agreed that the standard could have been expressed in whole using either written language or mathematical and technical metrics. *Id.*

In response, Tuscola emphasized that the Acoustics by Design report indicated that the ordinance could be reasonably construed as creating an L_{EQ} standard, and then explained why an L_{max} metric was problematic:

> The Lmax is a challenge two reasons [sic]. One, you would not be able to do an unattended program per se, there's just too much fluctuation in the maximum. And also, it's challenging when you're there. . . . So you'll get wind gust which is brief but it will cause your sound levels to vary, and that makes it a -- one of the challenges on trying to use an Lmax along with the other challenges regarding sound power, apples-to-apples comparison, all that other stuff I talked about. But in the field trying to take a measurement and you're seeing the sound levels change if you're looking at a sound level meter, you know, varying and that could be due to lots of things, not necessarily the wind turbine. So it's difficult to pinpoint that sound level to a particular event.

Id. at 71–72.

When asked whether the tester could simply disregard non-representative spikes in sound, Tuscola explained the difficulty in doing so:

> I mean, looking at it I can say okay, I felt the wind gust, all right, I'm going to throw this period out, but it becomes – it's on the observer. All right. The observer threw out a lot of periods and then somebody could go back and say well, why did you throw out all these periods? Well, it was a wind gust, I'm trying just to get an Lmax, and you can't go back and turn things off and try to get an Lmax background per se because the wind speeds vary and it's hard to pinpoint exact one-second level to an event. It's not impossible at times, but that's one of the challenges where you're depending on the observer to make that call versus just collecting data and seeing what the numbers bear out over a 10-minute period in leq.

Id. at 72–73.

At this point, Mr. Tussey asked whether Tuscola's position was that the L_{max} metric was never used. Tuscola admitted that it was used in some situations: "There are instances where Lmax could be appropriate to evaluate, and Kerry Stanley indicated that in his experience in Portland they used an Lmax, so it's not – I'm not going to say it's never used, but an leq has been determined in other instances to be a reasonable approach as well for a similar type worry." *Id* at 73.

Eventually, Planning Commission Chairman Braem acknowledged: "I guess our charge we've got to interpret what our ordinance says." *Id.* at 78. The Tuscola representative appeared to agree:

> I think it's an interpretation of what's reasonable. Is it meant to be a one-second exceedence? And if you feel that then that's an Lmax. If you feel that it's reasonable for some other duration, what's the reasonable way to apply this? I think that's the determination you have to make. I'm just giving you . . . what I've seen in other jurisdictions in my experience, and that's the leq.

Id. at 81.

Members of the Planning Commission then deliberated over whether they needed more information from Tuscola regarding the sounds emissions or whether they were prepared to make a determination regarding the proper interpretation of the ordinance. Ultimately, Chairman Braem moved to table consideration of the SLUP application and request further information from Tuscola. *Id.* at 94. The Planning Commission discussed the outstanding issues, and then approved the motion to adjourn. The Township's attorney summarized the requested information as follows: "[Y]ou want to request information from NextEra on property values, noise, sound models based on Lmax and if there is the justification you just referenced regarding the cost estimate on the decommissioning of the individual towers." *Id.* at 105.

H.

1.

On December 22, 2016, Tuscola provided the supplemental information which the Planning Commission had requested. Dec. 22, 2016, Supp. Info, ECF No. 30, Ex. T. Among other things, Tuscola provided a report addressing whether the proposed development would comply with the Zoning Ordinance, if interpreted as providing a 45 dBA L_{max} limit. In the report, Tuscola again explained why the L_{max} metric is a poor tool for measuring wind turbine emissions:

- It is not representative of long-term exposure to wind turbine sound. Rather, it is a short-term statistical anomaly that occurs 0.0000001% of a year (i.e. 1 second in a year).

- One cannot subtract background from L_{max} measured levels since the L_{max} is not an equivalent average sound level, but rather the result of a damping function applied to the measured sound levels.

- The L_{max} is highly variable as a metric that results in poor repeatability among similarly conducted measurements.

- Manufacturers of wind turbines do not report L_{max} sound power for their wind turbines – only L_{eq}.

- L_{max} is the result of many complex temporal interactions that cannot be reliably modeled, include synchronization of blade passages, angle to the turbine rotor, wind direction, turbulence, wind shear, previous sound levels, and several other factors.

- The ISO 9613-2 model forecasts equivalent average sound levels, not instantaneous L_{max}.

Dec. 22, 2016, Noise Emissions Memo. at 2, ECF No. 30, Ex. T.

Tuscola further explained:

> The report . . . makes it quite clear that using an Lmax metric would make development of commercial wind energy in Almer Township impossible. Indeed, using that metric, a single wind turbine could not be sited within 2,775 feet (over ½ mile) from a non-participating property line. As Epsilon and RSG conclude in their report, requiring an Lmax metric would preclude Tuscola Wind III from siting a single wind turbine in the Township.

Dec. 22, 2016, Supp. Info. at 1.

Tuscola further argued that the ordinance should not be interpreted as imposing an L_{max} standard because the ordinance was ambiguous, the industry standard is L_{EQ}, and because that interpretation "would not allow for any commercial wind development, which would be exclusionary and thus unlawful." *Id.* at 2.

Next, Tuscola addressed the Planning Commission's request for an economic impact study which provided information regarding the project's likely impact on local property values. Tuscola explained:

> We already provided the Planning Commission with multiple scientific studies showing that wind turbines do not have a measurable impact on nearby property values. Several of these studies are described in our application. . . . These scientific studies make it clear that the Tuscola III project will not substantially diminish and impair property values. The Township does not need an area-specific study to substantiate that conclusion. That being said, we have attached some additional information specific to Tuscola County further showing the positive economic impact of wind turbines on all property owners in the community.
>
> The first attachment is Standard & Poor's 2016 Bond Rating Report for Tuscola County, along with an article explaining the report. Standard & Poor gave the county a AA-bond rating, crediting wind development for expanding the tax base: "Although counties across the state experienced broad-based valuation declines, Tuscola's tax base has expanded during the past several years, largely as a result of the development of wind turbines and infrastructure."
>
> . . .
>
> If the Township were to deny our SLUP application based on the alleged failure to provide an adequate property value study, that would be a violation of our legal rights. No other special land use in Almer Township requires a property value study. Even sexually oriented businesses, which can be sited as close as 300 feet from a residential district and 1000 feet from a church or school (much closer than a turbine can be sited to non-participating property line) are not required to submit a property value study as part of their permitting process.

Id. at 3–4.

2.

On December 29, 2016, the Spicer Group responded to Tuscola's supplemental memorandum. Spicer Group Dec. 29, 2016, Resp., ECF No. 30, Ex. U. First, the Spicer Group addressed Tuscola's submissions regarding the local property values:

> We note that the zoning ordinance requires such studies to address "…the area affected by the WECS…" and shall include probable financial impact as to "…property values." The 12/22 submittal does not address property values in the area of Almer Township; the focus seems to be on personal property values (note, the term "property values" is broad and inclusive of real property and personal property; the term "personal property values" is more narrow and is specific to personal property.)

Id. at 2 (quoting § 1522(C)(3)).

Next, the Spicer Group addressed the noise emissions issue. The Spicer Group questioned the accuracy of the data Tuscola provided regarding probable sound emission levels under an L_{max} metric, explaining that the data was drawn from a Massachusetts study that might be premised on disparate conditions. The Spicer Group also challenged Tuscola's claim that application of an L_{max} standard would be illegally exclusionary: "This apparent claim of exclusionary zoning is without merit – the Almer Township zoning ordinance is not prohibiting the development of the Wind Energy Conversion System. The applicant could secure more leases with property-owners to ensure they have enough participating parcels." *Id.* at 4.

3.

On January 3, 2017, Tuscola's representative sent a letter to the Planning Commission addressing the Spicer Group's memorandum. Jan. 3, 2017, Letter, ECF No. 30, Ex. V. The letter first disputed the Spicer Group's contention that the property value data had been limited to information regarding personal property. Rather, the letter emphasized that the studies and reports provided had discussed the impact of wind turbines on real property values in a variety of contexts (albeit not in an Almer Township-specific context). *Id.* at 2–3. Second, the letter addressed a number of the Spicer Group's contentions regarding the sound emissions issue. In large part, the letter reiterated Tuscola's previous arguments regarding why the ordinance did not require application of the L_{max} metric and why that interpretation was not warranted. The Tuscola representative also defended its L_{max} model, explaining that the Spicer Group's concerns simply underscore the unhelpful nature of the L_{max} metric in the wind turbine context:

> Our acousticians' report explains the basis for the Lmax modeling and their conservative assumptions. As our report points out, expected Lmax sound levels are not generally evaluated with respect to a sound limit for wind energy systems. This coupled with a lack of manufacturers' data and lack of scientific studies comparing pre and post-construction studies for an Lmax results in a higher degree of uncertainty regarding an Lmax evaluation as compared to an Leq. Therefore,

> more conservatism is included in our acousticians' analysis. Spicer's questions further illustrate why it makes no sense to imply an Lmax metric in the ordinance in the first instance.

Id. at 4.

I.

1.

On January 4, 2017, the Planning Commission held its third and final public hearing on the SLUP application. Jan. 4, 2017, Hearing Tr., ECF No. 30, Ex. X. At the hearing, Tuscola summarized the documents it had submitted since the last hearing. As before, the discussion centered on the noise emissions issue. Planning Commission member Tussey asked whether the ordinance's standard (45 dBA), was an "incomplete metric." *Id.* at 18. The Tuscola representative asserted that "[i]t's ambiguous as to the metric used to measure 45 dB(A)." *Id.* Mr. Tussey continued: "And you're saying it's ambiguous because there's not more to 45 dB(A). There should be a dB(A) something, such as Leq one hour, and then it would be a complete metric. That's what you've said, that 45 dB(A) Leq one hour is a complete metric." *Id.* at 20. The Tuscola representative clarified the company's position: "45 dB(A) is not ambiguous. The ordinance is silent as to a metric, which means it requires interpretation." *Id.* Mr. Tussey then articulated his interpretation of the ordinance:

> [I]n the scientific community metric is -- are the units applied to whatever value. For example, miles per hour is a metric. . . . You can use additional qualifiers on the metric. For example, Ryan, I could say that you drove a 45 miles an hour to get here and everybody would understand that. And there would be no argument that miles per hour is the metric.
>
> . . .
>
> So the ordinance does state dB(A) and dB(A) is a valid metric. No one questions if dB(A) is, in fact, a dB(A). There are options to provide additional metric qualifiers to that metric, but dB(A) is the metric. And you have confused, I believe at a scientific level, the use of dB(A) with some qualifier with dB(A); and, hence,

> you're trying to make a presentation that somehow our ordinance is incomplete. And I do not find it incomplete. I find the ordinance quite complete. It says 45. Just as if the speed was said to be 45, not to exceed, any average person can understand that. . . . [T]he purpose of this body is not to rewrite an ordinance.

Id. at 20–22.

Tuscola responded: "[T]he ordinance is silent as to the way you measure 45 dB(A)." *Id.* at 23. Rather, the metric raises that question: "[W]hen you have a 45, you have to – is it instantaneous, is it - - is it a maximum, is it an Leq, is it L90? That metric is part of it, and it's not in this ordinance." *Id.*

After addressing other disputed issues, including whether Tuscola was required to provide Almer Township-specific property value studies, Planning Commission member Daniels moved to recommend denial of the SLUP application. *Id.* at 44. The Commissioners then discussed their opinions on the application. Chairman Braem asked Commissioner Tussey whether the ordinance should be interpreted as imposing an L_{max} standard since neighboring townships had interpreted similar language as creating an L_{EQ} standard. Tussey replied: "I'm not struggling with Lmax because 45dB(A) is a valid metric. . . . And the fact that the ordinance says not to exceed – and I believe even from a legal standpoint we're always to interpret the simplest definition in English. And that our job here isn't to interpret what they meant; it is to enforce what is written." *Id.* at 45–46.

Commissioner Daniels also articulated his rationale for recommending denial of the SLUP application. He asserted that "[t]he ordinance does not allow for the averaging varying levels of sound. We, as a Planning Commission, are not here to rewrite the ordinance, but to enforce the ordinance as written. And it mandates a maximum sound level of 45 decibels." *Id.* at 47. Commissioner Daniels also opined that Tuscola had not procured adequate insurance coverage for the turbines and had not made sufficient efforts to minimize shadow flicker for Almer Township

residents. Chairman Braem then briefly explained that he was satisfied with the insurance coverage, the economic impact study, and efforts to reduce shadow flicker.

Ultimately, the Planning Commission voted 3 to 1 to recommend denial of the SLUP application (two members did not vote because of a conflict of interest). *Id.* at 51–52.

2.

On January 17, 2017, the Almer Township Board held a public meeting to review the Planning Commission's recommendation regarding the SLUP application. Jan. 17, 2017, Tr., ECF No. 30, Ex. DD. After opening the floor to public comments (including comments by a Tuscola representative), the Board discussed the Planning Commission's recommendation to deny the SLUP application. Every Board member to discuss the recommendation on the record was supportive of the Planning Commission's rationale for denial. And most Board members appeared to focus on the noise emissions issue. For example, Board Member Rosenstangel stated that the Planning Commission's recommendation was "very well put together. And my concern was the 45 decibels shall not exceed. And I think that's what we should stick with is it shall not exceed the 45 decibels." *Id.* at 19. Board Member Graff made a similar statement:

> I also agree with the shall not exceed. I look at this not any different than a speed limit. If you're going 55 miles an hour, 55 miles an hour is the speed limit that you're supposed to have, you can't average it out. You can't drive from Saginaw to Cass City and go 75 miles an hour, but you have to slow down for all the little towns in between. When the police officer stops you outside of Cass City, you don't say, well, you have to relook at it because, if you average it out, I was only going 55 miles an hour.

Id. at 20–21.

Likewise, Board Member Tussey (who is the Board's Planning Commission representative) reiterated his reasons for opposing the SLUP application. Ultimately, the Almer Township Board voted 5 to 1 to deny the SLUP application. *Id.* at 33–35.

The Board simultaneously issued a Resolution articulating its rationale for denying the SLUP application. Res. Deny. SLUP, ECF No. 30, Ex. FF. In the Resolution, the Board identified five areas in which the SLUP application did not comply with the Zoning Ordinance. First, the Board faulted Tuscola for not providing an adequate economic impact study. Despite being asked to "provide a property values analysis that was localized to Almer Township," Tuscola "provided property value analyses based on other states, as well as some information concerning *personal* property values in Michigan, but still provided no *real property* value analyses using Michigan data." *Id.* at 6–7 (emphasis in original).

