# Identification of Trends in Growing Turbine Size, Capacity, and Other Developments Using the US Wind Turbine Database

[1*] **Mrs.MITALI MOHAPATRA**, [2] **Mr.NARESH KANUNGO,**
[1*] *Asst. Professor, Dept. Of Electrical Engineering, NIT BBSR,*
*Asst. Professor DEPT. of Electrical Engineering, NIT BBSR,*
[1*] mitalimohapatra@thenalanda.com, nareshkanungo@thenalanda.com

## Abstract

This article's goal was to examine information about developments in wind energy around the country. There is no known independent, credible, or up-to-date overview of these variables, despite the fact that governments, academics, and the commercial sector are usually aware of patterns of wind turbine growth (i.e., turbine size and capacity expanding in recent years). Using data collected by the Lawrence Berkeley National Laboratory and partners, this study used descriptive statistics to show turbine development and growth patterns from 1981-2019. The newly created United States Wind Turbine Database (USWTDB) represents the most comprehensive account of wind turbine information and was updated in January 2020. Variables I am interested in here are turbine manufacturer, state of project, turbine and project capacity, and turbine size. Findings provide empirical evidence to support the common, yet previously unrefined statements that wind turbines are growing larger in number, size and capacity. This growth is varied over spatial and temporal scales. I also provide evidence to show patterns of turbine manufacturing, with GE Wind dominating much of the US wind energy landscape today. I hope this work provides a timely resource for those interested in a variety of questions sur- rounding wind energy development in the United States. Perhaps more im- portantly, this analysis will hopefully inspire others to use what the USWTDB provides and answer larger questions surrounding wind energy futures.

## Keywords

Wind Energy, Wind Turbines, USWTDB, Renewable Energy, Turbine Capacity, Turbine Size

## 1. Introduction

Responding to intersecting problems including global climate change, air pollu-

tion, and domestic energy insecurity, wind energy has emerged as a major source of low-carbon electricity generation. In the United States alone, there are now more than 60,000 utility-scale turbines, representing nearly 100 gigawatts of wind energy capacity and 15% of the global total [1] [2]. Much of this has been intro-duced over the past decade, and yet up until recently, there was no publicly ac-cessible dataset that described wind turbines and their characteristics (e.g. size, capacity, location). Recognizing this void, researchers across three organizations— the Lawrence Berkeley National Laboratory (LBNL), the United Stated Geo- logical Survey (USGS), and the American Wind Energy Association (AWEA)— came together in 2018 to create such a dataset. Aptly named The US Wind Tur- bine Database (USWTDB), information is provided on turbines dating back to 1981 and is updated on a quarterly basis. Apart from the USWTDB Viewer [3], which provides a simple and interactive way for anyone to visualize wind tur- bines across the country, there is no known resource for those who want to understand trends in US wind energy growth. More specifically, the Viewer and any other known resources do not provide any way to understand summarized and/or precise changes to US wind energy landscapes.

In this paper, I use the USWTDB to analyze patterns of US wind energy growth over four decades. For government, this will help those who debate and design policy. In industry, this may help businesses of all sizes understand cur- rent (and perhaps future) landscapes of the sector. For academics, I see this pa-per as providing an important starting-point for discussions around the cluster- ing, size, and growing capacity of wind turbines. Echoing the benefits described
by Rand *et al*. [2], this paper may also provide important context for groups in-
terested in: climate change and air quality [4], local health and well-being [5], grid impacts [6], land requirements [7], local surface temperatures [8], sound and noise [9], property values [10] [11], renewable energy potentials [12], and
acceptance research [13] [14] [15].

For all of these groups listed above—and more—there is a general under- standing that turbines are getting larger in both in size, capacity and overall number. Yet, there is still a need for a study that analyses these trends in a sys- tematic way. I answer what I see is a call for this kind of resource. In doing so, I provide a clear, accessible, and available-to-all report.

## 2. Methods

### United States Wind Turbine Database

A full description of the USWTDB, including its process of creation, can be found in a recent publication by Rand *et al*. [2]. Here, I simply wish to clarify some important issues that directly relate to the variables used in this analysis. First, for many of the most pertinent variables, the USWTDB authors provide us their level of confidence (0 = not verified; 1 = no confidence; 2 = partial confi- dence; 3 = full confidence) regarding turbine characteristics (e.g. size, capacity, model, project name) and turbine location (coordinates). Of the total of 63,003
turbines, there was full confidence in turbine characteristics of 81% (9.5% with partial and 9.5% with no confidence). In terms of location, there was full confi- dence throughout 92.8% of the data (0.6% with partial and 6.5% with no confi- dence). This leaves us confident in the characteristics of 51,037 turbines and in the location of 58,494 turbines [2].

In most of the analysis here, I include only those turbines/projects with the highest level of confidence. This ensures transparency and should increase the reader's trust in the findings. Exceptions are seen when characteristics of wind turbines are not necessary (*i.e.* total number of turbines). As per the USWTDB, dismantled turbines are not included, but decommissioned turbines are. Resi- dential-scale turbines (usually less than 65 kW and 30 metres in height) are not
included in the dataset. Some exceptions to this may include smaller wind tur- bines built in California before 1990. At the time, these were considered to be utility-scale and thus are retained in the USWTDB.

.

ISSN: 2278-4632
Vol-10 Issue-3 No.01 March 2020

### Data Analysis

On March 28 2020, the USWTDB data was downloaded and input into SPSS 24 software. Based on Rand *et al*. [2] and verification of the data itself, the USWTDB included all turbines built and constructed by the end of 2019. The oldest wind turbines date back to 1981 (no confidence in turbine characteristics) or 1982 (full confidence in characteristics or any confidence in turbine location).

Before analysis took place, the dataset was cleaned to remove any missing va- riables. This was done for the variables of project year operational, project ca- pacity, turbine capacity, turbine hub height, turbine rotor diameter, and turbine rotor swept area. I then used simple descriptive statistics to identify trends in the dataset. Based on a combination of what I saw as gaps in the literature, and what the dataset provided, this includes: leading turbine manufacturers, turbine ca- pacity by year, the (physical) growth of wind turbines, and wind energy devel- opment by state (by year and decade). Below I present figures and tables that summarize such findings. Complete results of each section (via tables) can be found in the **Appendix A-H** [3].

## 3. Results

### Wind Turbine Manufacturers

As of the end of 2019, General Electric (GE) Wind was by far the leading manu-facturer of wind turbines across the United States (see **Figure 1**). Of the more than 51,000 turbines with full characteristics confidence, the company produced 21,774 (41.5%). Vestas (including Vestas North America; 24.1% or 12,322) pro- duced the next highest number. At 4901 (9.6%), Siemens came in third. Though due to a 2017 merge with Gamesa (which later became Siemens Gamesa Re- newable Energy), it may be argued that the new company is actually responsible for a total of 8137 turbines (15.9%) as of 2019. Mitsubishi (5.5%), Gamesa (5.2%), Suzlon (2.6%), Nordex (1.8%), Acciona (1.5%), NEG Micon (1.3%), Clipper (1.3%), Siemens Gamesea Renewable Energy (1.1%), and Repower (1.1%) represent the top 12 and include all those with at least 1% of turbines. A list of all those companies with at least five turbines as of 2019 (0.1% of total) can be found within the **Appendix B**.

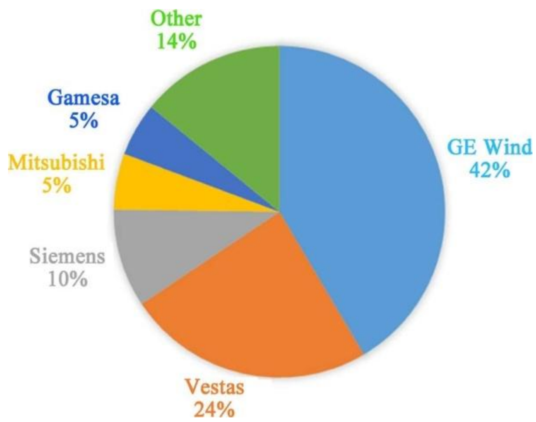
We can also look for recent changes in the above trends. As of 2009, things were much the same. GE Wind was still the leader (36.2%). Vestas was second (22.5%), followed by Mitsubishi (11.6%) and Siemens (6.1%). Going back two decades to 1999, Vestas was the undisputed leader with near a third (32.5%) of all turbines. Enron (20.5%) and NEG Micon (17.6%) followed.

