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Wind Power Growing Pains

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By K.K. DuVivier*

I. Introduction

Today, wind power provides more electricity to the United States than any other renewable energy source except hydropower. With over 65,000 megawatts of installed capacity, wind produced almost 182,000 gigawatt hours of electricity,[1] or 4.4% of total U.S. electricity generation in 2014.[2] Congress' reauthorization of the Production Tax Credit in the Consolidated Appropriations Act 2016[3] should provide enough investment certainty to ensure continued wind expansion for the near future.[4]

One reason for wind power's popularity is price: the cost of generating electricity by wind has dropped dramatically in recent years—a decline of 43% between 2009 and 2013—making it the lowest cost energy technology.[5] Much of this price-decline is attributable to rapidly improving technology.

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1. U.S. DEP'T OF ENERGY, 2014 RENEWABLE ENERGY DATA BOOK 58 (2014), *available at* http://www.nrel.gov/docs/fy16osti/64720.pdf [hereinafter U.S. DEP'T OF ENERGY, 2014 RENEWABLE ENERGY].

2. *Id.* at 28.

3. Consolidated Appropriations Act of 2016, Pub.L. 114-113, H.R. 2029, *available at* https://www.gpo.gov/fdsys/pkg/BILLS-114hr2029enr/pdf/BILLS-114hr2029enr.pdf.

4. The Act extended the expiration date for the PTC to December 31, 2019. It applies retroactively to January 1, 2015, and applies to wind projects that commenced construction by December 31, 2016. Unlike previous extensions of the PTC, this version phases-down over the years until it phases out. RENEWABLE ELECTRICITY PRODUCTION TAX CREDIT (PTC), http://energy.gov/savings/renewable-electricity-production-tax-credit-ptc [perma.cc/4P3K-WRDU](last visited Dec. 29, 2015).

5. *See, Lazard's Levelized Cost of Energy Analysis — Version 8.0*, 9 (2014), *available at* https://www.lazard.com/media/1777/levelized_cost_of_energy_-_version_80.pdf.

The basic process of converting wind energy to electricity has not changed significantly since early turbine designs in the 1970s[6]—wind turbine blades rotate gears in the nacelle at the top of a tower which houses an electric generator. What has changed is the type of support structure and the blade orientation and design, as shown in Figure 1 below. The support structures have moved from being wooden or metal trestles, much like oil derricks, to sleek monopoles. This change was motivated, in part, by efforts to discourage wildlife from building nests in the structure and, in part, by a desire to have a safer enclosed structure for workers to ascend to the nacelle.[7] Also, blades evolved from two-bladed propellers to three-bladed propellers, which act like sails to better catch the wind.[8]