Second, the Board found that the SLUP application did not comply with the Zoning Ordinance's limit on noise emissions. The Board explained that the ordinance's "limitation on noise emissions . . . is clear and unambiguous and requires no further qualifying metric or analysis." *Id.* at 7. In response to Tuscola's argument that an L_{EQ} standard should be utilized, the Board found that "using an L_{eq} standard is inconsistent with the plain and unambiguous language of the Zoning Ordinance, which clearly provides that noise from a WECS 'shall not exceed forty-five (45) decibels.'" *Id.* at 8. The Board further referenced the opinion of "acoustician Kerrie G. Standlee," who advised the Planning Commission that the language of the Zoning Ordinance would ordinarily be interpreted by acousticians as establishing a maximum noise level limit.[6]

Third, the Board explained that Tuscola had not complied with the ordinance's requirement that an eight foot security fence be placed around the turbines. The Board acknowledged that Tuscola sought a variance from that requirement from the Planning Commission, but noted that the variance was not approved. And the Board concurred with that decision: "The Township Board

[6] The Board further indicated that even if an L_{EQ} metric were adopted, the 1-hour L_{EQ} suggested by Tuscola was not warranted. Rather, a ten-minute interval would be more appropriate. Tuscola had previously indicated that, if a ten-minute interval were applied, the proposed locations of the wind turbines would have to be revisited. Thus, even if the Board adopted the L_{EQ} metric, Tuscola would still have been required to amend its proposal.

also does not approve this alternative, as the Township Board finds that the proposed alternative of having no fence will not adequately protect the public health, safety, and welfare." *Id.* at 10.

Fourth, the Board faulted Tuscola for not providing the turbine safety manual and thus confirming that the turbines are equipped with an adequate braking device: "The Applicant has withheld documentation . . . that would identify the braking device's capability, citing the Applicant's nondisclosure agreement with GE." *Id.* at 10–11.

Fifth, the Board found that Tuscola had not complied with the ordinance's requirement that the electrical lines stemming from the turbines be placed underground. Again, the Board concurred with the Planning Commission's refusal to waive that requirement: "The Township Board . . . does not grant the requested waiver because it finds that the proposed underground lines would be detrimental to the aesthetics of the Township and will not protect the public health, safety, and welfare." *Id.* at 11.

Finally, the Board noted that it had previously approved a moratorium on wind energy projects in the Township and thus was precluded from approving the SLUP application even if it had complied with the Zoning Ordinance.

3.

On January 9, 2017, several days after the Planning Commission recommended denial of the SLUP application, Tuscola requested an interpretation of the Zoning Ordinance's 45 dBA limit by the Zoning Board of Appeals. ZBA Interp. App., ECF No. 30, EX. Z. In the application, Tuscola asked the ZBA to provide expedited review: "Under Section 2401 of the Ordinance, the Township Board must make a decision on Tuscola Wind III's application within 30 days of the Planning Commission's recommendation; in other words, by February 3, 2017. Given that the ZBA's

interpretation will be binding on the Township Board, we respectfully request that the ZBA render its interpretation before that date." *Id.* at 4.

The ZBA did not give expedited consideration to Tuscola's request. When the Almer Township Board denied the SLUP application, the ZBA appeal had not yet been resolved. Tuscola subsequently withdrew its request for an interpretation of the Zoning Ordinance's provision regarding noise emissions. March 10, 2017, Email, ECF No. 35, Ex. 4.

II.

Review of Count One of the complaint (a claim of appeal from the Township Board decision denying the SLUP application) is governed by article 6, § 28 of the Michigan Constitution. Pursuant to that section, the review "shall include, as a minimum, the determination whether such final decisions, findings, rulings and orders are authorized by law; and, in cases in which a hearing is required, whether the same are supported by competent, material and substantial evidence on the whole record." Mich. Const. Art. 6, § 28.

Thus, the Court must determine both whether the decision was "authorized by law" and supported by "substantial evidence." A decision is "authorized by law" if "allowed, permitted, or empowered by law." *Northwestern. Nat. Cas. Co. v. Ins. Com'r*, 586 N.W.2d 563, 566 (1998) (citing Black's Law Dictionary (5th ed.)). In other words, "[t]he decision must be affirmed unless it is in violation of statute, in excess of the statutory authority or jurisdiction of the agency, made upon unlawful procedures resulting in material prejudice, or is arbitrary and capricious." *Brandon Sch. Dist. v. Michigan Educ. Special Servs. Ass'n*, 477 N.W.2d 138, 141 (1991). Thus, the "authorized by law" analysis "focuses on the agency's power and authority to act rather than on the objective correctness of its decision." *Northwestern*, 586 N.W.2d at 566.

"Substantial evidence" is "evidence that a reasonable person would accept as sufficient to support a conclusion. While this requires more than a scintilla of evidence, it may be substantially less than a preponderance." *Dowerk v. Charter Twp. of Oxford*, 233 Mich. App. 62, 72 (1998). The Michigan Supreme Court has discussed the nature of the "substantial evidence" standard:

> What the drafters of the Constitution intended was a thorough judicial review of administrative decision, a review which considers the whole record-that is, both sides of the record-not just those portions of the record supporting the findings of the administrative agency. Although such a review does not attain the status of De novo review, it necessarily entails a degree of qualitative and quantitative evaluation of evidence considered by an agency. Such review must be undertaken with considerable sensitivity in order that the courts accord due deference to administrative expertise and not invade the province of exclusive administrative fact-finding by displacing an agency's choice between two reasonably differing views.

Michigan Employment Relations Comm'n v. Detroit Symphony Orchestra, Inc., 393 Mich. 116, 124 (1974).

"Strict deference must be given to an administrative agency's findings of fact," and the "agency's decision must be upheld if it is supported by such evidence as a reasonable mind would accept as adequate to support the decision." *THM, Ltd. v. Comm'r of Ins.*, 176 Mich. App. 772, 776 (1989).

Pursuant to the Michigan Zoning Enabling Act, "[a] request for approval of a land use or activity shall be approved if the request is in compliance with the standards stated in the zoning ordinance, the conditions imposed under the zoning ordinance, other applicable ordinances, and state and federal statutes." M.C.L. 125.3504.

III.

Tuscola argues each of the Board's purported reasons for denying the SLUP application were contrary to Michigan law and not supported by substantial evidence. Tuscola further argues that the Board did not have the authority to enact a moratorium on wind energy projects in the Township. For its part, the Township argues that Tuscola's appeal is not ripe because the company

did not appeal from a final decision of the Township. Next, the Township argues that each of the Board's expressed reasons for denying the SLUP application were reasonable and permitted by law. And, finally, the Township argues that the temporary moratorium on wind energy project permits was valid.

A.

The Township argues that this case is not ripe for appeal. Practically speaking, this argument is about finality. The Township argues that because Tuscola did not appeal to the Zoning Board of Appeals, a final decision on the SLUP application had not been rendered. If appeal to the ZBA is a precondition to judicial review in this context, then this Court lacks jurisdiction to adjudicate this matter. Accordingly, this threshold issue will be resolved first.

Tuscola contends that the Court has jurisdiction to hear this appeal via article 6, section 28 of the Michigan Constitution. That provision states that "[a]ll *final* decisions, findings, rulings and orders of any administrative officer or agency existing under the constitution or by law, which are judicial or quasi-judicial and affect private rights or licenses, shall be subject to direct review by the courts as provided by law." *Id.* (emphasis added).

The Almer Township Zoning Ordinance establishes a Zoning Board of Appeals ("ZBA"). Almer Twp. Zoning Ord., Art. 23. The Almer Township's ZBA was created under the authority and direction provided by the Michigan Zoning Enabling Act, M.C. L. 125.3101 *et seq.* Pursuant to M.C.L. 125.3604(1),

> An appeal to the zoning board of appeals may be taken by a person aggrieved or by an officer, department, board, or bureau of this state or the local unit of government. In addition, a variance in the zoning ordinance may be applied for and granted under section 4 of the uniform condemnation procedures act, 1980 PA 87, MCL 213.54, and as provided under this act. The zoning board of appeals shall state the grounds of any determination made by the board.

Id.[7]

More importantly, M.C.L. 125.3605 specifies that "[t]he decision of the zoning board of appeals shall be final. A party aggrieved by the decision may appeal to the circuit court for the county in which the property is located as provided under section 606." Thus, the Michigan Zoning Enabling Act specifies that, generally, a decision regarding a zoning ordinance is final for purposes of article 6, section 28 of the Michigan Constitution only after the zoning board of appeals has decided the issue.[8]

Tuscola argues that "a ripeness challenge is appropriate only when a party challenges the constitutionality of an ordinance, not when the party claims an appeal from a township's administrative decision." Pl. Reply Br. at 1, ECF No. 37. In support of that contention, Tuscola cites *Arthur Land Co., LLC v. Otsego Cty.*, 645 N.W.2d 50 (Mich. Ct. App. 2002). There, the Michigan Court of Appeals explained that

> although there is no requirement that a plaintiff exhaust administrative remedies before bringing a taking or substantive due process claim, *Electro-Tech, Inc. v. H.F. Campbell Co.*, 433 Mich. 57, 79, 445 N.W.2d 61 (1989), a judicial challenge to the constitutionality of a zoning ordinance, as applied to a particular parcel of land, is not ripe for judicial review until the plaintiff has obtained a final, nonjudicial determination regarding the permitted use of the land (e.g., denial of a special-use permit or variance). *See Paragon*, *supra* at 576, 550 N.W.2d 772.

Id. at 58 n. 20.

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[7] M.C.L. 125.3604 permits local governments to give zoning boards of appeals the authority to grant use variances, but does not require them to do so. *Id.* at 125.3604(11).

[8] Note that M.C.L. 125.3607(1) permits "[a]ny party aggrieved by any order, determination, or decision of any officer, agency, board, commission, zoning board of appeals, or legislative body of any local unit of government made under section 208" to appeal directly to the circuit court. The cited section, M.C.L. 125.3208, involves scenarios where "the the use of a dwelling, building, or structure or of the land is lawful at the time of enactment of a zoning ordinance or an amendment to a zoning ordinance." In that situation, the local legislative body may provide provisions in the amended zoning ordinance addressing the treatment of prior existing but now nonconforming uses. That situation is not present here, but the exception to the general requirement of appeal to the ZBA prior to judicial review proves the rule.

But *Arthur Land* does stand for the proposition that Tuscola suggests. The footnote which Tuscola cites simply distinguishes between the kinds of constitutional claims which require finality. Here, Tuscola is challenging the Township Board's interpretation and application of the Zoning Ordinance, not advancing any kind of taking or substantive due process claim. And, further, the very section of the Michigan Constitution which Tuscola relies upon for jurisdiction predicates its applicability on the existence of a *final* decision. If the SLUP application has not been denied in a final, nonjudicial determination, this Court has no jurisdiction under article 6, section 28 of the Michigan Constitution.

The determinative question, then, is whether the Almer Township Board's denial of the SLUP application was a final decision. Tuscola argues that it was: "A township board's decision on a SLUP application is a final decision that does not need to be appealed to the ZBA unless required by the zoning ordinance." Pl. Reply Br. at 2. In support of that contention, Tuscola relies upon *Carleton Sportsman's Club v. Exeter Twp.*, 550 N.W.2d 867, 869 (Mich. Ct. App. 1996). In *Carleton*, the Michigan Court of Appeals held that "where a township zoning ordinance does not provide for review of a request for a special land-use permit by a zoning board of appeals, the township board's decision is final and subject to appellate review by the circuit court pursuant to Const. 1963, Art. 6, § 28." *Id.*

The *Carleton* decision was premised on the language in the Michigan's Township Rural Zoning Act, M.C.L. 125.271 *et seq.*, which specified that "an appeal of a township board's decisions regarding special land-use and planned unit development decisions, 'may be taken to the board of appeals only if provided for in the zoning ordinance.'" *Carleton*, 550 N.W.2d at 869 (quoting M.C.L. 125.290). The Michigan's Township Rural Zoning Act has since been replaced by the Michigan Zoning Enabling Act, but the operative language remains. *See* M.C.L. 125.3603

("For special land use and planned unit development decisions, an appeal may be taken to the zoning board of appeals only if provided for in the zoning ordinance.").

Here, the Almer Township Zoning Ordinance does not expressly grant the ZBA jurisdiction to consider Township Board denials of SLUP applications. The Zoning Ordinance gives the ZBA general jurisdiction to "hear and decide appeals where it is alleged there is error of law in any order, requirement, decision or determination made by the Zoning Administrative or *administrative body* in the enforcement of this Ordinance." Almer Twp. Zoning Ord., Art. 23, § 2302 (emphasis added). A township board is typically a legislative body, but can act in an administrative capacity in certain situations. The Michigan Court of Appeals has explained that "approval of special use permits" is typically an administrative function, but "where the city council is given the discretion to review the issue de novo and accept or reject the recommendations of the planning commission in the ordinance, the council's power is, instead, legislative." *Swiecicki v. City of Dearborn*, No. 262892, 2006 WL 2613593, at *7 (Mich. Ct. App. Sept. 12, 2006) (citing *Sun Communities v. Leroy Twp*, 617 NW2d 42 (Mich. Mc. App. 2000) and *Hesse Realty, Inc v. Ann Arbor*, 61 Mich. App 319, 323–324 (1975)). The Almer Township Zoning Ordinance grants the Township Board discretion to conduct a de novo review of the Planning Commission's recommendations regarding SLUP applications, and thus Tuscola is appealing from a legislative decision.

The Zoning Ordinance does not on its face permit appeals to the ZBA from legislative decisions by the Township Board. And such a dynamic would be counterintuitive because the members of the ZBA are appointed by the Township Board and are tasked with interpreting the provisions of the Zoning Ordinance as enacted *by* the Township Board. Because the Zoning Ordinance does not specifically provide for appeal of a SLUP application to the ZBA, the

Township Board's decision is a final and appealable order per *Carleton*. The denial of the SLUP application is ripe for review.

B.

Proceeding to the merits of the appeal,[9] Tuscola has not demonstrated that the denial of the SLUP application was contrary to law or not support by substantial evidence, as those standards have been articulated by Michigan courts. The Township Board based its denial of the application on five perceived deficiencies in the SLUP application. Accordingly, the Township Board's decision will be disturbed only if none of the five bases for denial were consistent with the law and supported by substantial evidence.

The record reflects that the Planning Commission, Township Board, and Tuscola devoted substantial attention to the proper interpretation of the Zoning Ordinance's section providing that noise emissions from wind turbines "shall not exceed" 45 dBA. Zoning Ordinance, § 1522(C)(14). Because so much of the record is devoted to that dispute, this issue will be addressed first. For several reasons, Tuscola's noncompliance with the noise emission limit was a permissible basis for the Township Board to premise its denial of the SLUP application.

1.

The initial issue which must be confronted is the extent to which this Court should defer to the Township Board's interpretation of its own Zoning Ordinance. Tuscola contends that the Court must conduct a de novo review of the proper interpretation of the ordinance. Appellant Br. at 20.

[9] Tuscola also challenges the validity of the moratorium which the Township Board enacted in November of 2016. Although the moratorium on wind energy projects was enacted after Tuscola's SLUP application was submitted (but before it was rejected), the Planning Commission and Township Board proceeded to consider the SLUP application on its merits. At most, the Township Board relied upon the moratorium as an alternative (and secondary) basis for denying the SLUP application. Because the Board's denial of the application was supported by substantial evidence and was not contrary to law, the legitimacy of the moratorium need not be resolved. And, importantly, because the moratorium has now ended, any opinion on the Township Board's prospective authority to enact another moratorium would constitute an advisory opinion. *See* Appellee Resp. Br. at 24–25.

In fact, Tuscola expressly identifies its "ZBA request for interpretation" as further articulating the reasons why the Township Board's interpretation was incorrect. *Id.* at 20 n. 14. Tuscola thus assumes that this Court's analysis should be conducted independently and without reference to the Township Board's. But such an approach is inconsistent with Michigan law.