### Growth of New Turbine Capacity and Total Number of Turbines

**Figure 2** shows the annual growth of average new turbine capacity and the an- nual number of new turbines. Because of gaps in data for turbine capacity through the 1980s and 1990s, here I include both the values given with full and partial confidence. The full dataset that makes up **Figure 2** can be found within the **Appendix C**.

Of the 51,036 turbines with full confidence in capacity, the average (mean) turbine capacity was 1831.85 kW (1.85 MW). Though as the figure shows, this has varied throughout time. In 1990, the average turbine was just 218.16 kW (0.218 MW). In 2005, this reached nearly 1.5 MW. In 2014, this rose to 1.93 MW and finally in 2019, the steady rise continued, with the average turbine having a capacity of 2.56 MW. The turbine with the largest capacity (of all years) became operational in 2016 and had a capacity of 6 MW. It was associated with a five-turbine project called Block Island (Washington County, Rhode Island).

Using an expanded set of all development, we see the number of turbines has generally grown year over year—but with some notable spikes and valleys. Up until 2000, new turbines averaged just under 300 per year. There were just two years in this set of 18 that saw more than 1000 turbines becoming operational— 1985 (n = 1596; all of which occurred across 16 wind farms in California), and




*Of the total number of wind turbines as of 2019 (n = 51,036). Though there were 51,037 turbines with full confidence in turbine characteristics, we found one turbine manufacturer as "missing". This may have been caused by a coding error.

**Figure 1.** Wind Turbines by manufacturer (percent of total*).

*For the year 1989, there was no information about average turbine capacity so I chose to insert a value that is equal to the average of the three preceding years. There were no turbines built in 1993 throughout the entire database, and so that year is not given a value (*i.e.* the year is ignored).

**Figure 2.** Number of wind turbines and average capacity (by year)*.

1999 (n = 1005; where 33 wind farms were built in 10 states).

From 2001 to 2019, the average number of turbines was 2897/year—though again with great variation. 2001 saw 1876 new turbines—a value that was not exceeded until 2007 when 3200 turbines became operational. This growth would continue until 2010 (n = 5780), when average turbines built from 2010-2011 dropped to just 3232. A recovery in 2012 marked the highest number of turbines ever built (n = 6774). Aside from a severe drop the following year (n = 610), new turbines have been relatively stable in recent history. This includes an average of 3366 turbines from 2014 to 2019.

## Wind Turbine Development by State

Given our understanding of the general growth of wind energy, it is important to recognize the geographic distribution of wind turbine development (*i.e.* by state; see **Figure 3** and **Appendix D**). Using the USWTDB's list of all turbines with a state/territory given, there are a few trends that stand out.

First is the dominance of California during the first two decades. From 1981-1991, California accounted for all new wind turbines (n = 4819; not shown). The late 1990s and 2000s brought with them much more diversity across the US energy landscape. By the end of 2009, there were 38 states with at least one tur- bine. Texas (n = 6094 or 22.2%) was just trailing behind California (n = 6278 or 22.9%) as the nation's leader. Other significant development had taken place in Iowa (9.2%), Minnesota (4.9%), Oregon (4.5%) and Washington state (4.3%).

From 2011-2019 there had been substantial growth in wind energy across the

**Figure 3.** Number of new wind turbines by state and year (1992-2019; Top 10 states as of 2019).

United States. Again, when using the dataset of all turbines, there is a 2.24x in- crease in wind turbines from 2009 to 2019—strongly aided by "spikes" in 2012 and 2015. By the end of 2019, Texas was the leader in wind turbines (n = 14,852 or 24.2%) while California was a distant second (13%). Iowa was in third (8.7%) and Oklahoma moved to fourth (6.6%). As of 2019, there were 22 states with at least 1% of all turbines. There were 40 states and 2 territories (Puerto Rico and Guam) with at least one turbine.

## Total Wind Energy Capacity by State

While the growth in number of turbines tells us something about the way wind energy development has taken place over the United States (**Figure 3** and **Ap- pendix D**), it is also helpful to understand the geographic distribution of wind energy capacity as well (**Figure 4**). That is because especially valuable given that more recently built turbines have capacities 5-6× larger than those from the 1980s (see **Figure 2**). **Figures 4-6** below show the top 10 leading states in terms of total wind energy capacity—as well as total turbines and average turbine ca- pacities—built in the 1990s, 2000s, and 2010s. The full dataset can be found in **Appendix E**.

Due to a concentration of new wind farms in Minnesota and Iowa in the late 1990s, both states overtook California by 2000. While still behind in total num- ber of turbines, advancements in wind energy technology (re: capacity) allowed for this to happen. In line with **Figure 3**, from 2010 onwards Texas also became the undisputed leader in terms of capacity—with nearly 8000 MW in 2010 and nearly 25,000 MW by the end of 2019. Other notable states to emerge as wind energy leaders over the past decade include Oklahoma (n = 7033.33 MW) and

**Figure 4.** Total new wind energy capacity in the 1990s by state (Top 10 states in the 1990s).

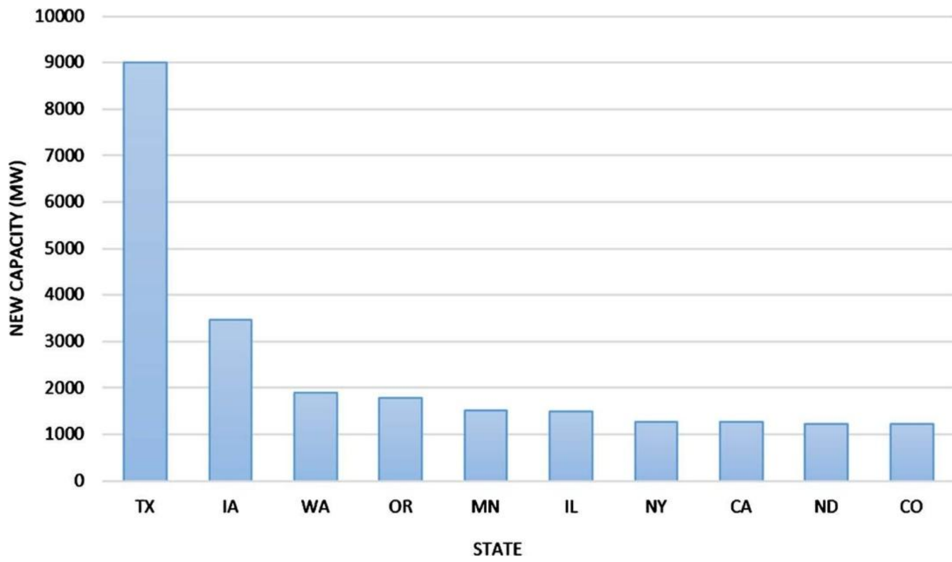



**Figure 5.** Total new wind energy capacity in the 2000s by state (Top 10 states in the 2000s).

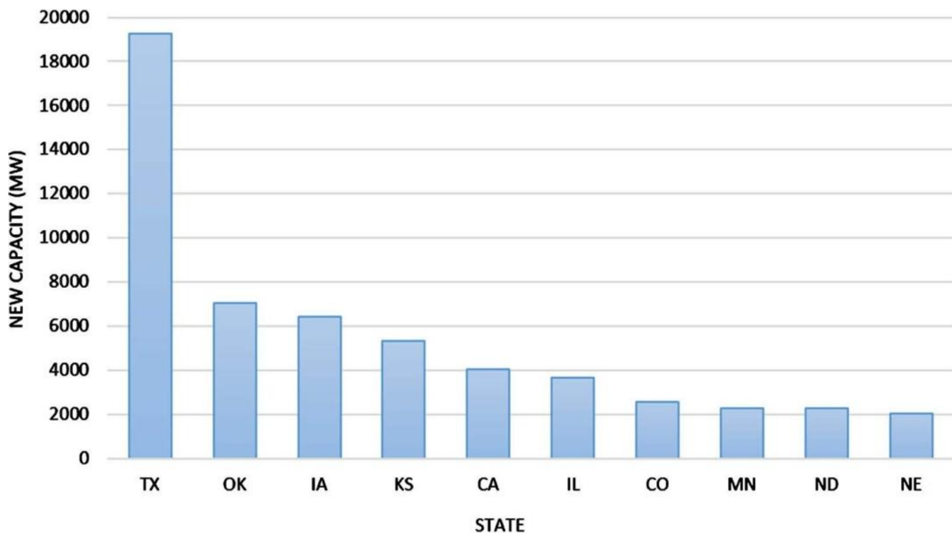



**Figure 6.** Total new wind energy capacity in the 2010s by state (Top 10 states in the 2010s). Kansas (n = 5331.98 MW).

