2020 Wind Energy Update

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January 2020

1. Introduction

The last papers I published with similar subjects to this one were in August and September of last year (2019). I have listed these below with links and brief descriptions, just in case some readers are looking for specific content that might be covered in one of these.

California Offshore Wind: This paper covers early-stage activity on the California coast.

https://www.energycentral.com/c/cp/california-offshore-wind

Recent Developments in Storage, Wind and PV: This post focused on large PV, wind and storage projects in the U.S. Also, recent news that impacts the cost of battery energy storage systems (BESS), and we started this paper with this subject.

https://www.energycentral.com/c/cp/recent-developments-storage-wind-and-pv

Off-Shore Wind Update: This two-part series where the first part focused on the positive political moves in many states on the U.S. East Coast, and part 2 focused on off-shore projects in this region, the latest turbine designs.

https://www.energycentral.com/c/cp/shore-wind-update-%E2%80%93-part-1

https://www.energycentral.com/c/cp/shore-wind-update-%E2%80%93-part-2

This paper contains several subjects. It starts with some "grand challenges" that wind power will face in the future. Following that we will briefly review technology improvements that have been made to small wind turbines. Finally we will review major projects throughout the world. This paper has gone over my normal 3,000 word limit, but not so much that I would consider splitting it.

2. Grand Challenges and Opportunities

The contents of this section are primarily drawn from one source referenced here[1], and a second source, here[2], strongly contributed to the first.

Globally, there were just over 51 gigawatts of new wind installations in 2018 and more than half a terawatt of operating capacity. The world's energy producers now invest approximately $100 billion per year in wind energy.

However, one of the world's largest energy consultants, DNV GL predicts that wind energy demand and the scale of deployment will grow by a factor of 10 by 2050. In spite

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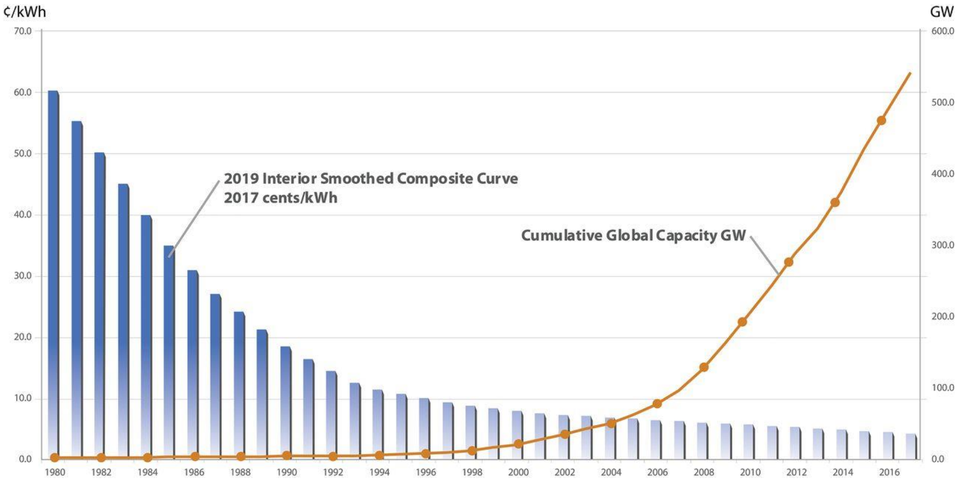
[1] Paul Veers et al, Science, "Grand challenges in the science of wind energy", 25 Oct 2019, https://science.sciencemag.org/content/366/6464/eaau2027

[2] Katherine Dykes et al, National Renewable Energy Laboratory (NREL), "Results of IEA Wind TCP Workshop on a Grand Vision for Wind Energy Technology", Prepared for the International Energy Agency Wind Implementing Agreement, April 2019, https://www.nrel.gov/docs/fy19osti/72437.pdf

of dramatic cost reductions in wind energy in the past (see chart below), major additional advancements are required to support this expansion.



Data per Global Wind Energy Council, and the American Wind Energy Association, chart from ref. 1

For the U.S. and other capitalistic countries, a major incentive to further deployments is continued reductions in levelized cost of energy (LCOE, as shown in the above chart) and also reductions of LCOE for storage to mitigate intermittence. Also off-shore wind is much less intermittent than on-shore, so much of the required expansion will use this variant.

Defining the financial and transmission infrastructure to allow the flow of remote sources of windpower across large areas (with typically different wind conditions) can also mitigate intermittence. In the future wind energy is projected to contribute one-third to more than one-half of consumed electricity, and the above infrastructure will support this.