Michigan Courts have repeatedly confirmed that courts should defer to municipal interpretations of zoning ordinances. *See Macenas v. Vill. of Michiana*, 446 N.W.2d 102, 110 (Mich. 1989) ("[T]he import of our case law is that a reviewing court is to give deference to a municipality's interpretation of its own ordinance."); *Id.* ("[I]n cases of ambiguity in a municipal zoning ordinance, where a construction has been applied over an extended period by the officer or agency charged with its administration, that construction should be accorded great weight in determining the meaning of the ordinance."); *Davis v. Bd. of Ed. for Sch. Dist. of River Rouge*, 280 N.W.2d 453, 454 (Mich. 1979) ("We acknowledge that the construction placed upon a statute by the agency legislatively chosen to administer it is entitled to great weight."); *Paye v. City of Grosse Pointe*, 271 N.W. 826, 828 (Mich. 1937) (holding that a municipality's construction of an ordinance is not binding on a court, but that the municipality's construction is "always entitled to the most respectful consideration" and should not "be overruled without cogent reasons") (internal citations omitted). *But see Kalinoff v. Columbus Twp.*, 542 N.W.2d 276, 277 (Mich. Ct. App. 1995) (holding that deference to the zoning board's interpretation would not be given because "when the language used in an ordinance is clear and unambiguous, we may not engage in judicial interpretation, and the ordinance must be enforced as written").

The Michigan Court of Appeals' decision in *Sinelli v. Birmingham Bd. of Zoning Appeals* is particularly instructive. 408 N.W.2d 412, 414 (Mich. Ct. App. 1987). In *Sinelli*, the dispute centered on the meaning of the term "public property" in the zoning ordinance. The plaintiffs in

Sinelli wished to prevent a new restaurant from leasing a portion of land zoned as "public property" from the City of Birmingham to use for parking. The City argued that its interpretation of "public property,"—specifically, that it included off-street private parking—was "a reasonable exercise of [its] discretion." *Id.* The circuit court granted summary disposition for the defendants. On appeal, the Michigan Court of Appeals emphasized that "Birmingham has consistently interpreted § 5.15 as allowing the city to lease for parking purposes property zoned 'public property.'" *Id.* In conjunction with a discussion regarding the proper construction of the ordinance, the court concluded that the City of Birmingham had arrived at "a reasonable interpretation of the provision." *Id.* And, the court explained, that was sufficient to justify judgment for the defendants: "This Court will not sit in judgment on matters wholly within the reasonable discretion of local zoning boards whose decisions are regarded as final and binding unless caprice, abuse of discretion, or arbitrary action is provable." *Id.* at 415.

Here, the final decision on the SLUP application was rendered by the Township Board, the legislative body which enacted the Zoning Ordinance in the first place. And, as explained above, the SLUP application denial constitutes a legislative decision under Michigan law. In this context, the importance of deferring to the Township Board's interpretation of the statute is even greater. When a statute or ordinance is ambiguous, the ultimate authority on the meaning of the language would naturally be the legislative body which drafted and enacted it. *See Macenas*, 446 N.W.2d at 111 ("When there is no readily apparent meaning to a statutory phrase, we ordinarily turn to an attempt to determine the intent of the legislative body that enacted the statute or ordinance."). Typically, courts must interpret ambiguous statutory language without the benefit of an interpretation by the relevant legislative body. But where, as here, the legislative body has provided

an interpretation of the ordinance it passed, it would be counterintuitive to provide that interpretation no deference.

Thus, this Court does not sit in de novo review of the Zoning Ordinance provision regarding noise emission levels (assuming that the ordinance is ambiguous). Rather, the question is whether the Township Board's interpretation of the ordinance was "reasonable." *Sinelli*, 408 N.W.2d at 414. *See also Macenas*, 446 N.W.2d at 112. If the Board's decision was the result of "caprice, abuse of discretion, or arbitrary action," then it was not reasonable. *Sinelli*, 408 N.W.2d at 415. But unless there are "cogent reasons" to conclude that the Board's consideration was not reasonable, the Board's interpretation must be affirmed. *Macenas*, 446 N.W.2d at 112.

2.

Tuscola argues that the "Board's interpretation of Section 1522(C)(14) as unambiguously providing for an L_{max} sound metric was not reasonable." Appellant's Br. at 20. But, for several reasons, that argument falls short. First, the plain language of § 1522(C)(14) is best interpreted as imposing an L_{max} standard. Second, even if the provision is considered to be ambiguous, there is at best equivocal support for construing the provision as imposing an L_{EQ} standard. Rather, even if the provision could reasonably be interpreted as imposing an L_{EQ} standard, Tuscola has simply demonstrated that several reasonable interpretations of the provision exist. In the absence of cogent reasons to find the Township Board's interpretation unreasonable, its interpretation must be affirmed.

i.

As indicated above, Michigan courts have held that "when the language used in an ordinance is clear and unambiguous, we may not engage in judicial interpretation, and the

ordinance must be enforced as written." *Kalinoff*, 542 N.W.2d at 277. Thus, if the provision in question is not ambiguous, no further analysis is necessary.

The provision in question reads, in full:

> Noise emissions from the operations of a [Wind Energy Conversion System] shall not exceed forty-five (45) decibels on the DBA scale as measured at the nearest property line of a non-participating property owner or road. A baseline noise emission study of the proposed site and impact upon all areas within one mile of the proposed WECS location must be done (at the applicant's cost) prior to any placement of a WECS and submitted to the Township. The applicant must also provide estimated noise levels to property lines at the time of a Special Use application.

§ 1522(C)(14).

In the written resolution which the Township Board issued in conjunction with its denial of the SLUP application, the Board reasoned that the "limitation on noise emissions . . . is clear and unambiguous and requires no further qualifying metric or analysis." Res. Deny SLUP at 7. Tuscola argues that the provision is facially ambiguous because "'[s]hall not exceed' is not a metric—it simply means that whatever metric is applied, that number shall not exceed 45 dBA." Appellant Br. at 21.

The fundamental dispute between the parties is whether the provision includes a metric for measuring 45 dBA or whether the "shall not exceed" language constitutes a definable means of measuring sound emissions. Several facts are uncontested. First, all parties agree that sound can be measured in different ways. *Compare* Appellants Br. at 21 *with* Appellate Resp. Br. at 15. *See also* Sound Modeling Rep. at 5–6. Possible sound emission metrics include L_{max}, L_{min}, L_n, or L_{EQ}. As detailed above, each of these metrics constitutes a distinct way of measuring sound levels over time. The dispute between the parties centers on whether the ordinance calls for use of L_{max} or L_{EQ}. As already explained, L_{max} is "the . . . maximum sound level . . . monitored over a period of time." *Id.* at 5. L_{EQ}, on the other hand, is the "continuous equivalent sound." *Id.* In other words, L_{EQ} is the

"logarithmic function of the average [sound] pressure" over an "entire monitoring period." *Id.* at 6, 5.

Both L_{max} and L_{EQ} are meaningful only in the context of a given period of time. L_{max} can be measured only in reference to a time period: the maximum sound level reached during the specified period of measurement. Similarly, a complete L_{EQ} metric requires a notation of the length of the monitoring period that is being averaged. *See id.* at 6 ("The monitoring period . . . can be for any amount of time. It could be one second ($L_{EQ\ 1\text{-}sec}$), one hour ($L_{EQ(1)}$), or 24 hours ($L_{EQ(24)}$)."). Tuscola concedes (even advances) this point: "[The Township] argues that L_{eq} makes no sense because that metric requires a monitoring period and no monitoring period is specified in the Ordinance. . . . But as the Township itself points out, L_{max} requires a monitoring period as well." Appellant Reply Br. at 4–5 (internal citations omitted).

Section 1522(C)(14) does not include any language expressly identifying the length of the monitoring period. As such, the ordinance is ambiguous on that point. But that point of ambiguity is not the basis on which the Township Board denied the SLUP application. As Tuscola implicitly recognizes in the argument just quoted, the ambiguity created by the absence of a specified monitoring period exists regardless of whether the ordinance is interpreted as imposing an L_{max} or L_{EQ} standard. In other words, if the Township Board construed the ordinance as imposing a ten minute monitoring period, the question of whether the 45 dBA limit had been violated during that ten minute period would still be dependent on the means of measuring sound emissions. If L_{max} were used, then a single instance of sound emissions exceeding 45 dBA during the ten minutes would put the turbine in violation of the ordinance. If L_{EQ} were used, then the ordinance would be violated only if the continuous equivalent sound pressure over the ten minutes exceeded 45 dBA.

Tuscola appears to concede that, if the L_{max} metric were adopted, then its turbines would be in noncompliance with the ordinance regardless of the length of the monitoring period. *See* Dec. 22, 2016, Supp. Info at 1 ("The report . . . makes it quite clear that using an Lmax metric would make development of commercial wind energy in Almer Township impossible."). The ambiguity regarding the monitoring period is thus irrelevant. Rather, the determinative issue (and the one on which the Township Board rested its conclusion) is whether the ordinance imposes an L_{max} or L_{EQ} standard. And the Township Board's conclusion that § 1522(C)(14)'s language unambiguously provides for an L_{max} standard was eminently reasonable.

L_{max} involves maximum sound level achieved over a period of time; L_{EQ} involves a logarithmic averaging of the sound pressure over a period of time. By definition, then, if sound emissions over one hour total 45 dBA L_{EQ}, then the sounds emissions during that period almost certainly included moments when the instantaneous sound level exceeded 45 dBA. In other words, the "continuous equivalent sound" measured during a specified period inevitably constitutes a midpoint between the absolute high and low values measured during that period. *See* Sound Modeling Rep. at 5.

The "[s]hall not exceed" language in § 1522(C)(14) is facially indistinguishable from a L_{max} standard. If a wind turbines emitted 46 dBA of noise, then a common-sense reading of the provision (relying only on the language of the provision and no extraneous information) would conclude that the turbine had violated § 1522(C)(14). No language in § 1522(C)(14) would support a conclusion that one *instantaneous* emission of 46 dBA of noise is not violative of the statute as long as the turbine's *average* emission does not exceed 45 dBA.

When § 1522(C)(14) is compared to other ordinances which the Township could have mirrored, the best interpretation of the section becomes clear. Take, for example, the language in

Huron County's noise ordinance: "The audible sound from a Wind Energy Facility at a Noise Sensitive Facility may not exceed the Equivalent A-Weighted Continuous Sound Level (L_{eq}) limits set forth in Table 1[.]" Appellee Resp. Br. at 17 (emphasis omitted). The Huron County Ordinance thus defines the L_{EQ} standard by using the words "equivalent" and "continuous." Conversely, the Almer Township Zoning Ordinance is devoid of any terms that correspond to an L_{EQ} standard: there is no mention of equivalent, continuous, or average sound levels. Rather, § 1522(C)(14) simply specifies that the emissions "[s]hall not exceed" 45 dBA. That language is coterminous with the definition of L_{max} (as defined by Tuscola itself): If the wind turbine emits a sound that exceeds 45 dBA, the ordinance has been violated. The ordinance does not, on its face, provide for an averaging of noise emissions. Thus, the best interpretation of § 1522(C)(14) is that it unambiguously provides for a L_{max} standard. Any alternative interpretion would require inclusion of additional language or terms; the L_{max} standard alone is consistent with the words, and only the words, of § 1522(C)(14).[10]

ii.

Even if the Court were to conclude that § 1522(C)(14) is ambiguous regarding how to measure sound emissions (and not just ambiguous regarding the length of time over which to measure them), Tuscola's argument still falls short. Tuscola argues, correctly, that when an ordinance is ambiguous, courts must apply principles of statutory interpretation. "Unless defined in the statute, every word or phrase of a statute should be accorded its plain and ordinary meaning, taking into account the context in which the words are used." *Alcona Cty. v. Wolverine Envtl.*

[10] The maxim "expressio unius est exclusio alterius" is applicable here: "the expression of one thing is the exclusion of another, [the maxim] means that the express mention of one thing in a statute implies the exclusion of other similar things." *Alcona Cty. v. Wolverine Envtl. Prod., Inc.*, 590 N.W.2d 586, 590 (Mich. Ct. App. 1998). The ordinance specifies that a certain noise level shall not be exceeded, but does not provide that noise emissions shall be averaged. Because language referring to average noise emissions or continuous equivalent pressure has been omitted, the implication is that such language has been purposely excluded.

Prod., Inc., 590 N.W.2d 586, 590 (Mich. Ct. App. 1998). "Statutory language should be construed reasonably and the purpose of the statute should be kept in mind." *Id.* (internal citations omitted). Tuscola emphasizes that some courts (though no Michigan courts) have relied upon industry standards when interpreting statutory language. Appellant Br. at 23. *See also Prill v. Hampton*, 453 N.W.2d 909, 912 (Ct. App. 1990). But even considering all the factors and evidence which Tuscola relies on, the company has at best shown that the ordinance could reasonably be interpreted in several different ways.

To begin with, Tuscola's assertion that the SLUP application denial was premised solely on a finding that the language of § 1522(C)(14) is unambiguous, as opposed to an interpretation of what the language should be construed as requiring, is inaccurate. Admittedly, the written resolution which the Township Board provided in conjunction with its on-the-record denial of the application does assert that "using an L_{eq} standard is inconsistent with the plain and unambiguous language of the Zoning Ordinance." Res. Deny SLUP at 7. But Tuscola's implicit assertion that the Township Board refused to consider the Ordinance's context and any extraneous information that might inform their interpretation of the language is manifestly inconsistent with the record. During the hearing, several members of the Board discussed the language of § 1522(C)(14) and explained why they believed that it was incompatible with an L_{EQ} standard. *See* Jan. 17, 2017m Tr. at 19, 21.[11] Likewise, in the written resolution the Township Board expressly relied on, and quoted, the testimony provided by acoustician Kerrie Standlee. Because of its significance, that testimony will be quoted, again, here:

> Without having access to any information regarding the ordinance author's intentions relative to the wording used in the ordinance, I would conclude that the 45 dBA limit specified in the ordinance is addressing a "maximum" noise level

[11] And, of course, the Township Board's decision was informed by the Planning Commissions' recommendation, which was made only after hearing extensive testimony by Tuscola representatives and sound engineers regarding the best interpretation of the provision.

> limit and not a limit associated with some other noise descriptor. Model noise ordinances written over the past 50 years have shown that noise ordinances can be written with a maximum noise level limit or they can be written with some other noise metric limit. However, in each case where a metric other than the maximum noise level is included, the noise metric was specified in the ordinance. When a noise limit is specified in an ordinance without reference to any specific noise metric, it is generally understood by acousticians that the limit is intended to be a "maximum" noise level limit and not a limit for a noise descriptor other than the maximum noise level.

Acoustics by Design Memo. at 3.

Tuscola challenges Standlee's opinion by asserting that his interpretation of the ordinance is simply "an improper legal conclusion." Appellant Br. at 21. But Standlee clearly premises his opinion on both his own experience in the industry and what he understands industry standards to be. Tuscola argues elsewhere in its brief that those factors are relevant for properly interpreting the ordinance, and so it cannot reasonably discount Standlee's opinion for discussing industry standards. Tuscola appears to fault Standlee for relying upon generalizations, but Standlee provided very specific examples in his testimony before the Planning Commission. At the November 10, 2016, public hearing, Standlee testified "when something is not specified, you take the normal interpretation, which would be Lmax." Nov. 10, 2016, Hearing Tr. at 130. Standlee continued:

> [T]he limit is stated in there that the level shall not exceed 45 dBA. It doesn't give any descriptor, is it supposed to be the Lmax or – and as was mentioned, an L90 or an L10 at 50, an Leq, it doesn't specify. Mr. James is correct in that when something is not specified, you take the normal interpretation, which would be Lmax. I'm with – I'm on the City of Portland Noise Review Board and we have an Lmax standard. It's not specified as the Lmax it's just – like yours it says it shall not exceed this level. And that is an absolute level, not – not an equivalent energy level.