## Turbine Size by Year

Finally, and corresponding to the growing capacity of wind developments, new turbines have grown in physical size since the 1980s. When using looking at hub height (*i.e.* the distance from the ground to the nacelle or centre of the wind tur- bine) there has been a 3.7× increase from 1985 (24.4 metres) to 2019 (90.3 me- tres). In looking at **Figure 7** below (see also **Appendix F**), this rise has also been relatively constant, especially over the past 20 years. Again, due to inconsisten- cies in the data, I use turbine hub height data with full (n = 51,032) and partial(n = 4168) confidence.

Using only those turbines with full confidence in hub heights, as of 2019 the largest onshore wind turbine has a hub height of 130 metres and is single turbine part of the UL Advanced Wind Turbine Test Facility (built in 2018 in Randall County, Texas). This is a 1.6× increase since the early to mid-2000s, where the largest hub heights were 80 metres (see **Figure 8** below).

Today, there are 1482turbines with a hub height of 100 metres or more. The multi-turbine wind de- velopment with the largest hub heights is the Hancock Wind Farm (Hancock County, Maine), which has 17, 116.5-metre turbines. More information on tall- est turbines (per year), can be found in **Appendix G**.

Although it is the most common approach, hub height is just one way to measure turbine size. Rotor diameter and turbine rotor swept area, which is the total area covered through one full rotation of turbine blades, are also used. Look- ing at only those turbines with full characteristics confidence, we can see the rise of both of these values over the past two decades (see **Figure 9** and **Appendix H**).

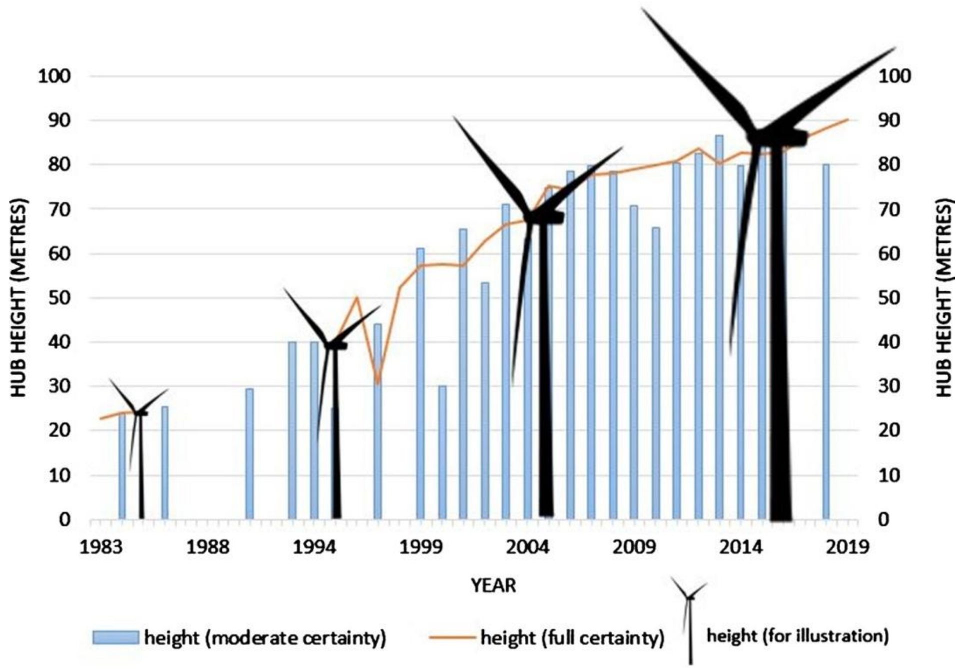
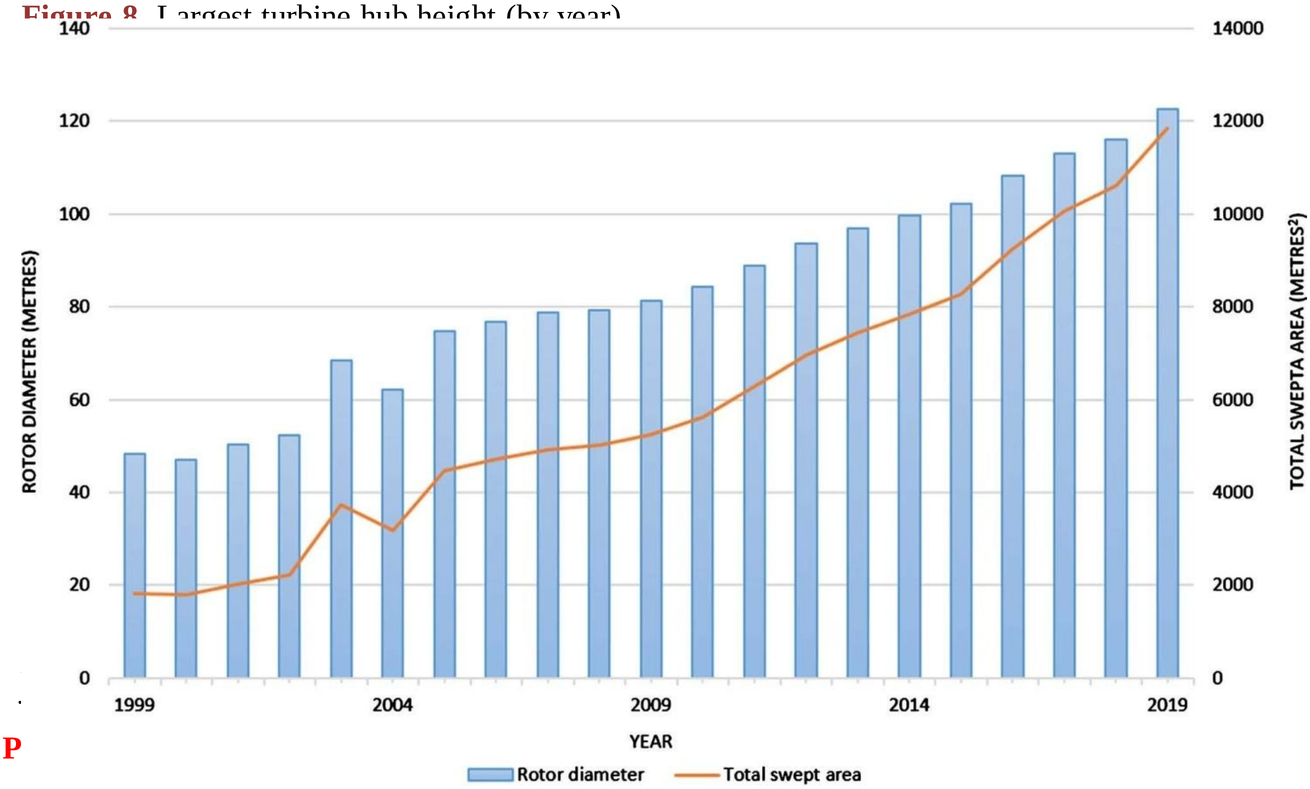



**Figure 7.** New turbine hub height (average) by year.

**Figure 8.** Largest turbine hub height (by year).




P

**Figure 9.** Average rotor diameter and total swept area by year.

Average rotor diameter increased from 48.22 metres in 1999 to 122.63 metres in 2019. The largest diameters during this same period ranged from 66 metres in 1999 to 150 metres (GE Haliade 150-6) in 2016.

Total swept area is a direct function of turbine diameter and thus why we see a perfect association between the two values in **Figure 9**. The total swept area is calculated by dividing the rotor diameter by two (*i.e.* to get radius/blade length), multiplying that value by itself, and then multiplying by the value of Pi (approx. 3.14159). It is represented through the following equation:

Total swept area    * rotor diameter  2 $^2$ /

1)

## 4. Discussion and Conclusions

Here I have presented a paper that has highlighted some major trends related to wind energy development across the United States. This was enabled by the newly-published United States Wind Turbine Database—an important, yet pre-viously unsynthesized resource.