Also in the future windpower and solar will offer very low cost energy. As we pointed out above, using storage and other methods will allow this to serve current consumption patterns, but using extreme time of use, and real-time energy pricing will allow consumers to develop use-pattern flexibility that takes advantage of the lowest costs. Late night and early morning electric vehicle charging is one element of this, as are consumers providing their own storage.

Before exploring future challenges below, we will look at another major innovation that has been made in wind turbine design, the blades (see figure below).

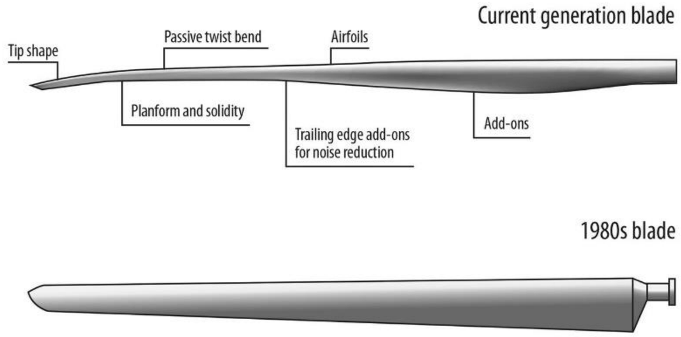


Figure from National Renewable Energy Laboratory (NREL) based on a concept by Henrik Stiesdal and Kenneth Thomsen (Siemens Gamesa)

"Some key innovations include higher tip speeds to reduce torque and minimize drivetrain weight; higher speed and high-lift airfoils for a more slender, lighter blade; and innovative tip shapes to mitigate noise. Innovations over time have led to modern blades that are 90% lighter than the 1980s blade simply scaled to current lengths. Examples include aero-elastic tailoring, which passively reduces the loads through coupling blade bending and twist; thicker flat-back airfoils, which enable improved aerodynamic performance …; add-ons such as vortex generators and flow fences; and a variety of manufacturing improvements.[1]

"[Future] *research challenges that are critical to realizing the full potential of wind energy stem from the complex and highly coupled phenomena that cross many physical and temporal scales relevant to wind energy and the broader power system. To extract maximum value at minimum cost while maintaining power system reliability and resiliency, it is important to look from global weather phenomena to regional weather activity to complex local flows, and ultimately, to the responses of the turbines within the power plant* (a.k.a. project, figure below)*. At the same time, the behavior of the wind resource varies greatly by location, as the wind resource behaves differently offshore, across plains, and over mountains. Moreover, a fleet of wind power plants must be in sync with the demands of power system operators as well as consumers at time scales ranging from the sub-second to the decade."*

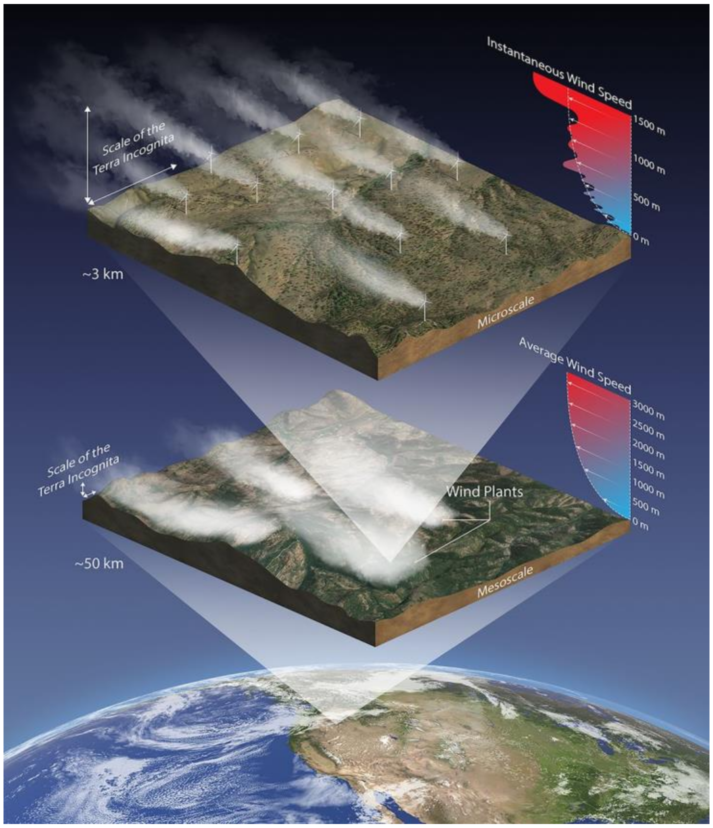


Illustration: Besiki Kazaishvili, NREL

2.1. Understanding Wind Flow Physics

In the above figure "microscale" is the scale of a single wind farm (a.k.a. plant or project), "mesoscale" is the scale of mutable nearby wind farms.