Id. at 131.

Thus, Standlee provided an expert opinion regarding how most acousticians would read the Almer Township Zoning Ordinance language, opined that the ordinance imposes an L_{max}

standard, and provided an example of another city ordinance (which uses the same language) that has been interpreted to mean L_{max}. Tuscola attempts to undermine Standlee's testimony by pointing to "the numerous concrete examples provided by TWIII's experts of sound provisions in wind ordinances, both in the Thumb and elsewhere, that either marry 'shall not exceed' language with an L_{eq} metric . . . or recognized L_{eq} as the appropriate metric in the absence of a specific metric." Appellant Br. at 22. Tuscola has not provided the language of the ordinances it refers to, and so it is difficult to ascertain the extent to which the statutory language is analogous.

The Township does provide the statutory language in the Akron Township and Huron County ordinances (which Tuscola cites for the proposition that "shall not exceed" language can be combined with an L_{EQ} standard), but both those ordinances expressly define the metric as L_{EQ}. It goes without saying that if the Zoning Ordinance specifically identified the metric, then no more interpretation would be needed. But the Almer Township Zoning Ordinance does not clearly identify the metric (or, at least, Tuscola repeatedly argues that the ordinance is ambiguous). The Akron Township and Huron County zoning ordinances utilize noise emission standards with materially different language and thus are of minimal relevance.

Ultimately, however, Tuscola's argument obfuscates the underlying analysis which must be conducted. The question is not whether the Zoning Ordinance could reasonably be interpreted as creating an L_{EQ} standard (though, as discussed above, the plain language of § 1522(C)(14) suggests that it could not). Rather, the question is whether the Township Board's interpretation was so unreasonable as to justify departure from the deference normally given to a municipality's interpretation of its own ordinance. As such, the language of other noise emission ordinances provides context, but is far from determinative.

Tuscola (and its experts) repeatedly, and perhaps accurately, assert that the industry standard is to measure wind turbine sound emissions using L_{EQ}, not L_{max}. But Tuscola's noise emission expert admitted that use of an L_{max} standard is not patently unreasonable:

> [Planning Commission Member Tussy:] Are you saying that dBA max is never used?
>
> [Tuscola Expert Lampeter:] There are instances where Lmax could be appropriate to evaluate, and Kerry Stanley indicated that in his experience in Portland they used an Lmax, so it's not – I'm not going to say that it's never used, but an leq has been determined in other instances to be a reasonable approach *as well* for a similar type worry."

Dec. 7, 2016, Hearing Tr. at 72 (emphasis added).

Later in the hearing, Mr. Lampeter again addressed the reasonableness of alternative interpretations. A Planning Commission member stated: "I guess our charge we've got to interpret what our ordinance says." *Id.* at 77. Mr. Lampeter agreed:

> I think the decision is what's reasonable and also what are we bound to in the ordinance, and I would say that jurisdictions have interpreted it as an leq, and I'd also say that's reasonable based on other standards . . . . I think it's an interpretation of what's reasonable. Is it meant to be a one-second exceedence? And if you feel that then that's an Lmax. If you feel that it's reasonable for some other duration, what's the reasonable way to apply this? I think that's the determination you have to make. I'm just giving you what I've seen in other jurisdictions in my experience, and that's the leq.

Id. at 78–80.

Thus, Tuscola's own expert appeared to concede that both L_{EQ} and L_{max} could reasonably be used. Mr. Lempeter's arguments (and the arguments Tuscola now makes) are fundamentally premised on the assertion that an L_{EQ} standard is a better choice. And that may be true. If this Court were making an independent determination of what metric is best suited for measuring wind turbine noise emissions, it might well select the L_{EQ} standard. But, for purposes of this review, it is not relevant whether L_{EQ} is the best way to measure noise emissions or whether the ordinance

could reasonably be construed as imposing that standard. Rather, Tuscola must demonstrate that the Township Board's adoption of the L_{max} standard *was not reasonable*.

Tuscola's expert agreed that the L_{max} standard is a valid metric which is used in certain municipal noise ordinances and that the Almer Township Zoning Ordinance could be interpreted in several reasonable ways. The Township's noise expert opined that most sound experts would read the Almer Township Zoning Ordinance as imposing an L_{max} standard, confirmed that the L_{max} standard is a valid metric, and identified a specific municipality where the noise emissions ordinance utilizes an L_{max} standard. Against this factual background (and considering the plain language of the statute), the Township Board's conclusion that § 1522(C)(14) imposes an L_{max} standard was reasonable. That conclusion was consistent with principles of statutory interpretation and supported by substantial evidence in the record. Reasonable minds might have arrived at a different conclusion. But the fact that several reasonable alternatives exist does not constitute a "cogent reason" to disregard a municipality's interpretation of its own ordinance. *See Macenas*, 446 N.W.2d at 112. To the contrary, that fact provides a persuasive rationale for deferring to the Municipality's decision. *See Alcona Cty.*, 590 N.W.2d at 596 n. 8 ("Although an agency's construction of a statute cannot be used to overcome a statute's plain meaning, . . . given that the position adopted by the MDEQ is plausible and is consistent with the language of the statute, it is entitled to reasonable deference."). The Court will do so here.

iii.

Tuscola's final argument regarding § 1522(C)(14) is that the Township Board's interpretation would result in exclusionary zoning, which is prohibited by Michigan law. Specifically, Tuscola argues that "[u]sing an L_{max} metric would make development of commercial wind energy in the Township impossible because a single wind turbine could not be sited within

at least a half-mile of a nonparticipating line." Appellant Br. at 24–25. This conclusory argument has no merit. Under Michigan, "a zoning ordinance may not totally exclude a land use where (1) there is a demonstrated need for that land use in the township or surrounding area, (2) the use is appropriate for the location, and (3) the use is lawful." *Eveline Twp. v. H & D Trucking Co.*, 448 N.W.2d 727, 730 (Mich. Ct. App. 1989). *See also* M.C.L. 125.3207. Even assuming that the Township Board's interpretation of the ordinance completely excludes wind energy development in the Township, Tuscola cannot prevail.[12]

Tuscola has made no attempt to show that there is a "demonstrated public need" for wind turbines in Almer Township, and the Court cannot comprehend why such a need would exist. "Presumably any entrepreneur seeking to use land for a particular purpose does so because of its perception that a demand exists for that use. To equate such a self-serving demand analysis with the 'demonstrated need' required by the statute would render that language mere surplusage or nugatory, in contravention of usual principles of construction." *Outdoor Sys., Inc. v. City of Clawson*, 686 N.W.2d 815, 819 (Mich. Ct. App. 2004). Further, "the public need must be more than mere convenience to the residents of the community." *DF Land Dev., LLC v. Charter Twp. of Ann Arbor*, No. 291362, 2010 WL 2757000, at *6 (Mich. Ct. App. July 13, 2010).

Wind turbines produce energy, which is, of course, needed by the Almer Township community. But Tuscola cannot reasonably argue that the Township will have inadequate access to energy absent the wind energy project. The Michigan Court of Appeals has explained that, to

[12] And that assumption is questionable. Tuscola asserts that application of an L_{max} standard would prevent the company from siting a turbine within 2,775 feet from a nonparticipating property line. *See* Dec. 22, 2016, Supp. Info. at 1. Thus, Tuscola would be forced to reach agreements with a significantly larger number of property owners in order to build the turbines as currently planned. But it seems plausible that Tuscola might be able to enter into more land use contracts with property owners and/or site a fewer number of turbines in Almer Township. Both of those alternatives would undoubtedly impact the profitability of the project, but Tuscola has not demonstrated that it is entitled to deferential or economically favorable conditions. Perhaps application of an L_{max} standard creates such an economic hardship that it constitutes de facto exclusionary zoning. But Tuscola's conclusory briefing on this point falls far short of showing that to be true.

show demonstrated public need, the plaintiff must do more than show that "residents of the township would *benefit* from" the excluded use. *Id.* (emphasis in original). Tuscola has not carried that burden here.

C.

The Township Board reasonably interpreted its Zoning Ordinance and, under that reasonable interpretation, Tuscola was undisputedly in noncompliance with the Zoning Ordinance. Because at least one of the bases on which the Board premised its denial was lawful, the remaining four bases need not be examined. The Township Board's denial will be affirmed.

IV.

Accordingly, it is **ORDERED** that Defendant Almer Township Board's denial of Plaintiff Tuscola Wind III, LLC's, SLUP application is **AFFIRMED.**

Dated: November 3, 2017

s/Thomas L. Ludington
THOMAS L. LUDINGTON
United States District Judge

PROOF OF SERVICE

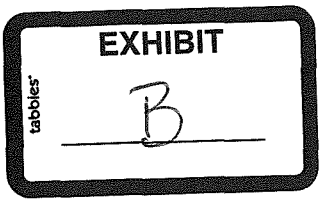
The undersigned certifies that a copy of the foregoing order was served upon each attorney or party of record herein by electronic means or first class U.S. mail on November 3, 2017.

s/Kelly Winslow
KELLY WINSLOW, Case Manager

windAction

The WindAction Group (www.windAction.org)

Facts, analysis, exposure to industrial wind energy's real impacts



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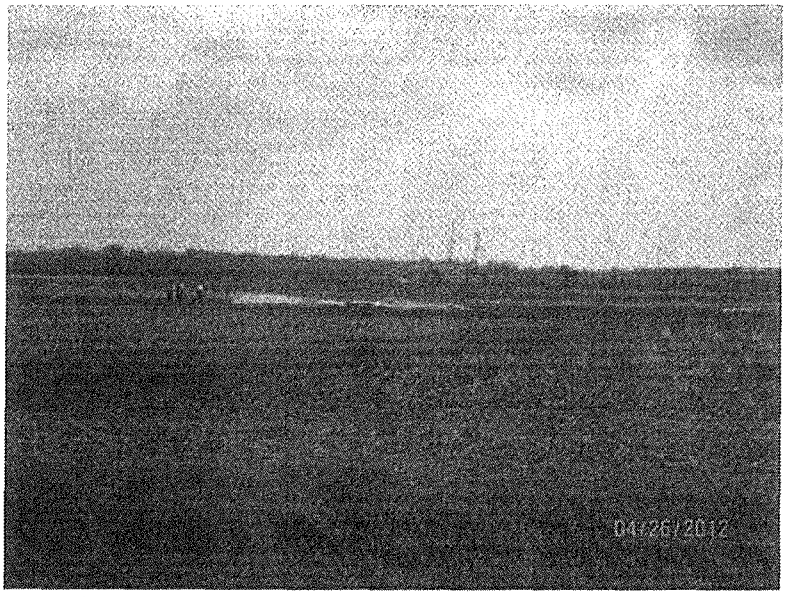
Picture

Vestas turbine blades shredded in high winds

- April 24, 2012

Safety *Structural Failure* *Ohio*

Two blades shattered on a recently installed Vestas V100 1.8 MW under windy conditions. Blade debris was thrown more than 1000 feet from the turbine site in a working farm field. The turbine was part of the Timber Road II facility located in Ohio just beyond the Indiana state line. The project is owned by Portuguese-based EDP Renewables.



Payne Oh Wind Turbine Damage 4 24 2012 011
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http://www.windaction.org/posts/33711-vestas-turbine-blades-shredded-in-high-winds

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RESEARCH ARTICLE

Analysis of throw distances of detached objects from horizontal-axis wind turbines

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ABSTRACT

This paper aims at predicting trajectories of the detached fragments from wind turbines, in order to better quantify consequences of wind turbine failures. The trajectories of thrown objects are attained using the solution to equations of motion and rotation, with the external loads and moments obtained using blade element approach. We have extended an earlier work by taking into account dynamic stall and wind variations due to shear, and investigated different scenarios of throw including throw of the entire or a part of blade, as well as throw of accumulated ice on the blade. Trajectories are simulated for modern wind turbines ranging in size from 2 to 20 MW using upscaling laws. Extensive parametric analyses are performed against initial release angle, tip speed ratio, detachment geometry, and blade pitch setting. It is found that, while at tip speeds of about 70 m/s (normal operating conditions), pieces of blade (with weights in the range of approximately 7-16 ton) would be thrown out less than 700 m for the entire range of wind turbines, and turbines operating at the extreme tip speed of 150 m/s may be subject to blade throw of up to 2 km from the turbine. For the ice throw cases, maximum distances of approximately 100 and 600 m are obtained for standstill and normal operating conditions of the wind turbine, respectively, with the ice pieces weighting from 0.4 to 6.5 kg. The simulations can be useful for revision of wind turbine setback standards, especially when combined with risk assessment studies.

KEYWORDS

wind turbine accidents; blade element theory; blade detachment; ice throw; aerodynamic model; HAWT

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1. INTRODUCTION

The ever-growing number of wind turbines installed near inhabited areas, buildings and community facilities, such as bridges, power installations or highways, has resulted in an increasing concern by authorities to determine risk levels associated with wind turbine blade failure. From a safety point of view, the most serious failure is associated with splintering of rotor blades and detachment of debris, which could be thrown over long distances and damage people or property. Ice-throw from wind turbines installed in cold climate is also of high concern, especially for wind turbines erected near highways where the ice pieces thrown from a wind turbine may strike a passing car, which in the worst case may cause a fatal accident.

Various types of hazards regarding operation of wind turbines have recently been reported by Durstwitz and the Caithness Windfarm Information Forum.[2,3] According to a recent survey by the Caithness Windfarm Information Forum, blade failures resulting in either whole blades or pieces of blades being thrown from the turbine are the most important causes of turbine accidents.[3] A comparative graph showing the growth of wind turbine accidents over the past four decades is shown in Figure 1, where the share of blade accidents and accidents due to fire, which may eventually cause throw of fire patches, are also presented. Due to such accident data, energy authorities all over the world have tried to enforce safety distances around wind turbines and wind farms. The safety distance is a distance within which it is not allowed to build human structures such as buildings and roads. Shown in Table I is an example of the safety distance standards defined by different authorities. It can be seen from the table the values of offset safety distances fall within an extensive range of

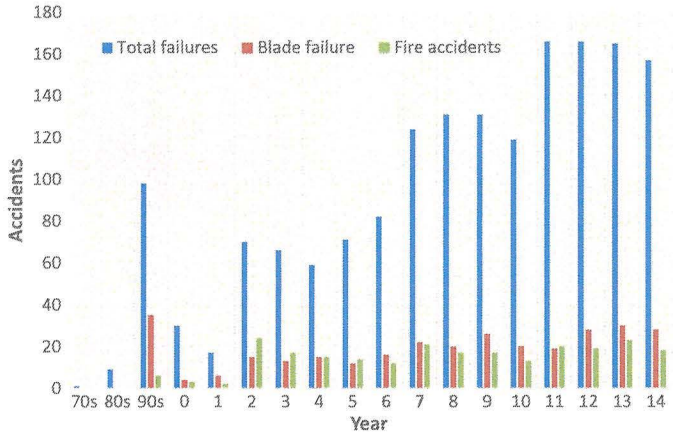

Figure 1. Comparison of wind turbine accidents and particularly blade failure data in a period from 1970s until 2014 (data taken from Caithness Windfarms[3]).