I have begun this important work here, quantifying patterns of wind energy growth in terms of variables such as total number of turbines, capacity, geo- graphic distribution, and size. In existing literatures, these factors are often writ-ten about as assumptions. That is, phrases like "as turbines grow larger in size"—without quantification or citation—are increasingly common. I attempt to help move past the tendency to write in this way. More specifically, I show that in terms of manufacturing, and with 42% of the total, GE Wind is the undisputed leader as of 2019. Despite some significant peaks and valleys, the number of US turbines has generally increased year over year—with an average of over 3300 from 2014-2019. Average turbine capacity has also increased over the past fourdecades, and is now at just over 2.5 MW. In terms of geographic distribution, California may be labelled as the "early adopter" of wind energy, dominating all (small turbine) developments throughout the 1980s and much of the 1990s. Since then, Texas—and states like Iowa, Oklahoma and Kansas to smaller degree—have challenged and surpassed the "Golden State" in terms of both number of tur- bines and/or total capacity. Finally, I confirm the popular refrain of turbines get- ting physically larger since the 1980s. Growth of hub heights, rotor diameters and (thus) total swept areas, have seen very consistent growth over nearly 40 years. The largest turbines are now more than twice as tall (up to 130 metres) as they were just 20 years ago. Turbine rotor (blade) diameters have risen from ap-proximately 50 metres in the early 2000s to just over 120 meters in 2019.

There are a few clear limitations of this study, some of which provide oppor- tunities for further research. First, regarding the USWTDB itself, it included tur- bines that had been decommissioned. It would have been ideal if the dataset only included operational turbines, however even when not "spinning", there is an impact living near these structures. I suggest the ~~USWTDB is edited to allow for analysis that identifies operational turbines, so that certain~~

research questions would benefit as such. Second, and despite their best efforts [2], there were still

some significant gaps in data throughout the USWTDB. These were especially prevalent throughout the 1980s and 1990s, so future research that depends on precise trends may want to focus on the past two decades only. Lastly, because the data only covered one country—albeit an important one in terms of global wind energy capacity—the results here are really only relevant to studies or re- ports that happen within the US. That said, and assuming there are similar data-sets elsewhere, I hope this analysis inspires others to summarize the major trends in their jurisdiction.

All of these findings shared here should support a wide variety of actors—in- cluding governments, industry, and researchers—across an even wider area of inquiry. Given my expertise in the social acceptance of wind energy research
[13] [14] [15], I see particular value to researchers here. I also want to highlight the opportunity for this research, and indeed the rich USWTDB as a whole, to help provide important context for a range of quantitative and qualitative stu- dies. In the former, the dataset could be combined with other survey work. Fruit- ful research in this area could include health surveys and/or real estate sales data. In the qualitative realm, this data can also provide important context for case study research. For example, it may offer some important wind-farm specific characteristics that can help shape a common understanding of local develop- ment.

## References

[1] Global Wind Energy Council (GWEC) (2019) GWEC: Over 60 GW of Wind Energy Capacity Installed in 2019, the Second Biggest Year in History. https://gwec.net/gwec-over-60gw-of-wind-energy-capacity-installed-in-2019-the-se cond-biggest-year-in-history

[2] Rand, J., Kramer, L., Garrity, C., *et al*. (2020) A Continuously Updated, Geospatially Rectified Database of Utility-Scale Wind Turbines in the United States. *Scientific Data*, **7**, Article No. 15. https://doi.org/10.1038/s41597-020-0353-6

[3] United States Geological Survey (USGS) (2020) USWTDB Viewer. https://eerscmap.usgs.gov/uswtdb/viewer/#3/37.25/-96.25

[4] Millstein, D., Wiser, R., Bolinger, M. and Barbose, G. (2017) The Climate and Air- Quality Benefits of Wind and Solar Power in the United States. *Nature Energy*, **2**, Article No. 17134. https://doi.org/10.1038/nenergy.2017.134

[5] Walker, C., Baxter, J. and Ouellette, D. (2015) Adding Insult to Injury: The Devel- opment of Psychosocial Stress in Ontario Wind Turbine Communities. *Social Sci- ence & Medicine*, **133**, 358-365. https://doi.org/10.1016/j.socscimed.2014.07.067

[6] Johlas, H., Witherby, S. and Doyle, J. (2020) Storage Requirements for High Grid Penetration of Wind and Solar Power for the MISO Region of North America: A Case Study. *Renewable Energy*, **146**, 1315-1324. https://doi.org/10.1016/j.renene.2019.07.043

[7] Arent, D., Pless, J., Mai, T., *et al*. (2014) Implications of High Renewable Electricity Penetration in the US for Water Use, Greenhouse Gas Emissions, Land-Use, and Materials Supply. *Applied*

*Energy*, **123**, 368-377. https://doi.org/10.1016/j.apenergy.2013.12.022

[8] Miller, L. and Keith, D. (2018) Climatic Impacts of Wind Power. *Joule*, **2**, 2618-2632. https://doi.org/10.1016/j.joule.2018.09.009

[9] Haac, T., Kaliski, K., Landis, M. *et al*. (2019) Wind Turbine Audibility and Noise Annoyance in a National US Survey: Individual Perception and Influencing Factors. *The Journal of the Acoustical Society of America*, **146**, 1124-1141. https://doi.org/10.1121/1.5121309

[10] Hoen, B., Brown, J., Jackson, T., Thayer, M., Wiser, R. and Cappers, P. (2015) Spa-tial Hedonic Analysis of the Effects of US Wind Energy Facilities on Surrounding Property Values. *The Journal of Real Estate Finance and Economics*, **51**, 22-51. https://doi.org/10.1007/s11146-014-9477-9

[11] Walker, C., Baxter, J., Mason, S., Luginaah, I. and Ouellette, D. (2014) Wind Energy Development and Perceived Real Estate Values in Ontario, Canada. *AIMS Energy*, **2**, 424-442. https://doi.org/10.3934/energy.2014.4.424

[12] Oakleaf, J., Kennedy, C., Baruch-Mordo, S., *et al*. (2019) Mapping Global Develop- ment Potential for Renewable Energy, Fossil Fuels, Mining and Agriculture Sectors. *Scientific Data*, **6**, 1-17. https://doi.org/10.1038/s41597-019-0084-8

[13] Rand, J. and Hoen, B. (2017) Thirty Years of North American Wind Energy Accep- tance Research: What Have We Learned? *Energy Research & Social Science*, **29**, 135-148. https://doi.org/10.1016/j.erss.2017.05.019

[14] Walker, C., Baxter, J. and Ouellette, D. (2014) Beyond Rhetoric to Understanding Determinants of Wind Turbine Support and Conflict in Two Ontario, Canada Com- munities. *Environment and Planning A*, **46**, 730-745. https://doi.org/10.1068/a130004p

[15] Baxter, J., Walker, C., Ellis, G., Devine-Wright, P., Adams, M. and Fullerton, R.S. (2020) Scale, History and Justice in Community Wind Energy: An Empirical Re- view. *Energy Research & Social Science*, **68**, Article ID: 101532. https://doi.org/10.1016/j.erss.2020.101532

## Appendix

### A. State and Territories: Abbreviations

| STATE | Abbreviation |
|---|---|
| **Alabama** | AL |
| **Alaska** | AK |
| **Arizona** | AZ |
| **Arkansas** | AR |
| **California** | CA |
| **Colorado** | CO |
| **Connecticut** | CT |
| **Delaware** | DE |
| **District of Columbia** | |

.

ISSN: 2278-4632
Vol-10 Issue-3 No.01 March 2020

D

C **Florida**

F

L

| | |
|---|---|
| **Georgia** | GA |
| **Guam** | GU |
| **Hawaii** | HI |
| **Idaho** | ID |
| **Illinois** | IL |
| **Indiana** | IN |
| **Iowa** | IA |
| **Kansas** | KS |
| **Kentucky** | KY |
| **Louisiana** | LA |
| **Maine** | ME |
| **Maryland** | MD |
| **Massachusetts** | MA |
| **Michigan** | MI |
| **Minnesota** | MN |
| **Mississippi** | MS |
| **Missouri** | MO |
| **Montana** | MT |
| **Nebraska** | NE |
| **Nevada** | NV |
| **New Hampshire** | NH |
| **New Jersey** | NJ |
| **New Mexico** | NM |
| **New York** | NY |
| **North Carolina** | NC |

C. Walker

**Continued**

.