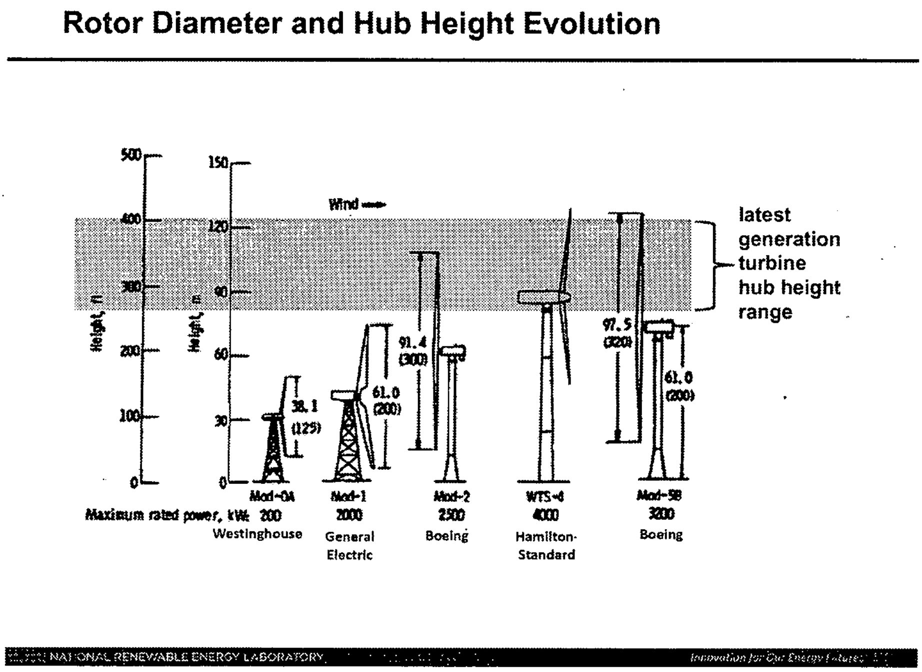


Figure 1: Neil D. Kelley, National Renewable Energy Laboratory, Boundary Layer Turbulence and Turbine Interactions with a Historical Perspective Slide 5 (Aug. 1, 2010) *available at* http://www.slideshare.net/ndkelley/wind-energy-applications-ams-short-course-august-1-2010-keystone-co.

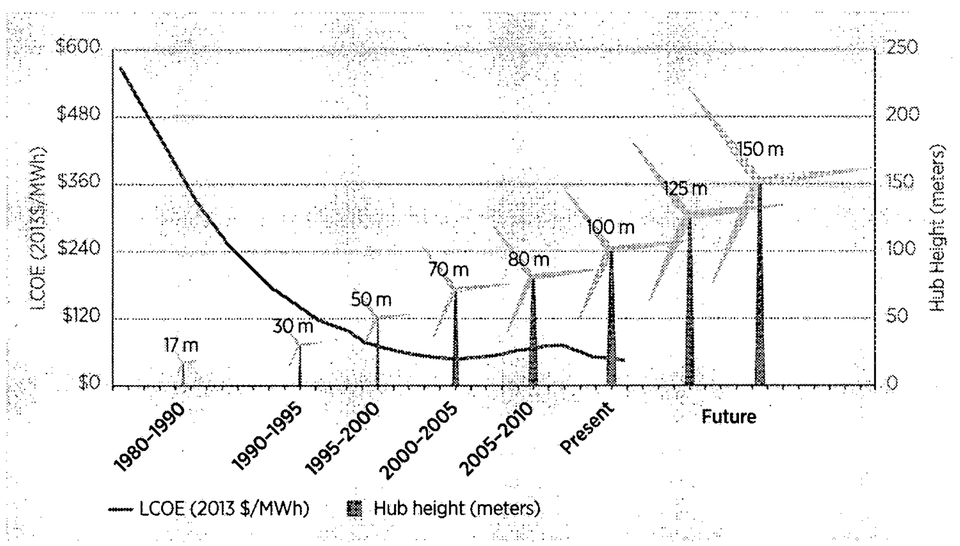
6. Notably, GoogleX's Makani Division is working on a dramatic new energy kite technology, but it is still in the demonstration phase. MAKANI, http://www.google.com/makani (last visited Jan. 24, 2016).

7. *See* Roger Drouin, *8 Ways Wind Power Companies Are Trying to Stop Killing Birds and Bats*, MOTHERJONES (Jan. 6, 2014 7:00 AM), *available at* http://www.motherjones.com/environment/2014/01/birds-bats-wind-turbines-deadly-collisions [https://perma.cc/FLH2-F4BL]; U.S. DEP'T OF ENERGY, EXECUTIVE SUMMARY: WIND VISION: A NEW ERA FOR WIND POWER IN THE UNITED STATES, (March 2015), *available at* http://www.energy.gov/sites/prod/files/wv_executive_summary_overview_and_key_chapter_findings_final.pdf [hereinafter U.S. DEP'T OF ENERGY, WIND VISION]; Interview with Robert J. Noun.

8. Interview with Robert J. Noun. Mr. Noun managed the National Renewable Energy Laboratory's (NREL) Wind Energy Research Program from 1981 to 1989 before becoming NREL's Executive Director of Communications and Public Affairs from 1989 to 2012.