Table I. Safety distances of wind turbines from human structures as practiced in different regions of the world.[17]

Authority/source	Safety distance [m] (ft)
France	1609 (5280)
Germany	1609 (5280)
Rural Manitoba, Canada (1981)	(6500)
US National Research Council	762 (2500)
IL, USA	457 (1500)
Riverside County, CA, USA	**3218 (10560)**
MI, USA	**304 (1000)**

scales between 3.2km and 300m, and that the setback standards are not even similar in different regions of the same country. To standardize such safety guidelines, it is useful to employ mathematical models of the throw in various conditions and risk assessment tools to associate the probability of failure in each particular setting.

Motions of solid particles in fluids were first addressed analytically by Kirchhoff.[4] He showed that the equations of motion for a solid body in an ideal fluid reduce to a set of ordinary differential equations (ODE) based on Euler's equations. Further experimental investigations on falling objects revealed, despite originating from Euler's equations, various states of chaotic motion. It was also mathematically shown that Kirchhoff's equations had been prone to yield chaotic solutions [5]. Tanabe *et al.*[6] developed a set of two-dimensional equations of motion (including rotation) based on simple mechanics in which plates of zero thickness were subject to lift, friction and gravity forces. Based on those assumptions, they found five different falling patterns, ranging from a periodic movement to chaotic random motions depending on the density ratio between the solid and the surrounding fluid and on the length of the object. Pesavento and Wang[7] and Andersen *et al.*[8] performed more detailed studies to determine the motion of a falling two-dimensional elliptic object using direct numerical simulation of the Navier–Stokes equations. They took added mass and added moment of inertia into account and analyzed the transient motion and local jumps of the falling object thoroughly.

Due to complications in a real-life blade accidents (erratic motions, high Reynolds numbers, complex geometries etc.), the fundamental studies mentioned above could only partially help understanding the physics of wind turbine blade throw patterns. To cope with the wind turbine problems, simplified approaches were used. Macqueen *et al.*,[9] for instance, studied the problem of blade-throw from wind turbines, using classical ballistics and also assumption of constant lift and drag. A lift coefficient of Cl = 0.8 and a drag coefficient of Cd = 0.4 were used for the gliding simulations, with Cl = 0.0 and Cd = 1.0 for the tumbling motion. However, the probability that gliding would occur was deemed very small. Their maximum throw studies using simple ballistic analysis, that is, by neglecting aerodynamic forces, showed that in the extreme throw velocity of approximately 310m/s, the maximum throw length reaches 10km.

One of the first detailed studies on the aerodynamics of a detached wind turbine blade was performed by Sørensen[1] using a blade element approach. In this approach, the detached blade is divided into a number of sections and the aerodynamic loads are determined for each section. The total external aerodynamic load on the whole blade would then be determined as the summation of the individual forces on each section.

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Recently, Rogers *et al.*[10] used a dynamic model employing quaternions instead of Euler angles and rotation vectors to form the orientation matrix and performed Monte Carlo simulations of a large set of initial conditions in order to obtain a range of the throw distances.

Ice throw has also been investigated, especially for the turbines erected in the cold climate. Seifert *et al.* measured ice-throw accidents together with a simple aerodynamic model and performed risk analysis of the ice fragments thrown from the blades.[11] Recently, a model of ice throw for a wind turbine in operation was presented by Biswas *et al.*,[12] in which calculations were carried out for ice pieces by neglecting lift and using a fixed drag coefficient of $C_d = 1.0$. It was also estimated that including the highest possible, lift increases the throw distance by approximately a factor of two.

The problem of blade/ice throw has also been investigated through the window of probabilistic methods. Such methods deal with risk levels and probabilities that a certain throw distance will occur. Such studies are typically performed together with a dynamic model for calculating the throw distances. Macqueen *et al.*,[9] Morgan,[13] Morgan and Bossanyi[14] and Rogers *et al.*[10] carried out risk analyses of ice throw to determine safety guidelines for wind developments in ice-prone areas. Sørensen[15] proposed a statistical model that determines risk levels of debris hitting people. Similarly, Carbone and Afferrante[16] performed a combined probabilistic and dynamic analyses to quantify hazards due to the blade throw.

In the present work, detailed aerodynamic analysis are performed for simulating flying debris. The cases include blade throw in which the blade together with its components is thrown, a case in which only a shell laminate is thrown and a case involving detachment of ice fragments. The governing equations of motion form a set of 18 ODEs responsible for the six degree-of-freedom motion. The resulting system of discretized equations are solved using an ordinary time integration method. Throw distances for four different turbine sizes ranging from 2.3 to 20 MW are compared, by employing simple upscaling rules. The computations are carried out for different wind and tip speeds.

2. MATHEMATICAL MODELING

The equations of motion for a detached blade include equations of translation and equations of rotation. These are obtained using Newton's second law and Euler's equations of motion, with the aerodynamic forces obtained from tabulated airfoil data. To be able to quantify the rotational motion of the detached blade, the moments of inertia around the rotation axes are calculated. This, however, cannot be calculated in a fixed coordinate system (i.e., an inertial system) since both the moments of inertia and the rotational speeds are varying and a solution would become very complicated. Instead, the equations are computed around the body-fixed principal axis, and the obtained values are subsequently transformed to the global (inertial) coordinate system to represent the absolute location and orientations. Two coordinate systems are defined here: a global coordinate system $\mathbf{x} = (x, y, z)$ with the origin on the tower basement and orthonormal right-handed unit vectors $(\vec{i}, \vec{j}, \vec{k})$, with the y-axis in the wind direction and the z-axis in the upward direction. A body-fixed coordinate system $\mathbf{b} = (x_b, y_b, z_b)$ is defined by an orthonormal right-handed unit vector $(\vec{r}_1, \vec{r}_2, \vec{r}_3)$, with the origin located at the center of gravity of the detached blade fragment and the third axis parallel to the length axis of the blade (Figure 2).

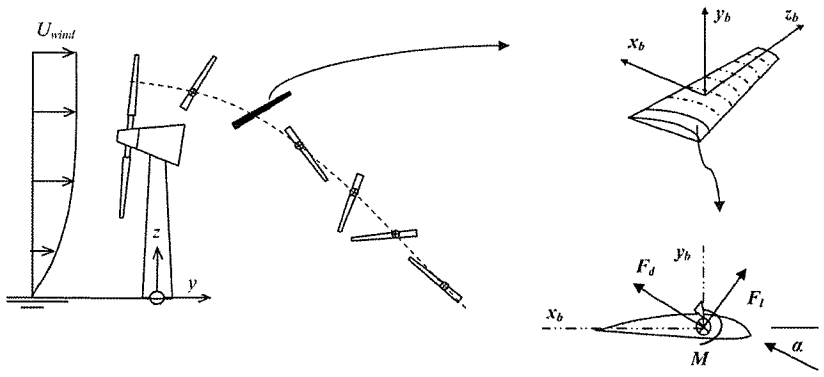

Figure 2. Sketch of the problem and definition of coordinate systems.

The orientation of the detached part is determined through a matrix $\mathbf{R}$, which gives the transformation from global coordinates to the body-fixed coordinates

$$\begin{bmatrix}\vec{r}_1\\ \vec{r}_2\\ \vec{r}_3\end{bmatrix} = [\mathbf{R}]\begin{bmatrix}\vec{i}\\ \vec{j}\\ \vec{k}\end{bmatrix} = \begin{bmatrix}r_{11} & r_{12} & r_{13}\\ r_{21} & r_{22} & r_{23}\\ r_{31} & r_{32} & r_{33}\end{bmatrix}\begin{bmatrix}\vec{i}\\ \vec{j}\\ \vec{k}\end{bmatrix} \quad \text{and similarly,} \quad \begin{bmatrix}\vec{i}\\ \vec{j}\\ \vec{k}\end{bmatrix} = [\mathbf{R}^{-1}]\begin{bmatrix}\vec{r}_1\\ \vec{r}_2\\ \vec{r}_3\end{bmatrix} \tag{1}$$

Equation (1) holds for transformation of any variable between the two coordinate systems. This way of defining a vectorized rotation matrix (as opposed to Euler's scalar angles) ensures uniqueness of orientation angles and avoids the problem known as gimbal lock.

The full six degree-of-freedom motion is governed by Newton's second law of motion and Euler's equations of motion:

$$m\underline{\ddot{x}}_g = \underline{F} + m\underline{g} \tag{2}$$

$$\underline{\underline{I}}.\underline{\dot{\omega}}_b = \underline{\omega}_b \times (\underline{\underline{I}}.\underline{\omega}_b) = \underline{M} \tag{3}$$

where m is the mass of the blade, $\underline{x}_g$ is the position vector of the center of gravity, $\underline{F}$ is the aerodynamic force acting on the center of gravity, g is the gravitational acceleration, $\underline{\underline{I}}$ is the moment of inertia tensor, $\underline{\omega}$ is the angular velocity in the rotating frame of reference, $\underline{M}$ is the aerodynamic force acting along the principal axis of the moment of inertia tensor and (.) denotes differentiation with respect to time. To close the system, the following relationship between the motion of the unit vectors of the body (the blade fragment) and the angular velocity is used:

$$\underline{\dot{r}} = \underline{\omega} \times \underline{r} \tag{4}$$

where $\underline{\omega}$ is the angular velocity of the blade fragment in the inertial coordinate system, which by equation (1) is transformed into the local body-fixed coordinate system. The total set of equations are solved using a fourth-order Runge–Kutta–Nystrom or a third-order Adams–Bashforth method. For more information about the mathematical and numerical treatment of the equations, readers are referred to the early work of Sørensen.[1]

2.1. Aerodynamic modeling

For the solution of the system of ODEs, a blade element approach is employed in which each blade is divided into n sections along the span. In each section, the external forces and moments are calculated from airfoil data based on the local wind speed and relative velocities.

The three-dimensional edge effects are to some extent considered through the finite aspect ratio assumption of the blade, and the aerodynamic coefficients of lift and drag are calculated for all angles of attack based on flat-plate theory. The induced velocities are, however, neglected, and the Reynolds-number dependence of the airfoil data is disregarded. Once the aerodynamic coefficients are found, the lift, drag and moments on the blade fragment are computed as

$$L_i = \frac{1}{2}\rho v_i^2 A_i C_{Li}, \quad D_i = \frac{1}{2}\rho v_i^2 A_i C_{Di} \tag{5}$$

where L_i and D_i are lift and drag forces on the i-th section, ρ is the air density, v_i is the local relative airspeed, $A_i = c_i \Delta r_i$ is the local planform area where c_i and Δr_i are the local chord and the section lengths, and C_{Li} and C_{Di} are the sectional lift and drag coefficients at the desired angle of attack.

The static forces aerodynamic coefficients of the airfoil only depend on the angle of attack. Unsteady effects at high angles of attack are included by using the dynamic stall model of Øye.[18] In this model, the dynamic lift coefficient is obtained by interpolating between the lift coefficient of an airfoil in a fully attached flow and a lift coefficient of the airfoil when the flow around the airfoil is fully separated, i.e.,

$$C_{l,dyn} = f_s C_{l,inv}(\alpha) + (1 - f_s) C_{l,fs}(\alpha) \tag{6}$$

where $C_{l,inv}$ is the lift coefficient for a fully attached flow (i.e., inviscid flow assumption) and $C_{l,fs}$ is the lift coefficient for fully separated flow. The stall-changing rate is defined as

$$\frac{df_s}{dt} = \frac{f_s^{st} - f_s}{\tau} \tag{7}$$

where f_s is the time-dependent separation function, which can be thought of as the unsteady weighting function between the fully attached and the fully separated flow. f_s^{st} is a function of airfoil section,

$$f_s^{st}(\alpha) = \frac{C_{l,st}(\alpha) - C_{l,fs}(\alpha)}{C_{l,inv}(\alpha) - C_{l,fs}(\alpha)} \tag{8}$$

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and τ is an empirically determined time constant giving the time lag between the dynamic value of f_s and its static value. It follows from equation (7) that

$$f_s(t+\Delta t) = f_s^{st} + \left(f_s(t) - f_s^{st}\right)\exp\left(\frac{-\Delta t}{\tau}\right) \tag{9}$$

2.2. The atmospheric boundary layer effects

The inlet wind is included as a velocity profile corresponding to the Atmospheric Boundary Layer (ABL). As a result, in addition to simulating uniform inflow,[1] it is possible to simulate throw distances for blades thrown in wind fields following a power or logarithmic law, depending on the specific site information. The ABL wind profile as a function of height and atmospheric conditions reads

$$u_z = \frac{u_*}{\kappa}\left[\ln\left(\frac{z}{z_0}\right) + \psi(z, z_0, L)\right] \tag{10}$$

where u_* is the friction velocity, κ is the von Karman constant (~ 0.41), z_0 is the roughness length, ψ is a function of atmospheric stability and L is the Monin–Obukhov stability parameter (see Wyngaard[19] for more details).

If no data are available in a specific site, and neutral ABL is assumed, a power law $u(z) = u_{hub}(z/z_{hub})^{\alpha}$, $\alpha \sim 0.14$ will be used for the wind velocity at different heights having the wind velocity at hub height as an input. The power-law method is used for the parametric studies in this paper.

Using the mentioned wind profile and denoting the local position vector of a point p on the wing as $\vec{r}_{pb}$, the local relative wind velocity $\vec{u}_{pb}$, as seen by the blade fragment, is given as

$$\vec{u}_{pb} = [\mathbf{R}].(\vec{u}_{wind} - \vec{u}_g) - \vec{\omega}_b \times \vec{r}_{pb} \tag{11}$$

where the wind vector is assumed to be $\vec{u}_{wind} = (0, u_y, 0)$, neglecting the vertical and lateral components.

3. SIMULATION RESULTS

Simulations of both blade-throw and ice-throw distances are performed by solving the equations derived in the previous sections using the in-house aerodynamic code *Savbal*[*]. The overall procedure for the solution consists of three stages, comprising coordinate transformation, aerodynamics load assessment and time integration. The initial position, orientation and velocities of the detached part are first evaluated at their local coordinates. Based on these values, an iterative procedure starts where the local velocities are evaluated, according to exerted aerodynamic loads, and integrated to give the location and orientation of the fragment in global coordinates until the fragment reaches the ground level.

For the blade-throw analysis, cases with different detached lengths and tip speeds are compared in two sub-cases: (1) the whole blade together with its sandwich structure is thrown and (2) only the shell layer of the blade is thrown. For ice-throw analysis, it turns out that the drag to mass ratio plays an important role for the magnitude of the throw distance. As a result, a few cases with different C_dA/m ratios (as discussed by Biswas *et al.*[12]) with both standstill and running turbine conditions are simulated. The analyses are performed for different wind turbine sizes.

3.1. Turbine upscaling laws

The throw distance analysis was initially performed for a 2.3 MW turbine using publicly available data. A series of empirical relations was then used to upscale the data for the larger turbines, and the analyses were performed for four different wind turbine sizes, i.e., 2.3, 5, 10 and 20 MW. The scale-up factors are first obtained for the blade length, which scales as the square root of the power ratio. Therefore, denoting the blade length, mass (applicable to both total sandwich structure and the shell laminate masses) and mass moment of inertia for the reference turbine with index a, i.e., r_a, m_a and $\mathbf{I_a}$, respectively, the corresponding values for the upscaled turbine, index b, can be obtained as

$$r_b = r_a\left(\frac{P_b}{P_a}\right)^{S_l},\quad m_b = m_a\left(\frac{r_b}{r_a}\right)^{S_m},\quad \mathbf{I}_b = \mathbf{I}_a\left(\frac{m_b}{m_a}\right)\left(\frac{r_b}{r_a}\right)^2 = \mathbf{I}_a\left(\frac{r_b}{r_a}\right)^{S_m+2} \tag{12}$$

[*]The computing code *Savbal* will be available upon request for further studies on this field.