ISSN: 2278-4632
Vol-10 Issue-3 No.01 March 2020

| | |
|---|---|
| **North Dakota** | ND |
| **Ohio** | OH |
| **Oklahoma** | OK |
| **Oregon** | OR |
| **Pennsylvania** | PA |
| **Puerto Rico** | PR |
| **Rhode Island** | RI |
| **South Carolina** | SC |
| **South Dakota** | SD |
| **Tennessee** | TN |
| **Texas** | TX |
| **Utah** | UT |
| **Vermont** | VT |
| **Virgin Islands** | VI |
| **Virginia** | VA |
| **Washington** | WA |
| **West Virginia** | WV |
| **Wisconsin** | WI |
| **Wyoming** | WY |

## B. US Wind Turbines by Manufacturer (As of 2019)

| COMPANY | NUMBER OF WIND TURBINES[a] | PERCENTAGE OF TOTAL (%) |
|---|---|---|
| GE Wind | 21,174 | 41.5 |
| Vestas (and Vestas North America) | 12,322 | 24.1 |
| Siemens | 4901 | 9.6 |
| Mitsubishi | 2796 | 5.5 |
| Gamesa | 2654 | 5.2 |
| Suzlon | 1306 | 2.6 |
| Nordex | 929 | 1.8 |
| Acciona | 758 | 1.5 |
| NEG Micon | 680 | 1.3 |
| Clipper | 676 | 1.3 |
| Siemens Gamesa Renewable Energy | 582 | 1.1 |
| Repower | 548 | 1.1 |
| Bonus | 404 | 0.8 |
| Enron | 396 | 0.8 |

**Continued**

| | | |
|---|---|---|
| Goldwind | 186 | 0.4 |
| Zond | 156 | 0.3 |
| Danwin | 115 | 0.2 |
| Nordtank | 90 | 0.2 |
| DeWind | 84 | 0.2 |
| Vensys | 28 | 0.1 |
| Northern Power Systems | 26 | 0.1 |
| Alstom | 24 | <0.1 |
| Fuhrlander | 19 | <0.1 |

.

ISSN: 2278-4632
Vol-10 Issue-3 No.01 March 2020

| | | |
|---|---|---|
| China Creative Wind Energy | 17 | <0.1 |
| Sany | 17 | <0.1 |
| Entegrity | 16 | <0.1 |
| HZ Windpower | 16 | <0.1 |
| NedWind | 13 | <0.1 |
| EWT | 11 | <0.1 |
| Vergnet | 9 | <0.1 |
| Seaforth Energy | 8 | <0.1 |
| PowerWind | 7 | <0.1 |
| Guodian | 6 | <0.1 |
| Windmatic | 5 | <0.1 |
| Aeronautica | 5 | <0.1 |
| RRB | 5 | <0.1 |
| ***TOTAL*** | 51,037 | 100.0 |

[a]Here I include only those wind turbines with full confidence in characteristics (n = 51,037) and those manufacturers with at least five turbines as of 2019. I thus exclude 22 manufacturers.

## C. Turbine Capacity by Year

| YEAR | NUMBER OF NEW WIND TURBINES[a] | MEAN TURBINE CAPACITY[b] (full certainty) | STANDARD DEVIATION | MEAN TURBINE CAPACITY[c] (moderate certainty) | STANDARD DEVIATION |
|---|---|---|---|---|---|
| 1981 | 10 | n/a | n/a | n/a | n/a |
| 1982 | 1073 | n/a | n/a | 221.98 | 87.16 |
| 1983 | 432 | 65 | 0.00 | n/a | n/a |
| 1984 | 196 | 65 | 0.00 | 70.40 | 10.35 |
| 1985 | 1596 | 65 | 0.00 | 95.41 | 45.32 |
| 1986 | 212 | n/a | n/a | 107.50 | 90.19 |
| 1987 | 387 | n/a | n/a | 101.45 | 6.51 |
| 1988 | 277 | 160 | 0.00 | 105 | . |

| | | | | | |
|---|---|---|---|---|---|
| 1998 | 189 | 722.38 | 65.25 | n/a | n/a |
| 1999 | 1005 | 715.33 | 84.52 | 771.84 | 219.07 |
| 2000 | 82 | 715.92 | 327.05 | 929.55 | 233.67 |
| 2001 | 1876 | 798.19 | 254.30 | 1408.06 | 281.61 |
| 2002 | 462 | 875 | 351.89 | 652.00 | 678.54 |
| 2003 | 1153 | 1377.18 | 340.39 | 1482.65 | 133.48 |
| 2004 | 328 | 1101.77 | 418.19 | 1321.88 | 244.12 |
| 2005 | 1653 | 1488.19 | 300.88 | 1475.27 | 193.54 |
| 2006 | 1506 | 1578.32 | 413.67 | 1664.01 | 398.67 |
| 2007 | 3 200 | 1646.23 | 420.28 | 1619.85 | 284.39 |
| 2008 | 5046 | 1680.19 | 459.26 | 1488.81 | 219.71 |
| 2009 | 5780 | 1732.86 | 412.07 | 1770.12 | 806.20 |
| 2010 | 2960 | 1792.39 | 394.02 | 1033.80 | 858.73 |
| 2011 | 3504 | 1969.19 | 459.62 | 2065.00 | 536.99 |
| 2012 | 6774 | 1952 | 444.24 | 1630.35 | 353.79 |
| 2013 | 610 | 1853.66 | 373.50 | 2105.56 | 592.82 |
| 2014 | 2512 | 1933.34 | 358.33 | 2061.81 | 280.92 |
| 2015 | 4300 | 2012.99 | 329.81 | 1828.24 | 479.47 |
| 2016 | 3810 | 2157.08 | 442.62 | 1957.26 | 387.08 |
| 2017 | 3090 | 2321.77 | 411.27 | n/a | n/a |
| 2018 | 3200 | 2443.37 | 483.59 | 1525 | 1096.02 |
| 2019 | 3283 | 2558.96 | 491.23 | n/a | n/a |
| TOTAL/AVERAGE | 61463 | 1831.93* | 604.28 | 1027.21 | 768.90 |

[a]Based on all turbines regardless of turbine characteristic or location confidence (n = 61,463). [b]I include all turbines with full confidence values in turbine capacity (n = 51,036). [c]I include all turbines with partial con- fidence values in turbine capacity (n = 6007).

## D. New Turbines by State and Year (Decade)

**1981-1989[a,b]**

| STATE | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1980s TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|
| CA | 10 | 1073 | 432 | 196 | 1596 | 212 | 387 | 277 | 288 | 4471 |

[a]I include all turbines, regardless of confidence of level, that provide a state/territory of each turbine (n = 4471). [b]All other states/territories with zero turbines in the 1980s are excluded within this table.

**1990-1999[a,b]**

| STATE | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 1990s TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|
| CA | 34 | 1 | 1 | 0 | 30 | 42 | 13 | 20 | 2 | 18 | 830 |

.

ISSN: 2278-4632
Vol-10 Issue-3 No.01 March 2020

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 7 | | | | | | | 7 | | 7 | |
| MN | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 142 | 192 | 335 |
| IA | 0 | 0 | 1 | 0 | 0 | 2 | 0 | 2 | 3 | 312 | 320 |
| TX | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 151 | 151 |
| WY | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 108 | 110 |
| OR | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 38 | 0 | 38 |
| CO | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 29 | 29 |
| WI | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 18 | 18 |
| AK | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 0 | 6 | 0 | 12 |
| VT | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 12 | 0 | 0 | 12 |
| NE | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 1 | 3 |
| ND | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 2 |
| IL | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 |
| MI | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| NM | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |

[a]I include all turbines, regardless of confidence of level, that provide a state/territory of each (n = 1863). [b]All other states/territories with zero turbines in the 1990s are excluded within this table.