Wind over (1) hilly and/or mountainous land, (2) flat lands, and (3) large lakes or oceans obey completely different rules of flow. These also vary during the day and night, and in different seasons. Current weather simulation (modeling) systems are not really suited to model this flow, either at a microscales or mesoscales. On land, both of these scales (referred to as the surface layer) are where obstructions such as trees, buildings, hills, and valleys cause turbulence and reduce the speed of the wind. For large bodies of water, both waves and nearby land masses also strongly affect wind speeds.

"The mesoscale and the microscale are numerically modeled in fundamentally different ways, thereby making the assessment of atmospheric effects on wind plants that span these scales extremely difficult. The mesoscale processes, which influence local weather, are on the order of 5 to hundreds of kilometers in size and are typically modeled using grid spacing of 1 to 10 km. Microscale processes, the phenomena that drive wind turbine and plant behavior, extend well below 1 km and have grid spacing between 5 and 100 m horizontally. Vertically, microscale model resolution may go to within a few meters of the surface, but the flow is treated as an average over the horizontal grid spacing, making resolution of flow details that affect a wind turbine impossible…"[1]

Microscale simulation will require a three-dimensional grid that allows three-dimensional wind-flow. Also this flow will be affected by the wind turbine designs, which keep changing, evolving to larger turbines and more efficient blade designs. New generations of turbine designs are introduced every few years. Also repowering projects extend blade lengths and shapes, and these occur more often (every five to ten years) than complete turbine replacements.

"Atmospheric phenomena that span approximately 1.5 to 0.5 km exist at the interface of mesoscale and microscale processes. This zone, dubbed the "terra incognita" (unknown territory) [in the above figure], *spans atmospheric processes and their respective physical models of fundamentally different character and understanding…*[1]

"The scale that characterizes the terra incognita has become increasingly important as the economics associated with wind turbines and plants have pushed blade tip heights and rotor sizes to 200 m, with expectations for even larger sizes in the future. At this scale, wind turbines are affected by turbulent flow features that are driven by mesoscale phenomena and play out within the terra incognita. Specifically, the spatial scale of these atmospheric processes begins to match the scale and height of the turbine rotor, and accordingly, the physics of this poorly understood zone becomes critical to ensuring optimal design and performance of individual turbines and entire wind power plants."

The existence of wakes from individual turbines and wind farms (shown as white-shaded areas in the above figure) further complicate the requirements for future models. Wakes have been explored with mesoscale modeling tools as well as measurements in existing wind farms but are not well-understood.

2.2. Future Larger Turbines

State of the art wind turbines are already pretty monstrous:

"…wind turbines have grown to become the largest flexible, rotating machines in the world—massive civil engineering structures that must operate continuously for 20 years or more (a typical design and financial amortization period) under constant complex loading. Blade lengths are approaching 80 m and towers are growing well above 100 m

for maximum tip heights, often exceeding 200 m, equivalent to a building more than 60 stories high. To put these dimensions in another context, three of the largest passenger aircraft, an Airbus A380-800s with a wingspan of 80 m, could fit within the swept area of one wind turbine rotor."

The largest wind-turbine currently is GE's Halide X 12-MW turbine with a 220-meter rotor. One unit is currently installed and operating – see section 4.2.

"The larger turbines of the future would operate partly above the often-studied atmospheric surface layer where they could encounter substantial variation in inflow because of poorly characterized factors, such as shear (vertical differences in wind speed), veer (vertical differences in wind direction), and wakes of upstream turbines. The challenge lies not only in understanding the atmosphere but in deciphering which factors are critical in both power-generation efficiency and structural safety. The design perspective must increasingly consider the interdependence of the meso-to-microscale transition and the turbine dynamics to assess, accurately predict, and manage loads.[1]

"The aerodynamic assumptions themselves are increasingly being questioned. The interaction between a highly variable inflow and the unsteady aerodynamics of the moving and deforming blades is pushing the limits of current theory. Recent experiments at the largest scales now possible by the Danish Technical University (65) suggest that the interaction of these large blades with turbulence of different intensities could be affecting the fundamental lift and drag characteristics of the airfoil, which is not a consideration at smaller scales."