Table II. Characteristics of different turbine sizes considered in the throw analyses.

Size	$L^* = \frac{L}{R}$	L (m)	m (kg)	I_x (kg·m^2)	I_y (kg·m^2)	I_z (kg·m^2)
2.3 MW $R = 45$ m, $H = 100$ m	1.0	45	7.3E+3	0.1E+7	0.1E+7	0.3E+04
	0.5	22.5	2.4E+3	0.1E+6	0.1E+6	0.40E+03
	0.2	10	4.1E+2	0.4E+04	0.4E+04	0.2E+02
5 MW $R = 66$ m, $H = 147$ m	1.0	66	2.6E+04	0.9E+07	0.9E+07	0.2E+05
	0.5	33	8.2E+03	0.1E+07	0.1E+07	0.3E+04
	0.2	14	1.7E+3	0.3E+05	0.3E+05	0.2E+03
10 MW $R = 93$ m, $H = 208$ m	1.0	93	8.2E+04	0.5E+08	0.5E+08	0.1E+06
	0.5	46.5	2.7E+04	0.6E+07	0.6E+07	0.2E+05
	0.2	20	5.3E+3	0.2E+06	0.2E+06	0.1E+04
20 MW $R = 132$ m, $H = 294$ m	1.0	132	2.6E+05	0.3E+09	0.3E+09	0.9E+06
	0.5	66	8.7E+04	0.4E+08	0.4E+08	0.1E+06
	0.2	29	1.6E+04	0.1E+07	0.1E+07	0.8E+04

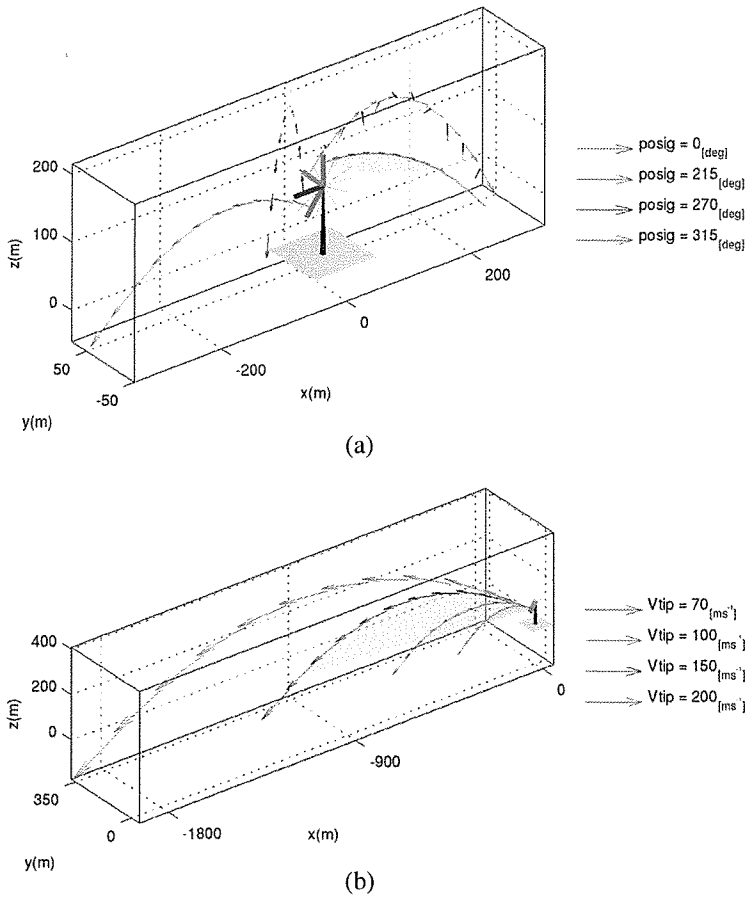

Figure 3. Schematic graphs of the throw distances for half-blade detachment changing (a) the initial release angles (upward-clockwise reference) and (b) the tip speed velocities for the 2.3 MW reference turbine.

where $\mathbf{I} = (I_x, I_y, I_z)$. In the previous relations, $S_l = 1/2$ and S_m depends on actual scaling laws when increasing the size of the rotor. From simple upscaling rules, S_m would be equal to 3 , but because of more elaborate rotor designs, this parameter is usually found to be somewhat smaller. In the present work, we employ $S_m = 2.3$ (see UpWind[20] and TPI Composites[21] for more information on turbine scaling).

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3.2. Full-blade throw analysis

In this section, the throw distance analyses are performed for four different turbine sizes based on the upscaling rules presented previously. Here, the term full blade refers to the case of blade shell including stiffening members (upper and lower shells, spar, etc.). The dimensions and other characteristics of each turbine size are reported in Table II. In accordance with the copyright policies of the turbine manufacturers, the data for the reference turbine (2.3 MW) do not correspond to an existing turbine but are chosen to mimic a real turbine.

The analysis included a parametric study, where the effects of the length of the detached parts, incoming wind speeds, blade tip speeds and wind turbine size on the blade-throw distances were investigated. The height of the tower is in all considered cases assumed to be equal to the rotor diameter. Figure 3 shows three-dimensional visualizations of the throw distances of a half-blade piece thrown of the 2.3 MW machine for different initial conditions. The small colored patches in the figure shows the instantaneous orientation of the detached part. For the sake of clarity, only some selected curves are shown in the figure. Figure 3(a) shows the effect of release angle on the throw distance, and Figure 3(b) shows the effect

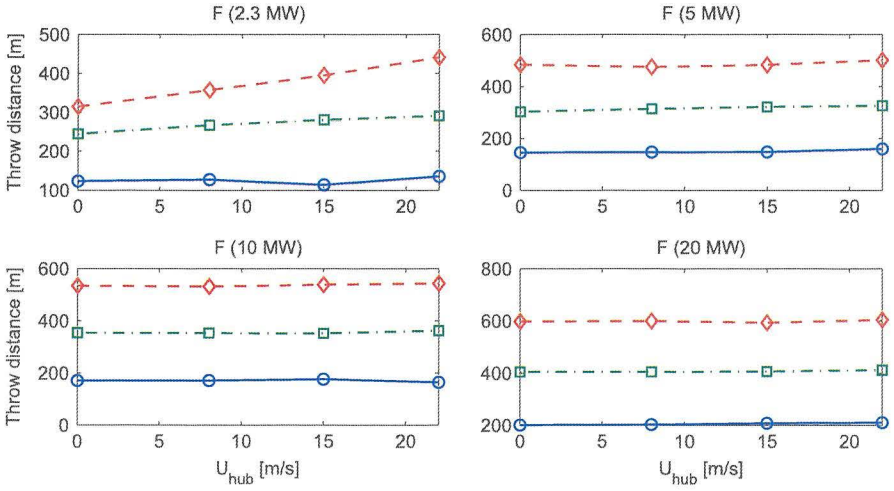

Figure 4. Throw distance calculations of full blade with three different detached lengths for 2.3, 5, 10 and 20 MW turbines at the normal operating condition of V_{tip} = 70 m/s. The horizontal axis shows the wind speed at the hub height and the vertical axis represents the throw distance. ◇ ◇ ◇: L^* = 0.2; □ □ □: L^* = 0.5; and o o o: L^* = 1.

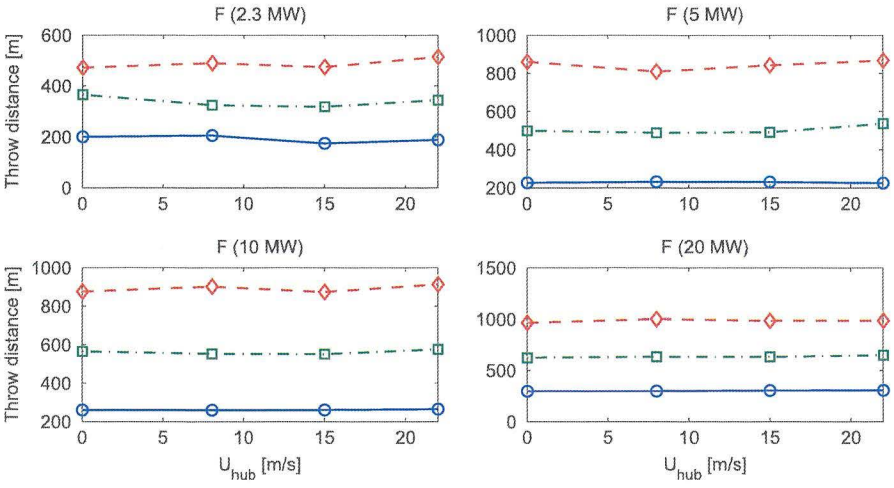

Figure 5. Throw distance calculations of full blade with three different detached lengths at a high tip speed of V_{tip} = 100 m/s. Legends are similar to those in Figure 4.

of release tip velocity. As can be seen, the release tip speed is a very important factor influencing the maximum throw distances. Normal operating conditions with $V_{tip} = 70$ m/s result in throw distances of about 500 m long, whereas a tip speed of $V_{tip} = 150$ m/s may lead to throw distances up to 2 km.

For the quantitative analysis performed in the next section, the fragments are thrown at a release angle of 45° from the horizon (225° measured upward-clockwise) in all calculations. The full-blade and blade-shell throw calculations are performed using flat-plate assumption for the aerodynamic coefficients.

Figures 4, 5 and 6 show the throw distances for three different fragments of the full blade for a combination of three blade tip speeds ($v_{tip} = 70,\ 100\ 150$ m/s) and four different incoming wind velocities (with power-law profiles) ranging between 0 and 22 m/s at hub height.

The figures are divided into three groups, the first group (Figure 4) shows the throw distances, relative to the tower position, for different incoming wind speeds (shown on the horizontal axis) and different detachment lengths at a tip speed of $V_{tip} = 70$ m/s. The detachment length L^*, shown with markers, is the length of the detached piece, measured from the blade tip and normalized by the blade length. The throw distances are calculated and plotted for the four considered wind turbine sizes ranging from 2.3 to 20 MW. As can be seen, except for the 2.3 MW machine, the effect of the incoming wind on the throw distance is almost negligible. Similarly, the effect of turbine size on the throw distance is minimal and the main

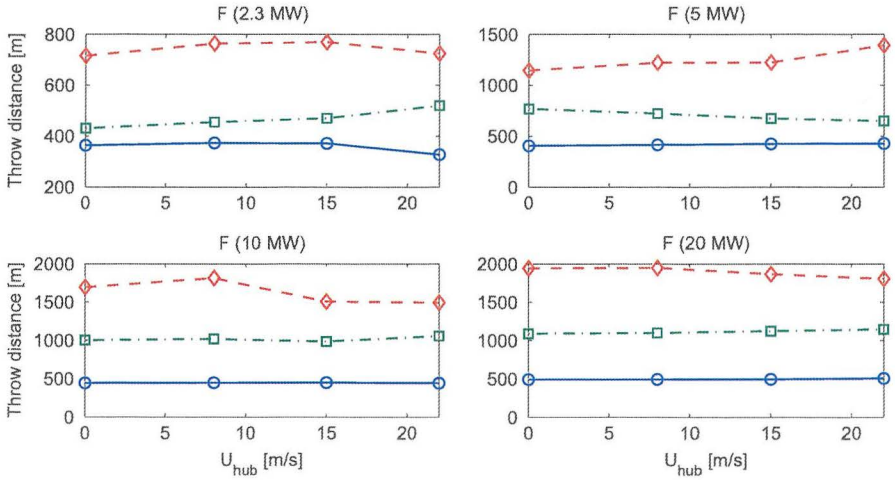

Figure 6. Throw distance calculations of full blade with three different detached lengths at an extreme tip speed of $V_{tip} = 150$ m/s. Legends are similar to those in Figure 4.

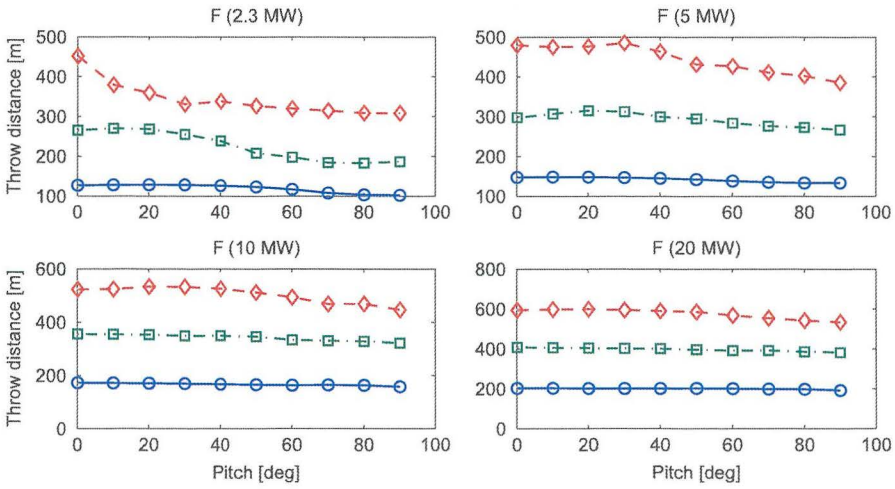

Figure 7. Sensitivity of throw distances of full blade to the initial pitch setting for 2.3, 5, 10 and 20 MW turbines operating at $V_{tip} = 70$ m/s. ◇ ◇ ◇: $L^* = 0.2$; □ □ □: $L^* = 0.5$; and o o o: $L^* = 1$.

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parameter governing the throw distance is the detachment length. The minimum throw distance is obtained for the heaviest fragment ($L^* = 0.2$) thrown from the 2.3 MW turbine, while the maximum throw distance of all cases at $V_{tip} = 70$ m/s is around 600 m for the lightest fragment ($L^* = 0.2$).

Figure 5 shows the same graphs for the higher tip speed of $V_{tip} = 100$ m/s, where the maximum throw distances for the smallest and largest turbines are about 500 and 1000 m, respectively, while the minimum throw distance is reached for a full-blade throw ($L^* = 1$) of a 2.3 MW turbine. Also, it is clear that the effect of the hub-height wind velocity is still very small. Figure 6 shows the same plots for the most extreme case considered, i.e., using a tip speed of $V_{tip} = 150$ m/s. Here, the thrown pieces reach throw distances ranging from approximately 350 m for the full-blade throw for a 2.3 MW turbine to about 2000 m for the lightest fragment thrown from the 20 MW turbine.

As can be seen from the red curve in Figure 6 for the 10 MW turbine (bottom-left), the throw distance has unexpectedly decreased when increasing the wind speed from 10 to 15 m/s. This behavior is somehow repeated to a smaller extent in other cases, especially at higher tip velocities. The unexpected results can happen because of the fact that a small change in the initial conditions can change the force/moment distributions on the fragments, thereby changing the trajectory drastically. To investigate the erratic motion further, the effect of initial pitch setting on the trajectory is analyzed in the next section.