**2000-2009*[a,b]***

| STATE | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2000s TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|
| TX | 0 | 852 | 0 | 186 | 0 | 434 | 395 | 980 | 1694 | 1402 | 5943 |
| IA | 0 | 91 | 150 | 32 | 108 | 152 | 67 | 161 | 912 | 534 | 2207 |
| OR | 0 | 181 | 102 | 41 | 0 | 50 | 67 | 260 | 102 | 403 | 1206 |
| WA | 0 | 270 | 37 | 12 | 0 | 83 | 260 | 165 | 104 | 243 | 1174 |
| MN | 18 | 41 | 18 | 165 | 28 | 77 | 81 | 263 | 269 | 41 | 1001 |
| CA | 10 | 108 | 104 | 141 | 104 | 93 | 152 | 21 | 71 | 173 | 977 |
| IL | 0 | 0 | 0 | 0 | 1 | 34 | 0 | 358 | 129 | 430 | 952 |
| CO | 0 | 48 | 0 | 108 | 5 | 1 | 40 | 591 | 1 | 83 | 877 |
| NY | 17 | 19 | 1 | 0 | 0 | 82 | 112 | 31 | 188 | 345 | 795 |

ISSN: 2278-4632
Vol-10 Issue-3 No.01 March 2020

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ND | 0 | 1 | 3 | 41 | 0 | 22 | 50 | 111 | 247 | 301 | 776 |
| OK | 0 | 1 | 0 | 113 | 0 | 182 | 40 | 85 | 91 | 154 | 666 |
| WY | 31 | 49 | 0 | 80 | 0 | 2 | 0 | 0 | 226 | 274 | 662 |

**Continued**

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| KS | 0 | 170 | 0 | 0 | 0 | 100 | 68 | 0 | 222 | 73 | 633 |
| IN | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 88 | 529 | 617 |
| NM | 0 | 0 | 0 | 138 | 60 | 140 | 90 | 0 | 1 | 40 | 469 |
| PA | 0 | 16 | 0 | 63 | 0 | 0 | 25 | 65 | 32 | 211 | 412 |
| MT | 0 | 0 | 0 | 0 | 0 | 108 | 6 | 8 | 83 | 69 | 274 |
| WI | 0 | 20 | 0 | 0 | 1 | 0 | 0 | 0 | 216 | 37 | 274 |
| SD | 0 | 4 | 2 | 28 | 0 | 0 | 0 | 36 | 59 | 68 | 197 |
| WV | 0 | 0 | 44 | 0 | 0 | 0 | 0 | 0 | 132 | 0 | 176 |
| MO | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 27 | 51 | 73 | 151 |
| UT | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 9 | 98 | 109 |
| ME | 0 | 0 | 0 | 0 | 0 | 0 | 7 | 21 | 3 | 64 | 95 |
| MI | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 80 | 7 | 89 |
| ID | 0 | 0 | 0 | 0 | 0 | 50 | 0 | 0 | 0 | 34 | 84 |
| NE | 0 | 1 | 0 | 0 | 0 | 36 | 0 | 0 | 0 | 27 | 64 |
| AK | 2 | 1 | 1 | 2 | 4 | 0 | 6 | 2 | 21 | 14 | 53 |
| HI | 0 | 0 | 0 | 0 | 0 | 0 | 36 | 14 | 0 | 0 | 50 |
| AZ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 30 | 30 |
| MA | 0 | 1 | 0 | 0 | 0 | 1 | 2 | 1 | 3 | 13 | 21 |
| TN | 3 | 0 | 0 | 0 | 15 | 0 | 0 | 0 | 0 | 0 | 18 |
| NH | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 12 | 1 | 13 |
| OH | 0 | 0 | 0 | 2 | 2 | 0 | 1 | 0 | 0 | 4 | 9 |
| NJ | 0 | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 5 |
| RI | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 2 | 3 |
| VT | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 2 |

ISSN: 2278-4632
Vol-10 Issue-3 No.01 March 2020

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| AR | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| NC | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |

[a]I include all turbines, regardless of confidence of level, that provide a state/territory of each (n = 21,086).

[b]All other states/territories with zero turbines in the 2000s are excluded within this table.

**2010-2019*[a,b]***

| STATE | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2010s TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|
| TX | 353 | 136 | 920 | 84 | 964 | 1796 | 1211 | 946 | 919 | 1429 | 8758 |
| OK | 195 | 257 | 596 | 0 | 369 | 710 | 602 | 323 | 290 | 18 | 3360 |
| IA | 5 | 282 | 385 | 26 | 219 | 226 | 304 | 195 | 506 | 690 | 2838 |
| KS | 46 | 112 | 802 | 141 | 1 | 413 | 376 | 277 | 210 | 235 | 2613 |
| IL | 284 | 405 | 493 | 0 | 0 | 153 | 93 | 139 | 233 | 161 | 1961 |
| CA | 212 | 375 | 789 | 115 | 36 | 94 | 3 | 23 | 114 | 6 | 1767 |
| O | 35 | 262 | 308 | 18 | 153 | 232 | 36 | 36 | 300 | 35 | 1415 |
| MN | 229 | 332 | 152 | 2 | 32 | 100 | 145 | 100 | 41 | 106 | 1239 |
| **Continued** | | | | | | | | | | | |
| MI | 10 | 121 | 353 | 103 | 207 | 0 | 44 | 101 | 19 | 114 | 1072 |
| ND | 128 | 9 | 80 | 1 | 65 | 118 | 311 | 124 | 45 | 145 | 1026 |
| NE | 43 | 85 | 73 | 46 | 161 | 47 | 221 | 45 | 232 | 56 | 1009 |
| OR | 129 | 209 | 253 | 0 | 0 | 0 | 6 | 25 | 0 | 56 | 678 |
| NM | 64 | 28 | 14 | 5 | 21 | 134 | 16 | 260 | 22 | 84 | 648 |
| IN | 184 | 1 | 128 | 1 | 101 | 65 | 0 | 106 | 61 | 0 | 647 |
| WA | 162 | 158 | 119 | 0 | 117 | 2 | 0 | 0 | 0 | 0 | 558 |

.

ISSN: 2278-4632
Vol-10 Issue-3 No.01 March 2020

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| SD | 229 | 51 | 0 | 0 | 11 | 98 | 0 | 0 | 18 | 83 | 490 |
| ID | 134 | 155 | 168 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 457 |
| OH | 15 | 58 | 166 | 2 | 1 | 7 | 49 | 34 | 49 | 6 | 387 |
| MO | 101 | 0 | 1 | 0 | 1 | 0 | 92 | 165 | 0 | 24 | 384 |
| NY | 2 | 67 | 78 | 52 | 16 | 6 | 40 | 7 | 77 | 1 | 346 |
| PA | 0 | 21 | 279 | 0 | 0 | 0 | 14 | 0 | 5 | 20 | 339 |
| ME | 41 | 72 | 19 | 0 | 3 | 57 | 91 | 8 | 0 | 0 | 291 |
| MT | 8 | 0 | 171 | 1 | 12 | 0 | 13 | 0 | 48 | 1 | 254 |
| WY | 186 | 0 | 0 | 0 | 0 | 0 | 46 | 0 | 0 | 0 | 232 |
| WV | 66 | 76 | 8 | 0 | 0 | 0 | 49 | 0 | 0 | 0 | 199 |
| WI | 11 | 90 | 11 | 1 | 0 | 0 | 0 | 49 | 0 | 0 | 162 |
| AZ | 31 | 6 | 62 | 0 | 0 | 15 | 0 | 0 | 0 | 0 | 114 |
| NC | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 104 | 0 | 0 | 104 |
| UT | 0 | 68 | 0 | 0 | 0 | 1 | 28 | 0 | 0 | 0 | 97 |
| MD | 31 | 20 | 0 | 0 | 16 | 12 | 0 | 1 | 0 | 0 | 80 |
| AK | 13 | 4 | 45 | 4 | 2 | 4 | 0 | 0 | 4 | 1 | 77 |
| HI | 0 | 12 | 53 | 1 | 0 | 3 | 0 | 5 | 0 | 0 | 74 |
| NH | 0 | 0 | 57 | 0 | 0 | 5 | 0 | 0 | 0 | 9 | 71 |
| MA | 9 | 16 | 34 | 2 | 1 | 0 | 4 | 1 | 0 | 3 | 70 |
| NV | 0 | 0 | 67 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 70 |
| PR | 0 | 0 | 58 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 61 |
| VT | 2 | 16 | 25 | 1 | 0 | 0 | 0 | 15 | 0 | 0 | 59 |
| RI | 0 | 0 | 6 | 0 | 0 | 0 | 15 | 1 | 7 | 0 | 29 |
| CT | 1 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 3 |
| DE | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| FL | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| GU | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| NJ | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |

[a]I include all turbines, regardless of confidence of level, that provide a state/territory of each (n = 34,043).

[b]All other states/territories with zero turbines in the 2010s are excluded within this table.

### E. Total Capacity by State and Decade

**1981-1989[a]**

.

| STATE | 1980s TOTAL[b] | AVERAGE TURBINE CAPACITY (kW)[c] | STANDARD DEVIATION | TOTAL NEW CAPACITY (kW) | TOTAL NEW CAPACITY (MW) |
|---|---|---|---|---|---|
| CA | 4471 | 79.40 | 34.08 | 354,997.40 | 355 |

[a]All other states/territories with zero turbines in the 1980s are excluded within this table. [b]I include all tur- bines, regardless of confidence of level, that provide a state/territory of each (n = 4,471). [c]I include only tur- bine capacities with full confidence in the 1980s (n = 759).