For purposes of this article, the most significant design change has been the height of the turbines, as measured from the hub, or the center, of the blade rotors. Taller hub heights allow longer blades, which increase the rotor disk, or the circle inscribed by the sweep of the wind turbine blades.[9] According to the U.S. Department of Energy, hub heights between 1980 to 1990, the early days of industrial-scale wind farms in the United States, averaged seventeen meters or about fifty-six feet.[10] The average hub height for terrestrial, as opposed to offshore, U.S. wind turbines installed in 2015 was 100-meters, or 328 feet, more than five times higher than the average turbine height in the early days.[11] This dramatic increase in size, and resulting efficiency, has caused significant cost reductions for wind power, as shown in Figure 2. Furthermore, experts estimate that "by pursuing hub heights of 140 meters, the technical potential for wind deployment [will] grow to 4.6 million square kilometers, a 67% increase compared to current technology with 80-meter hub heights."[12]

Scale-up of wind technology has supported cost reductions.



Note: LCOE is estimated in good to excellent wind resource sites (typically those with average wind speeds of 7.5 m/s or higher), excluding the federal production tax credit. Hub heights reflect typical turbine model size for the time period.

Figure 2: U.S. DEP'T OF ENERGY, WIND VISION, *supra* note 7, at xxxviii.

However, increased wind turbine hub heights have resulted in growing pains for the wind industry as it attempts to quantify the wind resource for additional and taller wind

9. U.S. DEP'T OF ENERGY, ENABLING WIND POWER NATIONWIDE, at i (May 2015), http://energy.gov/sites/prod/files/2015/05/f22/Enabling%20Wind%20Power%20Nationwide_18MAY2015_FINAL.pdf [hereinafter U.S. DEP'T OF ENERGY, ENABLING WIND POWER].

10. U.S. DEP'T OF ENERGY, WIND VISION, *supra* note 7, at xxxviii.

11. *Id.*

12. U.S. DEP'T OF ENERGY, ENABLING WIND POWER, *supra* note 9, at i.

turbines. An accurate assessment of the wind resource is needed to assure the safety, equipment reliability, and economic feasibility of a particular project; such an assessment may assist in accurate wind generation predictions to assure better grid integration and stability.[13] While lawyers do not need to understand the detailed atmospheric measurements and simulations that provide a basis for resource assessment, a basic grasp of how increased turbine sizes impacts prior assumptions is critical for addressing client contracting needs and project planning.

II. Wind Wakes

In certain ways, wind development parallels that of oil and gas development. Conventional oil and gas development occurred in specific optimal locations that involved an ideal combination of factors. Oil and gas is lighter than surrounding rock, and as such it migrates through porous formations until it becomes trapped at the top of a geologic fold (a syncline) or by a fault, which causes less porous rock to cut off further migration through the porous formations. While current technologies such as directional drilling, three-dimensional seismic surveys, and hydraulic fracturing (or "fracking") now allow recovery of oil and gas before it migrates, early oil and gas development occurred in locations where these traps allowed the resource to accumulate into sufficient quantities, which made those locations economically most favorable.

Similarly, the early development of wind power occurred in specific locations where topographic and weather patterns created some of the most favorable wind conditions for wind turbine technologies. At the time, these conditions were approximately twenty meters above the surface of the ground. For example, wind farms were developed in the early 1980s in two mountain pass areas approximately fifty miles outside of the Los Angeles (L.A.) metropolitan area: Tehachapi Pass to the northeast of L.A. and San Gorgonio Pass almost due east.

In both of these locations, the channeling of the terrain caused almost unidirectional wind flows through these mountain passes, so that up to 90% of the total wind came from the same dominant direction, northwesterly or west-northwesterly, as the "wind rose" in Figure 3 shows.

13. AWS TRUEPOWER, LLC, CALIFORNIA ENERGY COMMISSION, ADVANCED CHARACTERIZATION OF WIND RESOURCES IN SELECTED FOCUS AREAS OF CALIFORNIA 2 (Dec. 2010), http://www.energy.ca.gov/2013publications/CEC-500-2013-155/CEC-500-2013-155.pdf.