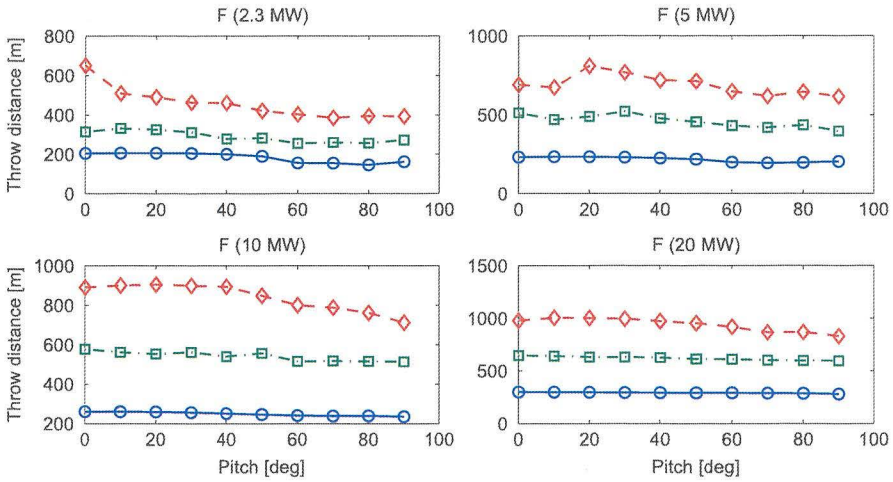

Figure 8. Sensitivity of throw distances of full blade to the initial pitch setting at $V_{tip} = 100$ m/s. Legends are similar to those in Figure 7.

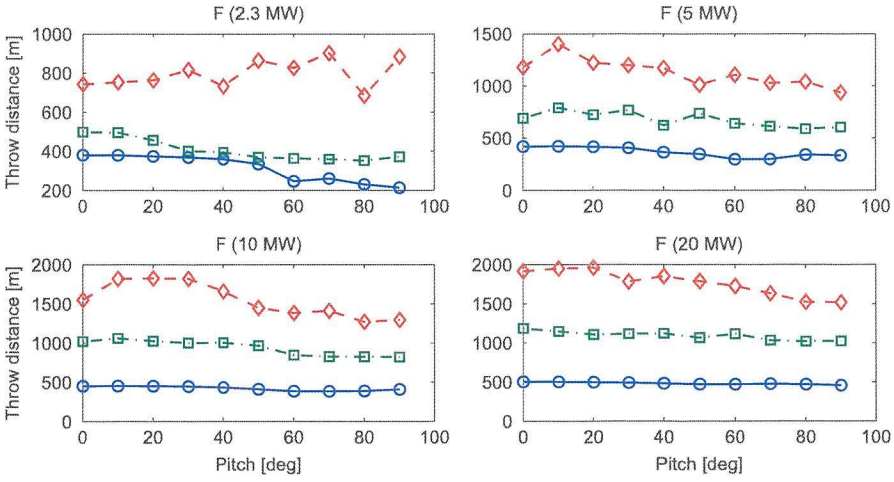

Figure 9. Sensitivity of throw distances of full blade to the initial pitch setting at $V_{tip} = 150$ m/s. Legends are similar to those in Figure 7.

3.2.1. Effect of initial pitch settings.

As explained earlier, analyses of the throw trajectories show that the throw distance for a particular wind turbine sometimes exhibits an erratic behavior going from one dominant solution to another with only a slight change in the initial conditions.

Table III. Aspect ratios, reference chord length C_{ref} and detached mass m of the blade shells (ρ_{shell} = 1700 kg/m^3) used for throw simulation from turbines of different sizes.

	2.3 MW		5 MW		10 MW		20 MW	
Cases – AR	C_{ref} (m)	m (kg)	C_{ref} (m)	m (kg)	C_{ref} (m)	m (kg)	C_{ref} (m)	m (kg)
$AR = 1$		34		83		184		408
$AR = 5$	1	170	1.5	415	2.1	920	3	2040
$AR = 10$		340		830		1840		4080

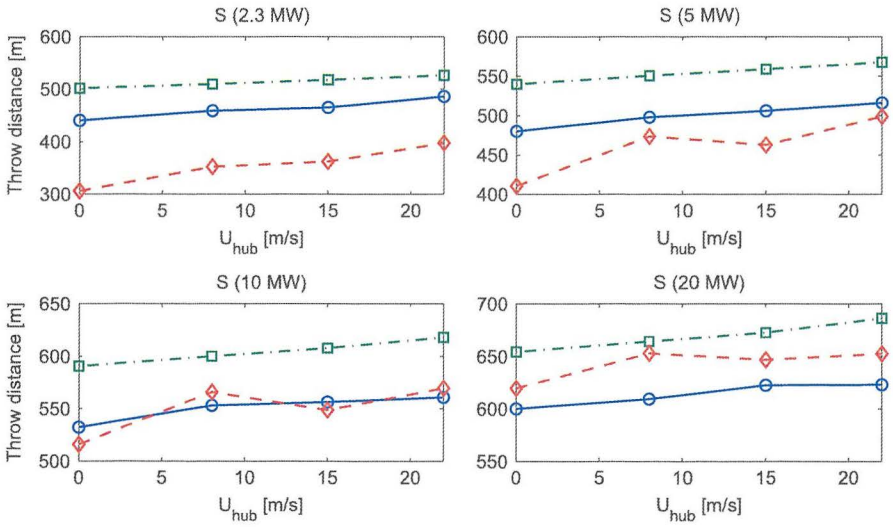

Figure 10. Throw distance calculations of blade shell with three different aspect ratios (invariant chord length for each turbine) for 2.3, 5, 10 and 20 MW turbines at a normal operating condition of V_{tip} = 70 m/s. ◇ ◇ ◇: $AR = 1$; □ □ □: $AR = 5$; and o o o: $AR = 10$.

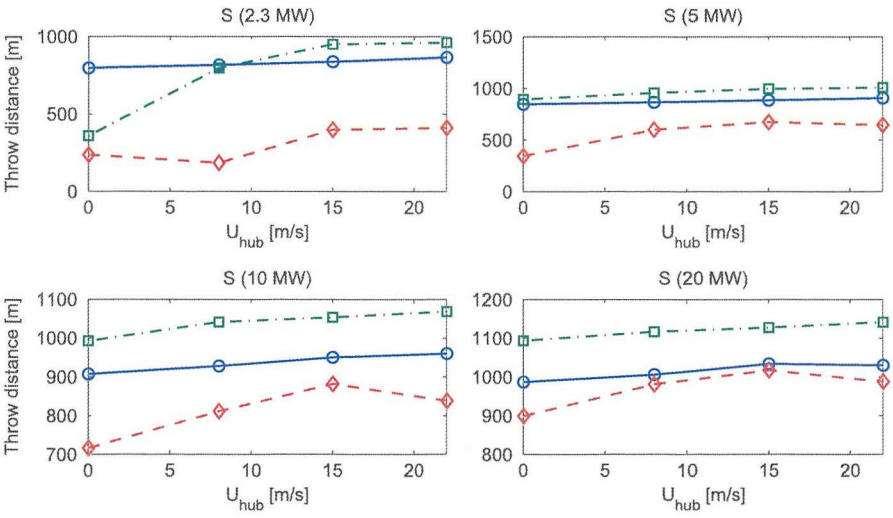

Figure 11. Throw distance calculations of blade shell at high tip speed of V_{tip} = 100 m/s. Legends are similar to those in Figure 10.

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To understand this behavior, a sensitivity study is performed to investigate the effects of the initial pitch settings on the trajectory. Figures 7–9 demonstrate the pitch angle dependence of the full-blade throw distances for different turbine sizes and tip speeds, where the throw distances are obtained for release pitch angles ranging from 0° to 90°. As can be seen, the pitch setting has a substantial impact especially for the lighter parts. In general, higher throw distances are achieved using fragments thrown at lower pitch angles, which are due to the reduced drag. The effect of pitch angle on the heavier pieces (green and blue curves) is, however, smaller. The reason for this is that the aerodynamics plays a less significant role for the heavy parts in the throw distance calculation and the distance is mainly governed by the inertial forces. For the extreme tip velocity, and especially for the 2.3 MW turbine, increasing the pitch angle produces erratic throw distances for the lightest fragments. The exact reason for such erratic behavior has not been yet understood, but it is most likely explained by the physics of the problem, as explained earlier.

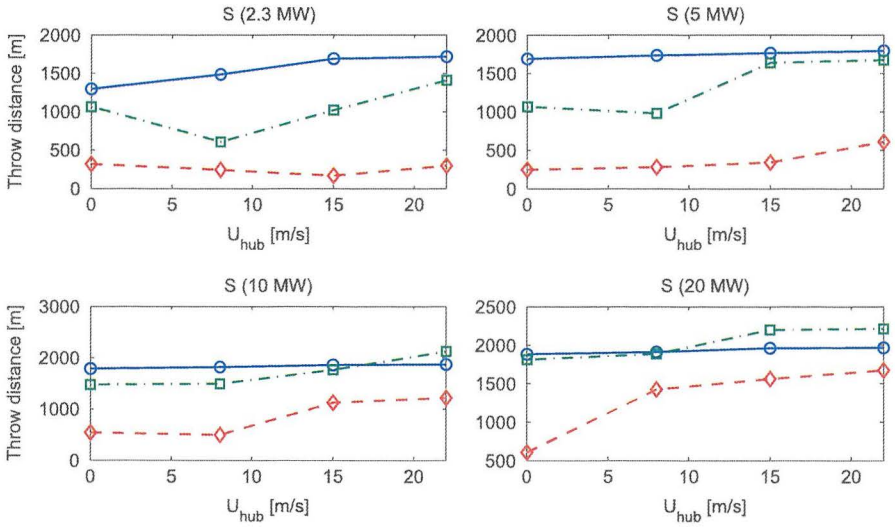

Figure 12. Throw distance calculations of blade shell at an extreme tip speed of V_{tip} = 150 m/s. Legends are similar to those in Figure 10.

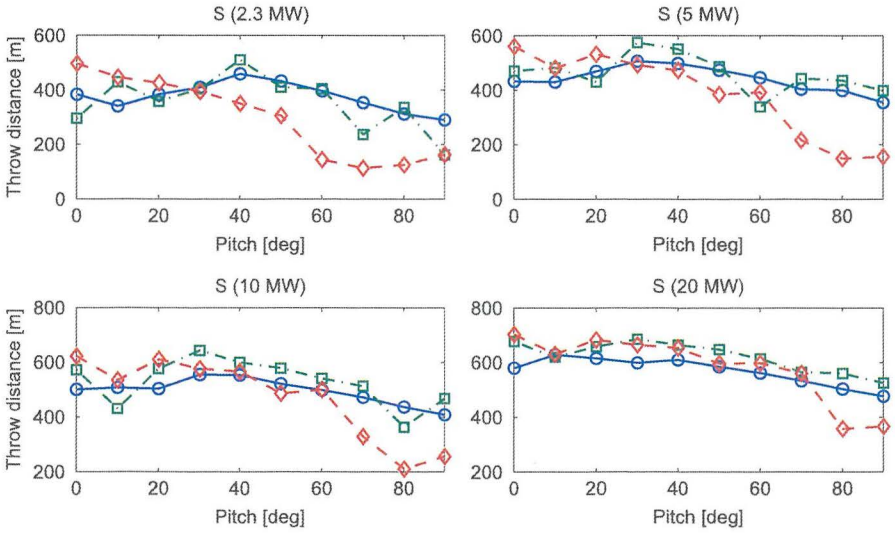

Figure 13. Sensitivity of throw distances of blade shell to the initial pitch setting at V_{tip} = 70 m/s. Legends are the same as in Figure 10.

3.3. Blade-shell throw analysis

An analysis of available data from blade failure accidents shows that depending on the manufacturing method and the structural integrity of the blade, it might first shatter into lighter parts, with the consequence that the shell layer is most likely to be thrown away. Three cases of different aspect ratios are considered for the shell throw analyses. For the reference case of 2.3 MW turbine, an average chord of 1 m and a shell thickness of 2 cm are chosen, and three aspect ratios (where AR is defined as the ratio of span to average chord) of 1, 5 and 10 are investigated. Then keeping the same AR, the analysis is repeated for each of the turbines introduced in the preceding sections. The density of the shell, consisting of fiber and glass, is assumed to be 1700 kg/m^3. Table III shows the test cases used for blade shell throw simulations.

Throw distances for the four different turbine sizes with the same working conditions as those for the full-blade case are plotted in Figures 10–12. Here, the non-dimensional length is replaced by the aspect ratio of the blade shell and three different aspect ratios are considered. As can be seen, increasing the hub-height wind speed and the turbine size generally results in larger throw distance. Nevertheless, an erratic behavior, as mentioned in the previous section, appears in the

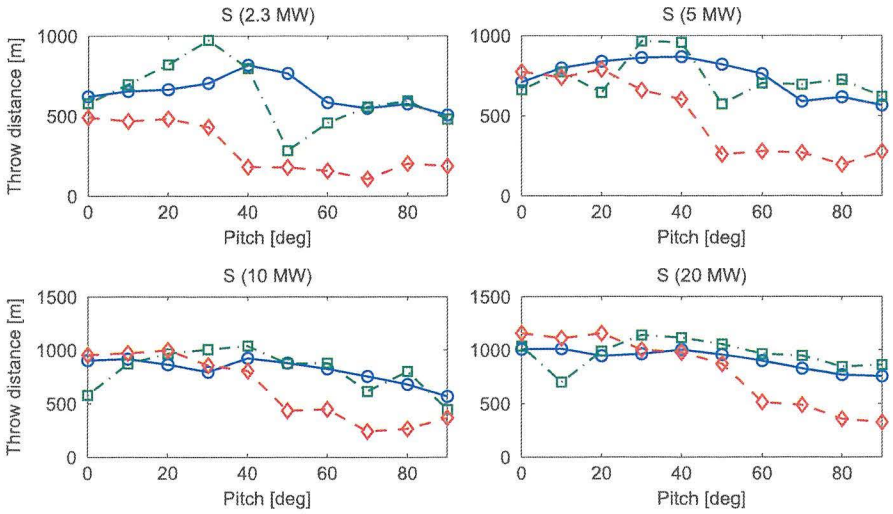

Figure 14. Sensitivity of throw distances of blade shell to the initial pitch setting at V_{tip} = 100 m/s. Legends are the same as in Figure 10.

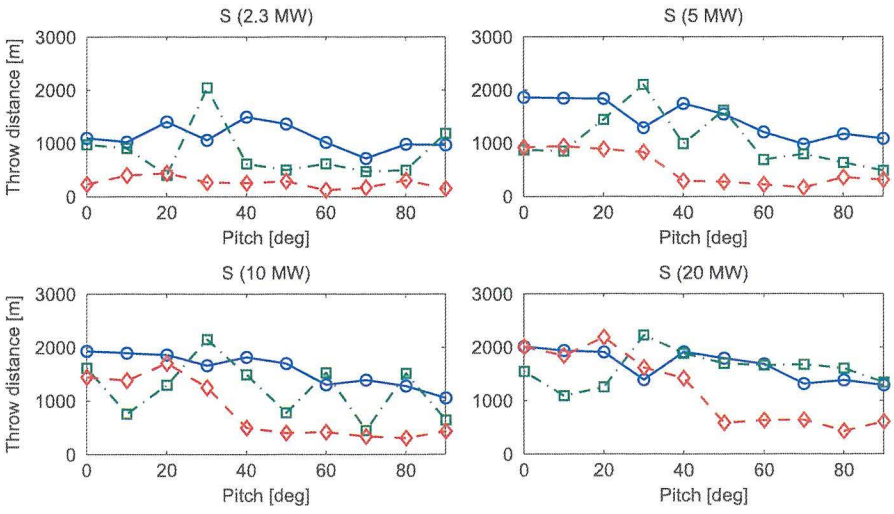

Figure 15. Sensitivity of throw distances of blade shell to the initial pitch setting at V_{tip} = 150 m/s. Legends are the same as in Figure 10.