**1990-1999[a]**

| STATE[a] | 1990s TURBINES TOTAL[b] | AVERAGE TURBINE CAPACITY (kW)[c] | SD | TOTAL NEW CAPACITY (kW) | TOTAL NEW CAPACITY (MW) |
|---|---|---|---|---|---|
| CA | 1177 | 580.38 | 212.64 | 683,107.26 | 683.11 |
| IA | 320 | 745.82 | 42.29 | 238,662.4 | 238.66 |
| MN | 335 | 675.71 | 196.54 | 226,362.85 | 226.36 |
| TX | 151 | 702.18 | 119.11 | 106,029.18 | 106.03 |
| WY | 110 | 647.73 | 68.40 | 71,250.3 | 71.25 |
| OR | 38 | 660.00 | 0.00 | 25,080 | 25.08 |
| CO | 29 | 750.00 | 0.00 | 21,750 | 21.75 |
| WI | 18 | 660.00 | 0.00 | 11,880 | 11.88 |
| VT[c] | 12 | 545.83 | 202.77 | 6549.96 | 6.55 |
| NE | 3 | 660.00 | 0.00 | 1980 | 1.98 |
| AK | 12 | 74.09 | 50.59 | 889.08 | 0.89 |
| NM[c] | 1 | 660.00 | . | 660 | 0.66 |
| MI | 1 | 600.00 | . | 600 | 0.60 |
| IL[c] | 1 | 550.00 | . | 550 | 0.55 |
| ND[c] | 2 | 100.00 | .00 | 200 | 0.20 |

[a]All other states/territories with zero turbines in the 1990s are excluded within this table. [b]I include all tur- bines, regardless of confidence of level, that provide a state/territory of each (n = 1863). [c]I include only tur-bine capacities with full confidence (n = 1168).

**2000-2009*[a]***

| STATE | 2000s TURBINES TOTAL | AVERAGE TURBINE CAPACITY (kW) | STANDARD DEVIATION | TOTAL NEW CAPACITY (kW) | (MW) |
|---|---|---|---|---|---|
| TX | 5943 | 1515.71 | 530.75 | 9,007,864.53 | 9007.86 |
| IA | 2207 | 1568.76 | 479.78 | 3,462,253.32 | 3462.25 |
| WA | 1174 | 1613.20 | 598.88 | 1,893,896.8 | 1893.90 |
| OR | 1206 | 1485.64 | 590.58 | 1,791,681.84 | 1791.68 |
| MN | 1001 | 1505.24 | 389.81 | 1,506,745.24 | 1506.75 |
| IL | 952 | 1563.88 | 170.38 | 1,488,813.76 | 1488.81 |

ISSN: 2278-4632
Vol-10 Issue-3 No.01 March 2020

**TOTAL NEW CAPCITY**

| **Continued** | | | | | |
|---|---|---|---|---|---|
| CA | 977 | 1301.50 | 637.23 | 1,271,565.5 | 1271.57 |
| ND | 776 | 1585.43 | 224.97 | 1,230,293.68 | 1230.29 |
| CO | 877 | 1395.84 | 360.02 | 1,224,151.68 | 1224.15 |
| OK | 666 | 1722.03 | 307.14 | 1,146,871.98 | 1146.87 |
| WY | 662 | 1616.16 | 364.94 | 1,069,897.92 | 1069.90 |
| IN | 617 | 1678.03 | 261.68 | 1,035,344.51 | 1035.34 |
| KS | 633 | 1610.12 | 823.55 | 1,019,205.96 | 1019.21 |
| PA | 412 | 1790.53 | 309.98 | 737,698.36 | 737.70 |
| NM | 469 | 1238.02 | 460.55 | 580,631.38 | 580.63 |
| WI | 274 | 1571.23 | 119.49 | 430,517.02 | 430.52 |
| MT | 274 | 1439.05 | 289.94 | 394,299.7 | 394.30 |
| WV | 176 | 1875.00 | 217.12 | 330,000 | 330.00 |
| SD | 197 | 1620.47 | 292.99 | 319,232.59 | 319.23 |
| MO | 151 | 2029.14 | 138.13 | 306,400.14 | 306.40 |
| UT | 109 | 2084.67 | 489.21 | 227,229.03 | 227.23 |
| ME | 95 | 1837.89 | 647.94 | 174,599.55 | 174.60 |
| ID | 84 | 1742.86 | 296.28 | 146,400.24 | 146.40 |
| MI | 89 | 1607.30 | 224.18 | 143,049.7 | 143.05 |
| NE | 64 | 2204.06 | 696.25 | 141,059.84 | 141.06 |
| AZ | 30 | 2100 | .00 | 63,000 | 63.00 |
| HI | 50 | 1126.67 | 423.32 | 56,333.5 | 56.33 |

| | | | | | |
|---|---|---|---|---|---|
| TN | 18 | 1610.00 | 437.17 | 28,980 | 28.98 |
| NH | 13 | 2000.00 | .00 | 26,000 | 26.00 |
| MA | 21 | 926.25 | 597.45 | 19,451.25 | 19.45 |
| OH | 9 | 1250.83 | 852.00 | 11,257.47 | 11.26 |
| AK | 53 | 210.94 | 424.33 | 11,179.82 | 11.18 |
| NJ | 5 | 1500.00 | .00 | 7500 | 7.50 |
| RI | 3 | 380.00 | 395.98 | 1140 | 1.14 |
| VT[d] | 2 | 100.00 | .00 | 200 | 0.20 |
| AR[d] | 1 | 175.83 | 330.57 | 175.83 | 0.18 |
| NC[e] | 1 | n/a | n/a | n/a | n/a |

[a]All other states/territories with zero turbines in the 2000s are excluded within this table. [b]I include all tur- bines, regardless of confidence of level, that provide a state/territory of each (n = 21,086). [c]When available, I include only turbine capacities with full confidence (n = 18,045). [d]For these states, I use the average turbine capacities with moderate confidence (n = 2969). [e]There was no turbine capacity data for North Carolina's single turbine.

**2010-2019*[a]***

| STATE | 2010s TURBINES TOTAL | AVERAGE TURBINE CAPACITY (kW) | STANDARD DEVIATION | TOTAL NEW CAPACITY (kW) | TOTAL NEW (MW) |
|---|---|---|---|---|---|
| **TX** | 8758 | 2200.60 | 478.76 | 19,272,854.80 | 19272.85 |
| **OK** | 3360 | 2093.37 | 430.85 | 7,033,723.20 | 7033.72 |
| **IA** | 2838 | 2259.60 | 303.23 | 6,412,744.80 | 6412.74 |
| **KS** | 2613 | 2040.56 | 476.51 | 5,331,983.28 | 5331.98 |
| **CA** | 1767 | 2293.76 | 663.68 | 4,053,073.92 | 4053.07 |
| **IL** | 1961 | 1860.68 | 315.74 | 3,648,793.48 | 3648.79 |
| **CO** | 1415 | 1795.34 | 217.23 | 2,540,406.10 | 2540.41 |
| **MN** | 1239 | 1841.12 | 322.14 | 2,281,147.68 | 2281.15 |
| **ND** | 1026 | 2199.49 | 541.92 | 2,256,676.74 | 2256.68 |

| | | | | | |
|---|---|---|---|---|---|
| **NE** | 1009 | 2015.47 | 496.39 | 2,033,609.23 | 2033.61 |
| **MI** | 1072 | 1879.77 | 386.90 | 2,015,113.44 | 2015.11 |
| **OR** | 678 | 2237.86 | 389.78 | 1,517,269.08 | 1517.27 |
| **NM** | 648 | 2118.89 | 291.41 | 1,373,040.72 | 1373.04 |
| **IN** | 647 | 1972.26 | 549.34 | 1,276,052.22 | 1276.05 |
| **WA** | 558 | 2114.46 | 315.54 | 1,179,868.68 | 1179.87 |
| **SD** | 490 | 1738.42 | 240.91 | 851,825.80 | 851.83 |
| **ID** | 457 | 1813.14 | 332.71 | 828,604.98 | 828.60 |
| **OH** | 387 | 1996.03 | 323.75 | 772,463.61 | 772.46 |
| **ME** | 291 | 2590.31 | 702.21 | 753,780.21 | 753.78 |
| **NY** | 346 | 2159.73 | 559.10 | 747,266.58 | 747.27 |
| **MO** | 384 | 1873.27 | 247.18 | 719,335.68 | 719.34 |
| **PA** | 339 | 2049.00 | 349.15 | 694,611 | 694.61 |
| **MT** | 254 | 1708.55 | 377.22 | 433,971.70 | 433.97 |
| **WY** | 232 | 1722.08 | 312.09 | 399,522.56 | 399.52 |
| **WV** | 199 | 1780.40 | 324.06 | 354,299.6 | 354.30 |
| **WI** | 162 | 1874.84 | 276.33 | 303,724.08 | 303.72 |
| **NC** | 104 | 2000.00 | .00 | 208,000 | 208 |
| **AZ** | 114 | 1807.96 | 232.66 | 206,107.44 | 206.11 |
| **MD** | 80 | 2477.27 | 199.43 | 198,181.6 | 198.18 |
| **NH** | 71 | 2600.81 | 483.03 | 184,657.51 | 184.66 |
| **UT** | 97 | 1728.02 | 360.89 | 167,617.94 | 167.62 |
| **NV** | 70 | 2300.00 | .00 | 161,000 | 161 |