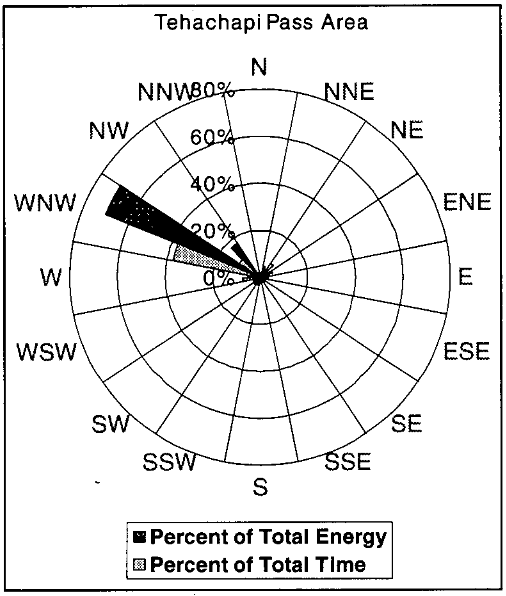


Figure 3: Tehachapi Pass "Wind Rose": AWS TRUEPOWER, LLC, *supra* note 13, at 14.

In contrast, locations with less channeled wind show much wider variations for incoming wind direction, as illustrated by the "wind rose" in Figure 4 from a wind farm in central Iowa. (Note especially that the outer ring in Figure 3 is 80%, whereas it is only 12% in Figure 4.)

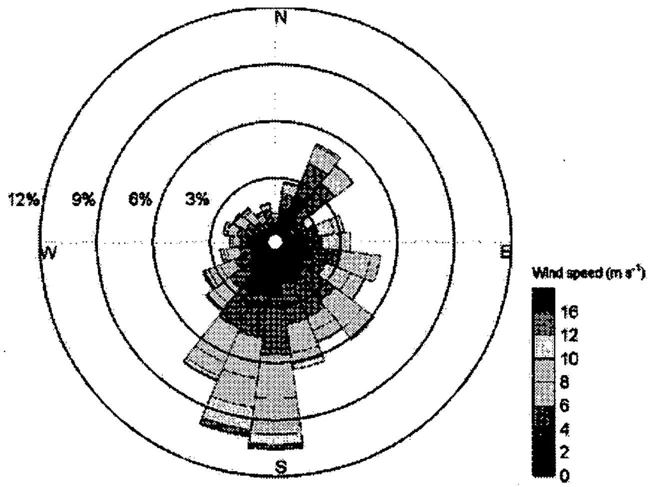


Figure 4: Central Iowa Farm "Wind Rose": Michael E. Rhodes & Julie K. Lundquist, The Effect of Wind-Turbine Wakes on Summertime U.S. Midwest Atmospheric Wind Profiles as Observed with Ground-Based Doppler Lidar, 149 BOUNDARY-LAYER METEOROLOGY 85, 88 (Oct. 2013), available at http://link.springer.com/article/10.1007/s10546-013-9834-x/fulltext.html.

While oil and gas can be transported to generate energy offsite, wind power production does not have this portability. Consequently, other elements besides wind resource factor into choosing the best sites for wind farm development. Four of the most important elements include government incentives, land plays, access to transmission lines, and proximity to load centers to use the power generated. The convergence of these non-resource based factors, along with favorable wind patterns at sufficient velocities to justify investment, narrows down the options and results in the co-location, or clustering, of wind farms in particular locations.

Co-location, however, creates new problems. Each wind turbine generates a wake, much like the wake behind a boat in water. In contrast to wind turbines that receive unobstructed "free flow" wind, turbines located downwind of other turbines may be buffeted by vibrations from wake turbulence. This may cause premature fatigue and mechanical failures. In addition, the wake from upwind turbines can diminish the production of downwind turbines to the point of rendering a preexisting downwind wind farm uneconomical for certain wind directions.[14] When turbines are clustered in large arrays, they alter the air flow and restrict wake recovery in what is called the "deep array effect."[15] Such clustering practices can result in waste of both infrastructure and energy resources.

While a ship wake usually dissipates within three ship-lengths,[16] early wind developers, and the resulting legal agreements, often made assumptions that wind wakes would dissipate within a distance of six to ten rotor diameters directly downwind.[17] For example, the twenty-three-meter-tall turbines in the San Gorgonio wind farm (built in the early 1980s), have 8.5-meter-long rotor blades, resulting in a rotor diameter of approximately nineteen meters. These turbines are arranged in rows spaced 120 meters or 6.1 rotor-diameters apart.[18] Even if this rule-of-thumb is extended out to ten rotor diameters,[19] the assumption was that turbines with a thirty-meter (100 feet) rotor diameter could be spaced at 300 meters (1,000 feet) without impacting one another. Even modern wind farm layouts were based on these assumptions. For example, the London Array

14. Nicolai Gayle Nygaard, *Wakes in Very Large Wind Farms and the Effect of Neighbouring Wind Farms,* 524 JOURNAL OF PHYSICS: CONFERENCE SERIES 012162, *1 (2014), *available at* https://www.researchgate.net/publication/263128350_Wakes_in_very_large_wind_farms_and_the_effect_of_neighbouring_wind_farms.