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simulation results. By comparing the shell-throw graphs with the corresponding figures from the full-blade analysis, the throwing range of the blade shells and that of the full-blade structure are seen to be of the same order of magnitude. That is, the range is between 300 m for the 2.3 MW turbine operating at $V_{tip} = 70$ m/s and a maximum of 2200 m obtained for the 20 MW turbine in the extreme case of $V_{tip} = 150$ m/s. However, unlike the full-blade throw cases, the case with the smallest length ($AR = 1$) reaches the least throw distance, whereas for the full blade, the smallest fragment reaches the highest distance. This is most probably due to the fact that the small shell object is lighter and the corresponding inertial force is relatively small as compared with the drag forces.

As a comparison, the throw distances obtained for the ballistic motion of an equivalent particle in vacuum was also performed (results not shown), in which case there is no aerodynamic forcing on the objects. The results revealed that the ballistic throw distances are the most extreme cases in terms of throw distance.

3.3.1. Effect of initial pitch settings.

Similar to Section 3.2.1, the role of initial pitch setting on the trajectory of thrown blade-shell debris is assessed. Figures 13–15 show the pitch angle dependence of the throw distances for different turbine sizes and tip speeds for the blade-shell cases. Similar to the full-blade throw cases, the pitch setting has a substantial impact on the throw distance of thrown blade-shell structures. One major difference with the full-blade cases is, however, that the effect of the shell aspect ratios on the throw distance is much less significant and all of the cases show similar behavior with AR = 1 cases (red diamonds), predicting smaller throw distances in general.

3.4. Ice throw

For the analysis of the ice throw, the same procedure as for the blade throw is applied except that the throw analysis is not performed for the extreme tip speed conditions but only for the standstill where the tip speed is zero, and the running conditions, where the turbine is assumed to rotate in its normal operational mode at a tip speed of 70 m/s. For the icing case,

Table IV. Aspect ratios, reference chord length C_{ref} and detached mass m of the ice fragments ($\rho_{ice} = 0.7$ kg/m^3) used for throw simulation of turbines of different sizes.

	2.3 MW		5 MW		10 MW		20 MW	
Cases – AR	C_{ref} (m)	m (kg)	C_{ref} (m)	m (kg)	C_{ref} (m)	m (kg)	C_{ref} (m)	m (kg)
$AR = 1$		0.18		0.43		0.97		2.16
$AR = 2$	0.1	0.36	0.15	0.87	0.2	1.95	0.3	4.33
$AR = 3$		0.54		1.31		2.94		6.49

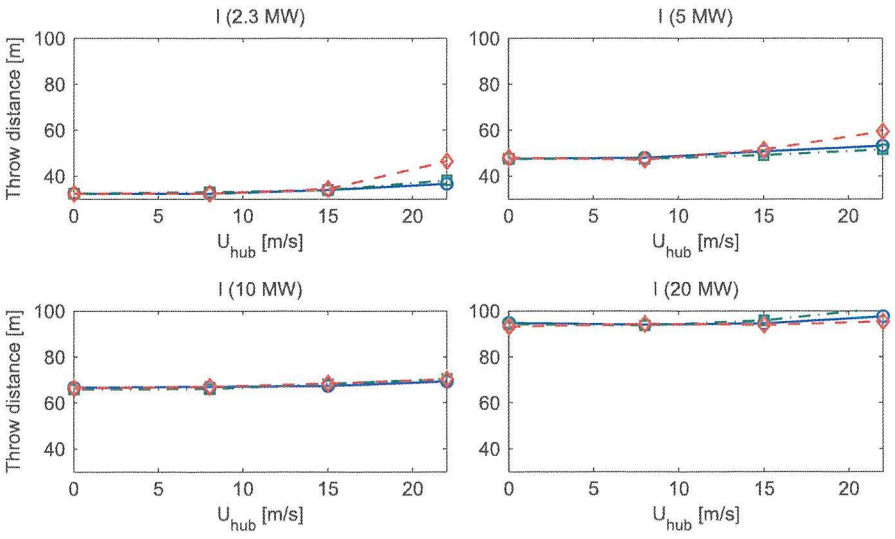

Figure 16. Throw distance calculations of ice fragments for three different aspect ratios for 2.3, 5, 10 and 20 MW turbines in standstill operation ($V_{tip} = 0$ m/s). ◇ ◇ ◇: $AR = 1$; □ □ □: $AR = 2$; and o o o: $AR = 3$.

a density of 700 kg/m^3 is used (see also Seifert *et al.*[11]). The dimensions of the tested ice fragments and corresponding turbine sizes are shown in Table IV. According to field studies performed by, e.g., Cattin *et al.*,[22] most of the ice fragments thrown away from turbine are broken into objects that typically are smaller than 1 kg. However, fragments as heavy as up to 1.8 kg have also been observed. Because the pieces are so light, the throw distance of an ice piece is mainly governed by the drag forces applied on it (which are only functions of mass–area ratio) and the incoming wind.

Similar to the previous section, studies of the effects of different parameters on throw distances are performed and plotted in Figures 16 and 17 with the graphs structured in the same way as in the previous sections.

For the simulations, no lift is considered and the drag coefficient according to the flat-plate assumption is used. Figure 16 shows that the throw distances of the standstill case range from 30 to 100 m for different turbine sizes and incoming wind speeds. For the running conditions however, the fragments can reach distances up to 600 m. It is also clear from the figure that in many cases the aspect ratio does not play a significant role in the determination of throw distances.

3.5. Maximum throw distances

This section presents a summary of the previous results in terms of maximum throw distances. The maximum throw distances are obtained from the entire set of previous simulations regardless of the size and upcoming wind speed and plotted in Figure 18 for the full-blade and blade-shell cases and in Figure 19 for the ice-throw cases, respectively. In all

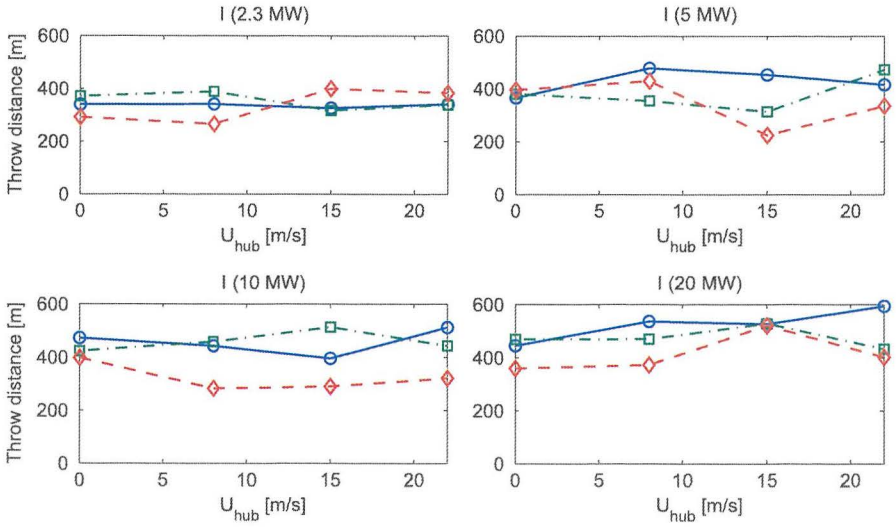

Figure 17. Throw distance calculations of ice fragments for three different aspect ratios for turbines in normal operation (V_{tip} = 70 m/s). Legends are the same as in Figure 16.

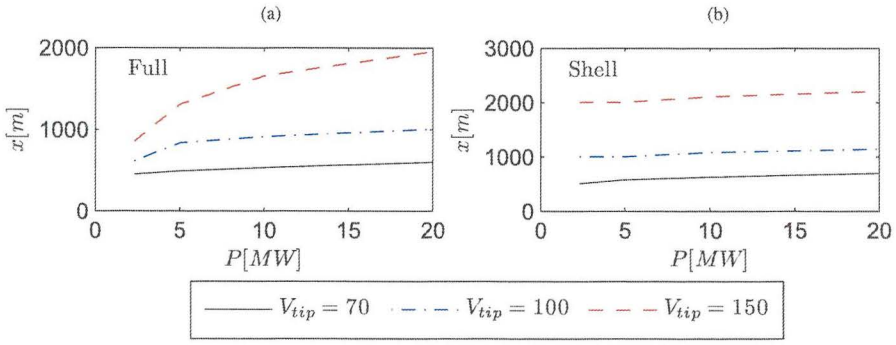

Figure 18. Maximum throw distances obtained for (a) full blade and (b) blade shell in different operating conditions. Blue line: V_{tip} = 70 m/s as a function of turbines power.

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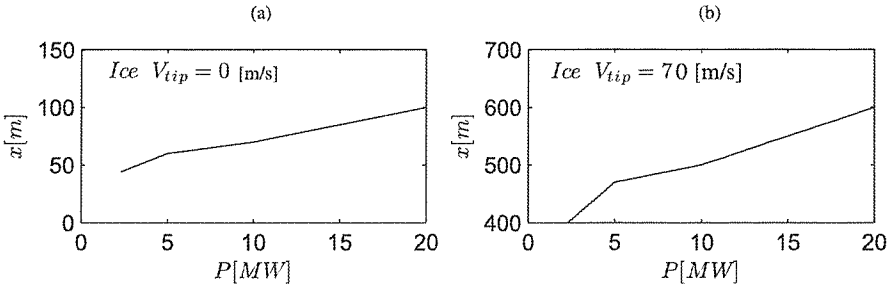

Figure 19. Maximum throw distances obtained for the ice throw in (a) standstill operation, i.e., $V_{tip} = 0$ m/s and (b) normal operating condition, i.e., $V_{tip} = 70$ m/s as a function of turbines power.

figures, the horizontal axis shows the turbine capacity and the vertical axis represents the maximum throw distance. It can be concluded that, in general, the tip speed has a large impact on the throw distances. From Figure 18(a), the turbine size does not affect the throw distances drastically for the lower tip speeds, whereas throw distances at high tip speeds experience a significant growth with increasing turbine size. Figure 18(b), on the other hand, shows that the effect of turbine size on the throw distance for the shell parts is almost negligible.

4. CONCLUDING REMARKS

Trajectory analysis of detached parts of blades and ice fragments thrown from horizontal-axis wind turbines was studied extensively using Newton's and Euler's equations of motion and rotation, employing a blade element approach for the aerodynamics. Full-blade and blade-shell analyses were performed for turbines running under different tip velocities. Turbine upscaling laws were derived, and simulations of throw distances were performed for four different turbine sizes, ranging from existing 2.3 MW machines to future 20 MW turbines.

In some cases, erratic behavior was observed in the computations, where a small change in one parameter could influence throw distance drastically. The behavior was believed to depend highly on the initial conditions. A likely explanation is that a small change in positioning and velocity components in some cases alters the distribution of forces on the detached objects and causes significant changes in the trajectory.

Maximum throw distances obtained at different tip speeds and detachment sizes were analyzed, and it was shown that the tip speed plays the most important role in the throw distance. From the full-blade throw analysis, it was shown that, when released at extreme tip speeds, throw distance picks up more rapidly with the tip speed rather than throw at lower tip speeds (looking at the absolute throw distances). The considered [thrown] full-blade pieces reached approximately 700, 900 and 2000 m at tip speeds of 70, 100 and 150 m/s, respectively. For the blade shell, throw distances were found to be approximately constant as turbine size escalates, and of the same order of magnitude as in the full-blade throw. Throw calculations were also obtained at the tip speeds of $V_{tip} = 0$ and $V_{tip} = 70$ m/s for ice pieces of three different aspect ratios and it was seen that the maximum throw distances scaled almost linearly with the turbine size irrespective of the tip speed. The ice-throw distances reached about 100 and 600 m in standstill $V_{tip} = 0$ m/s and normal operating conditions $V_{tip} = 70$ m/s, respectively. The throw distances presented by this study were obtained with respect to a set of initial parameters without taking into account their probabilities of occurrence. The authors are extending the current study to include the risk levels associated with each of the cases.

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- Leave the wind farm.
- Wait in a vehicle at a safe distance from the WT – approx. 1 km – until the thunderstorm has passed.
- Wait one hour after the thunderstorm has passed before entering the WT.

9.3 Fire

⚠ DANGER

Life-threatening injuries due to falling turbine parts

In case of a fire in the tower, in the nacelle or on the rotor, parts may fall off the WT.

Keep a safety distance of 500 m around the WT.

Do not enter the WT.

⚠ DANGER

Risk of death when using the service lift in case of fire

Do not use the service lift in the event of a fire in the WT.

NOTE

The WT is equipped with fire extinguishers for fighting incipient fires.

At least one fire extinguisher is located in the tower base near the door and another in the nacelle near the Topbox.

This makes it possible to extinguish burning solids and liquids, as well as fires in electrical systems of up to 1000 V.

These fire extinguishers are not suitable for extinguishing a fire on the high-voltage elements, see chapter 9.3.2 "Fire in the nacelle".

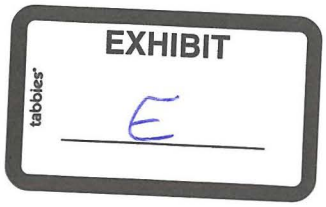
9.3.1 Fire in the WT

- Remove any persons from the danger area.
- The burning object must be disconnected from the grid, if possible.

[redacted]

- Call the Nordex emergency phone number and describe the situation.

Vestas



Green light for **green energy**

At Vestas, the future is green. We believe sustainable energy sources – wind power in particular – will dominate the energy market in place of fossil fuels. This means increasing the public acceptance of turbines, a task best achieved by winning the hearts and minds of communities.

Shadow flicker – the effect caused by the sun shining through the rotating blades of a turbine – is one of the drawbacks of locating a wind farm near houses. In fact, shadow flicker can sometimes dictate whether planning permission is granted or not.

By equipping our turbines with Vestas Shadow Detection System, we can open up more areas for wind farm investment. And that means more opportunities for investors to profit from harvesting wind energy.

Farewell to the flicker

In response to this, we've developed our Vestas Shadow Detection System (VSDS) to overcome shadow flicker.

A reliable and economic solution

To provide the diagnostics and performance required by our customers, the VSDS system is engineered for complete technological reliability. Its direct connection to the turbine means it can operate even if the SCADA systems fail.

VSDS has a good track record with more than fifty installations already in operation. For flawless compatibility, the control box and interfaces is designed with Vestas in control of overall specifications.

Your benefits at a glance:

- Higher chance of planning permission
- Greater community acceptance of wind farms
- Economical to install and maintain
- Reliable, proven technology
- Suitable for a range of turbines and environments

Product Availability:

VSDS is available across a range of turbines and is a reliable and effective option for Vestas turbines with:

- Free IO signals
- VMP global software platform