ISSN: 2278-4632
Vol-10 Issue-3 No.01 March 2020

| | | | | | |
|---|---|---|---|---|---|
| **HI** | 74 | 2134.78 | 605.42 | 157,973.72 | 157.97 |
| **VT** | 59 | 2468.97 | 599.18 | 145,669.23 | 145.67 |
| **PR** | 61 | 2090.42 | 467.89 | 127,515.62 | 127.52 |
| **Continued** | | | | | |
| **MA** | 70 | 1593.71 | 303.61 | 111,559.70 | 111.56 |
| **AK** | 77 | 1173.94 | 764.05 | 90,393.38 | 90.39 |
| **RI** | 29 | 2552.59 | 1772.13 | 74,025.11 | 74.03 |
| **CT** | 3 | 2850.00 | .00 | 8550 | 8.55 |
| **DE** | 1 | 2000.00 | . | 2000 | 2 |
| **NJ** | 1 | 1500.00 | . | 1500 | 1.5 |
| **GU** | 1 | 275.00 | . | 275 | 0.275 |
| **FL[d]** | 1 | n/a | n/a | n/a | n/a |

[a] All other states/territories with zero turbines in the 2010s are excluded within this table. [b] I include all tur- bines, regardless of confidence of level, that provide a state/territory of each (n = 34,043). [c] When available, I include only turbine capacities with full confidence (n = 31,031). [d] There was no turbine capacity data for Florida's single turbine.

## F. Size of Turbines by Year

| YEAR | AVERAGE HUB HEIGHT[a] (metres; full certainty) | STANDARD DEVIATION | AVERAGE HUB HEIGHT (metres; partial certainty) | STANDARD DEVIATION HEIGHT[b] |
|---|---|---|---|---|
| 1983 | 22.80 | 0.00 | n/a | n/a |
| 1984 | 24.00 | 0.00 | 24 | .00 |
| 1985 | 24.39 | 0.29 | n/a | n/a |
| 1986 | n/a | | 25.31 | 6.80 |
| 1987 | n/a | | n/a | n/a |

ISSN: 2278-4632
Vol-10 Issue-3 No.01 March 2020

| | | | | |
|---|---|---|---|---|
| 1988 | 23.00 | .00 | n/a | n/a |
| 1989 | n/a | n/a | n/a | n/a |
| 1990 | n/a | n/a | 29.32 | 2.76 |
| 1991 | n/a | n/a | n/a | n/a |
| 1992 | 43.00 | . | 40 | . |
| 1994 | n/a | n/a | 40 | .00 |
| 1995 | 39.77 | 1.52 | 25 | . |
| 1996 | 50.00 | . | n/a | n/a |
| 1997 | 30.50 | 0.00 | 44.04 | 6.33 |
| 1998 | 52.29 | 3.56 | n/a | n/a |
| 1999 | 57.23 | 7.23 | 61.05 | 6.90 |
| 2000 | 57.56 | 9.29 | 30.00 | . |
| 2001 | 57.10 | 7.81 | 65.41 | 5.79 |
| 2002 | 62.74 | 5.83 | 53.25 | 37.83 |
| 2003 | 66.70 | 7.38 | 70.94 | 7.56 |
| 2004 | 67.63 | 9.39 | 63.32 | 2.43 |
| 2005 | 75.24 | 8.06 | 74.91 | 9.72 |

ISSN: 2278-4632
Vol-10 Issue-3 No.01 March 2020

| | | | | |
|---|---|---|---|---|
| 2010 | 79.79 | 2.25 | 65.89 | 21.86 |
| 2011 | 80.89 | 5.58 | 80.40 | 5.91 |
| 2012 | 83.75 | 9.26 | 82.61 | 7.01 |
| 2013 | 80.23 | 3.55 | 86.50 | 9.49 |
| 2014 | 82.85 | 5.61 | 79.65 | 3.81 |
| 2015 | 82.30 | 5.39 | 87.71 | 17.27 |
| 2016 | 82.98 | 6.02 | 88.05 | 18.73 |
| 2017 | 86.01 | 6.69 | n/a | n/a |
| 2018 | 88.26 | 5.87 | 80 | . |
| 2019 | 90.30 | 6.88 | n/a | n/a |
| **TOTAL/ AVERAGE** | 79 | 11.72 | 70.96 | 17.54 |

[a]I include all turbines with full confidence values in hub height (n = 51,035). [b]I include all turbines with partial confidence values in hub height turbine (n = 4168).

## G. Largest Turbines by Year (Hub Height; 2000-2019)

| YEAR | TALLEST TURBINE (HUB HEIGHT; METRES)[a] |
|---|---|
| 2000 | 67 |
| 2001 | 80 |
| 2002 | 80 |
| 2003 | 80 |
| 2004 | 80 |
| 2005 | 85 |
| 2006 | 80 |
| 2007 | 105 |
| 2008 | 100 |
| 2009 | 80 |
| 2010 | 100 |
| 2011 | 100 |
| 2012 | 100 |
| 2013 | 103 |
| 2014 | 100 |
| 2015 | 100 |
| 2016 | 116.5 |
| 2017 | 95 |
| 2018 | 130 |
| 2019 | 114 |

**Continued**

**TOTAL/AVERAGE** 79

[a]I include all turbines with full confidence values in hub height from 2000-2019 (n = 49,105).

## H. Turbine Rotor Diameter and Swept Area (1999-2019)

| YEAR | AVERAGE ROTOR DIAMETER (metres; full certainty)[a] | STANDARD DEVIATION | AVERAGE TOTAL SWEPT AREA ($metres^2$; full certainty)[b] | STANDARD DEVIATION |
|---|---|---|---|---|
| 1999 | 48.22 | 3.08 | 1833.71 | 195.30 |
| 2000 | 47.15 | 8.18 | 1798.27 | 598.58 |
| 2001 | 50.36 | 6.35 | 2023.83 | 549.64 |
| 2002 | 52.48 | 8.97 | 2226.36 | 813.07 |
| 2003 | 68.36 | 8.57 | 3727.21 | 885.81 |
| 2004 | 62.11 | 13.89 | 3170.71 | 1307.07 |
| 2005 | 74.78 | 9.33 | 4460.39 | 904.72 |
| 2006 | 76.71 | 10.76 | 4711.93 | 1192.97 |
| 2007 | 78.70 | 9.11 | 4929.53 | 1099.01 |
| 2008 | [illegible] | [illegible] | [illegible] | [illegible] |
| 2009 | 81.36 | 8.42 | 5254.04 | 1039.99 |
| 2010 | 84.22 | 7.67 | 5617.48 | 1024.65 |
| 2011 | 88.92 | 8.93 | 6272.06 | 1196.47 |
| 2012 | 93.62 | 10.65 | 6972.71 | 1488.44 |
| 2013 | 96.87 | 9.15 | 7435.97 | 1178.05 |
| 2014 | 99.59 | 7.40 | 7832.87 | 1131.63 |
| 2015 | 102.29 | 7.98 | 8267.02 | 1246.57 |
| 2016 | 108.26 | 7.57 | 9250.39 | 1267.75 |
| 2017 | 112.99 | 7.08 | 10066.30 | 1204.18 |
| 2018 | 115.96 | 8.09 | 10611.66 | 1489.73 |
| 2019 | 122.63 | 7.18 | 11850.43 | 1374.05 |
| **TOTAL/AV** | 90.81 | 19.14 | 6764.93 | 2654.08 |

**ERAGE**

[a]I include all turbines with full confidence values in rotor diameter and total swept area (n = 51,035)