15. *Id.* at *9–10.

16. Kimberly E. Diamond & Ellen J. Crivella, *Wind Turbine Wakes, Wake Effect Impacts, and Wind Leases: Using Solar Access Laws as the Model for Capitalizing on Wind Rights during the Evolution of Wind Policy Standards*, 22 DUKE EVNTL L. & POL'Y F. 195, 199 (Feb. 2011).

17. *See* MICHAEL C. BROWER, BROWER'S WIND RESOURCE ASSESSMENT HANDBOOK 234 and 244 (2012) (noting that six to ten rotor diameters in the dominant wind flow direction and only three to four in the prevailing crosswind direction), *available at* http://www.wiley.com/WileyCDA/WileyTitle/productCd-1118022327.html.

18. Somnath Baidya Roy & Justin J. Traiteur, *Impacts of Wind Farms on Surface Air Temperatures,* 107 PROC. OF THE NAT'L ACAD. OF SCI. OF THE U.S.A. 17899, 17899 (2010), *available at* http://www.pnas.org/content/107/42/17899.full. .

19. Diamond & Crivella, *supra* note 16, at 204.

started generating power in 2012, and has turbine spacing of 5.4 rotor diameters in one direction and 8.3 rotor diameters in the other direction.[20]

However, recent wind research has shown that these wake recovery distances are too short, and that using this rule-of-thumb significantly underestimates losses to downwind turbines. One study has shown power losses of up to 40% due to wakes from turbines six rotor diameters downwind.[21] In addition, simulations have shown wakes in stable nighttime conditions extending sixty kilometers, or over thirty-seven miles![22]

It may be difficult to avoid wake effects in locations of constantly shifting incoming wind directions, such as Iowa in Figure 4. In these locations, a non-nuisance rule—"wind turbine wake interference can *never* give rise to any legal claim"—may make the most sense.[23] However, locations with almost unidirectional wind flows, like Tehachapi or offshore, may warrant alternative legal treatment. In these areas, the potential for an existing wind farm to suffer devastating losses due to the placement of a subsequent development upwind may warrant alternative planning mechanisms to avoid waste.

III. FAA Regulation of Met-Towers

Wind speed and direction is impacted by a number of factors over the course of a day, driven by the daily cycle of temperature. Between 1980 and the mid-1990s, wind turbines at under thirty meter heights produced power from winds at the surface layer of the atmosphere. As turbines increased in height, they penetrated into more complex atmospheric conditions. Both wind speed and wind direction change with elevation in ways that are not often considered in basic wind resource assessment.[24] These changes may be felt across the full sweep of the wind turbine rotor disk, but may not be quantified by measurements collected lower in the atmosphere.

Higher hub heights have caused new problems for accurately measuring wind resources. Since wind and wind wakes are not visible to the naked eye, wind resource assessment engineers use meteorological towers ("met-towers") to measure the speed and direction of incoming wind at certain elevations. This data is compiled into "wind rose" diagrams, as seen in Figures 3 and 4. At sites of interest, wind development companies will deploy a number of towers to measure the wind resource over several months or even years.

20. Nygaard, *supra* note 14, at *4.

21. R.J. Barthelmie et al, *Quantifying the Impact of Wind Turbine Wakes on Power Output at Offshore Wind Farms,* 27 J. OF ATMOSPHERIC AND OCEANIC TECH. 1302, 1309, Fig. 5 (2010).

22. Anna C. Fitch, Julie K. Lundquist, and Joseph B. Olson, *Mesoscale Influences of Wind Farms throughout a Diurnal Cycle,* 141 MONTHLY WEATHER REV. 2173, 2181 (2013).

23. TROY A. RULE, SOLAR, WIND, AND LAND: CONFLICTS IN RENEWABLE ENERGY DEVELOPMENT 63 (2014)(emphasis in original).

24. *See, e.g.*, Michael E. Rhodes & Julie K. Lundquist, *The Effect of Wind-Turbine Wakes on Summertime U.S. Midwest Atmospheric Wind Profiles as Observed with Ground-Based Doppler Lidar*, 149 BOUNDARY-LAYER METEOROLOGY 85, 88 (Oct. 2013), *available at* http://link.springer.com/article/10.1007/s10546-013-9834-x/fulltext.html.

Free data is available through the National Weather Service (NWS), which is now housed in the National Oceanic and Atmospheric Administration (NOAA), a branch of the Department of Commerce. NWS, along with the Federal Aviation Administration (FAA) and the Department of Defense, has constructed an array of Automated Surface Observing Stations (ASOS) and Automated Surface Weather Observation Stations (AWOS) across the United States to measure meteorological, hydrological, and climatological information.[25] These met-towers automatically transmit routine data and make special observations when conditions exceed preset thresholds. While the ASOS and AWOS stations measure visibility, dew point, and other data, the primary data of interest to wind farms is wind speed and direction. The NWS met-towers provide wind developers with free data sets for predicting wind resources. However, most of the NWS met-towers are at low altitudes—two to ten meters above the surface, or a maximum of approximately thirty-three feet.[26]

Although wind development companies do not rely solely on NWS met-towers, early developers could supplement their measurements with this data because the winds at the NWS met-tower height were in the same atmospheric layer as those for the original low-hub wind turbines. Thus, wind speed and wind direction for turbine production could be fairly accurately extrapolated from the NWS met-tower data. However, this is not true for the newer hundred-meter hub-height turbines. Because these turbines capture winds that are more complex than those at the surface layer, the ability to accurately predict wind patterns at this elevation is significantly compromised without taller met-towers.

A few stakeholders are making efforts to fill the void. For example, Texas has been the leading state for wind power production for over a decade.[27] Its cumulative installed wind power capacity was 14,098 megawatts in 2014.[28] Although Texas has not installed additional taller met-towers, Texas Tech has developed the West Texas Mesonet.[29] The West Texas Mesonet is a collaboration of the Atmospheric Science Group and the National Wind Institute to provide meteorological data for West Texas, the leading wind development area of the state. The West Texas Mesonet's goal is to measure larger mesoscale weather conditions such as thunderstorms or squall lines. The wider mesonet network helps understand how these larger weather conditions evolve and dissipate.[30]

The West Texas Mesonet network includes ninety-four mesonet stations, most of which are only ten meters high. However, the Mesonet also allows higher atmospheric

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25. *See Automated Surface Observing System*, NOAA'S NATIONAL WEATHER SERVICE, http://www.nws.noaa.gov/asos/.

26. NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION, AUTOMATED SURFACE OBSERVING SYSTEM: USERS' GUIDE, 14 (1998), http://www.nws.noaa.gov/asos/pdfs/aum-toc.pdf.

27. *Understanding Texas Wind Power: A Policy Guide*, TEXAS COALITION FOR AFFORDABLE POWER (last visited Feb. 10, 2016), http://texaswindenergy.tcaptx.com.

28. U.S. DEP'T OF ENERGY, 2014 RENEWABLE ENERGY, *supra* note 1, at 8.

29. *See* WEST TEXAS MESONET, http://www.mesonet.ttu.edu (last visited Feb. 10. 2016).

30. *See id.*

measurements through seven boundary layer sodar (SOnic Detection And Ranging) system units.[31] Just as radar uses radio detection and lidar uses light detection, sodar measures wind speeds by scattering and measuring deflected sound waves. This publically-available data can be helpful for wind developers.

Once the leading state in wind power development, California is now number two with 5,917 cumulative megawatts of installed capacity.[32] Although the California Energy Commission does not regulate wind farm siting,[33] the Energy Commission generated a report in 2010 "to improve the understanding and predictability of wind regimes within some of California's attractive wind development regions."[34] The publically-available one-year study involved fifty meter met-towers and a shared sodar system.[35]

Where wind data from higher meteorological towers, sodar, or lidar is not available, developers must rely solely on their own onsite data collection, which most developers are reluctant to share with others. While the best wind data for developing a wind farm would be at the hub height, which is typically around 100 meters, many wind developers purposefully chose to install sixty-meter towers. There are at least two major reasons why developers purposely install sixty-meter met-towers.

First, they do this to avoid the added cost and scrutiny of FAA regulation. FAA regulations require markings and lighting for met-towers that exceed 200 feet or approximately sixty-one meters. Second, developers chose lower met-towers for competitive reasons. Increasing demands for wind power encourage potential wind developers to seek secrecy while "prospecting" for wind farm locations.[36] If landowners are not aware of the competitive market, the developer may be able to negotiate better lease terms. Thus, avoiding FAA markings and blinking lights for met-towers under sixty meters might give these wind developers a competitive advantage in terms of cost and exclusivity.

However, these competitive incentives can have dire consequences. The FAA requires lighting and marking for towers over 200 feet to protect agricultural pilots, such as those who do aerial crop dusting or seeding. Unfortunately, a grey unmarked met-tower can be camouflaged in farm country, and multiple pilots have died flying into them.[37] In a 2014 lawsuit, the family of one pilot received $6.7 million in a wrongful

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31. *See Team Mesonet: Who We Are*, WEST TEXAS MESONET,, http://www.mesonet.ttu.edu/Tech/1-output/who.htm (last visited Feb. 10, 2016).

32. U.S. DEP'T OF ENERGY, 2014 RENEWABLE ENERGY, *supra* note 1, at 58.

33. K.K. DuVivier, *The Superagency Solution*, 46 MCGEORGE L. REV. 189, 191 (2014).

34. AWS TRUEPOWER, LLC, *supra* note 13, at iii.

35. *Id.* at 1.

36. Roger A. Dreyer, *Making Agricultural Aviator Safety a Priority*, THOMPSON REUTERS, Dec. 2, 2015, *available at*, http://blog.thomsonreuters.com/index.php/making-agricultural-aviator-safety-a-priority/.

37. According to the National Agricultural Aviation Association, there were 12 tower strikes – in Arkansas, Arizona, California, Florida, Iowa, Kansas, Louisiana, Mississippi and Texas – resulting in five fatalities from 2005 to 2014. *See id.* at fn. 2.

death settlement.[38] The pilot was killed when he struck an unmarked sixty meter met-tower while executing a contract to aerially plant wheat seed. The wind developer's tower stood just three feet under the FAA standard of 200 feet, a height made possible by not installing the manufacturer-included lightning rod for the tower. If the lightning rod had been installed, the tower would have measured 203 feet and would have required FAA markings and light warning devices.[39]

Consequently, it may be tempting for developers to employ met-towers that fall below the FAA threshold, any attorney advising them should warn clients about the risks of injuries to pilots and the potential for liability, especially if a tower is not installed according to manufacturer instructions.

IV. Conclusion

As with oil and gas, new technologies are expanding the potential for developing domestic U.S. energy by allowing the capture of new energy resources. Wind towers with 100-meter hub heights are able to exploit different winds from those driving earlier seventeen-to-thirty-meter wind turbines. These advances allow the development of resources not previously available. Growing wind turbine heights are good news for the industry because they can provide significant cost reductions for providing wind electricity.

However, the growing hub heights are also pushing wind development into a new frontier of the sky. The consequences increase potential for wake impacts and increased competition for air space.[40] Attorneys who represent wind interests must be aware of this evolution and conform legal advice to wind resource data collection as well as the potential wake effects of one wind turbine to another.

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38. Allen et al. v. NRG Sys. et al., No. MSC12-00880, notice of settlement filed (Cal. Super. Ct., Contra Costa Cty. Sept. 8, 2014).

39. Dreyer, *supra* note 37.

40. It is beyond the scope of this article to address drones, but the number of consumer drones reached approximately 700,000 in 2015. The FAA received about 1,000 reports of small drones interfering with civilian air traffic, and the Air Force reported a drone at 3,800 feet, which forced one of its KC-10 flying tankers to take evasive action. The Washington Post, *Pentagon: Popular Toys are Becoming Dangerous*, THE DENVER POST, Dec. 25, 2015, at 20A.