However, in addition to greatly improved modeling tools (as described in the prior subsection), the structural design elements of the turbines must be optimized for long-term durability and efficiency, but these tasks strongly rely on having adequate simulations.

2.3. Integration of Wind Farms into Future Electricity Grids

I'm most familiar with California, and further the modeling that California Independent System Operator (CAISO) does of the entire western grid. The good news about this is that, in conjunction with its role managing the Energy Imbalance Market and as Reliability Coordinator West, CAISO does a very thorough job of modeling the western grid. Also the western grid has extensive renewables including wind power, and the capacity of these renewables are traded across the western grid. See the paper linked below and the other paper: "CAISO part 6" linked therein.

https://www.energycentral.com/c/iu/caiso-part-6a-%E2%80%93-expansion-update

The bad news is that as the overall wind capacity increases in future years to decades, and very large turbines (compared to current turbines) are integrated into the wind farms, there could be many undesirable side-effects. These should be understood in the near future and strategies to mitigate them developed. The only way to do this is to (1) understand what these side effects might be (both of the above challenges feed unto this) and (2) enhance existing grid modeling tools to simulate and mitigate these.

"As a first step, researchers must solve challenges related to wind plants by providing sufficient control authority to serve an expanding set of functionalities. Growing experience with wind plants is revealing the complexity of managing systems with hundreds of stochastically (randomly) *driven individual wind turbine agents. Recent research highlights the possibility of not only maximizing energy production but also*

managing the flow field to increase system performance. By probing the collective data available during real-time operation, new opportunities for power plant control are emerging. Greater comprehension of the wind flow and dynamics enables real-time characterization of the plant operational state and the ability to control the flow and turbine responses in the short term. Innovative controls could leverage the attributes of the machines to supply ancillary services (e.g., the rotational inertia of the blades could be tapped to ride through grid faults, or the distributed power electronics in the converters connected to the generators could be used to manage grid requirements). For example, recent work has used such integrated modeling approaches to investigate the potential for active power control from wind power plants."[1]

3. Small Wind

The last time I included a thorough section on small wind turbines was over two years ago. See the paper linked below, section 3. These have largely been relegated to niche applications, where neither large wind turbines nor photovoltaic arrays are practical, and the conditions are suitable for small wind turbines.

https://www.energycentral.com/c/pip/large-wind-small-wind-and-future-wind

However, this minor role for small wind has not kept the U.S. Department of Energy from continuing to invest in their development, and this investment has resulted in some improvement in their economics.

Photo Courtesy | Bergey Windpower

"Pictured above is the Excel 15 wind turbine. This turbine is anticipated to be 40% more efficient than Bergey's 10 kW turbine, produce 85% more energy, and be sold at a similar price point."[3]

4. Major Global Projects

It has been about four months since I reviewed major off-shore projects along the U.S. East Coast (referenced in the Introduction). A few months before that, I did a review that included U.S. onshore projects (link below).

https://www.energycentral.com/c/cp/wind-power-update

[3] https://www.energy.gov/eere/success-stories/articles/eere-success-story-distributed-wind-competitiveness-improvement

In this update I will focus on large projects of all types (onshore and offshore, greenfield and repowering) that are announced to deploy anywhere in the world, but only by the three leading turbine vendors in the U.S. (GE, Siemens Gamesa, and Vestas). Also, I'm running out of words for my normal 3,000 word limit, so the descriptions below will be brief, but will include a reference (link only).

4.1. Siemens Gamesa (SGRE)

Walney Extension: This 659-megawatt offshore park is located in the Irish Sea, off the coast of England. Orsted is the developer. This development contains 40 MHI Vestas 8 MW turbines and 47 SGRE 7 MW turbines.[4]

Dominion Energy: Selected SGRE as the preferred supplier for their planned 2,600 megawatts of wind development off of the coast of Virginia. SGRE was the turbine supplier for Dominion's pilot project using two 6 MW turbines.[5]

Hywind Tampen: This project off the coast of Norway will use 11 SGRE 8.0 MW turbines. This is the second Hywind floating wind turbine project, and the first, off the coast of Scotland, also used SGRE turbines.[6]

Hollandse Kust Zuid: SGRE and Swedish energy company Vattenfall upgraded an existing contract to supply 10 MW turbines for the Dutch 700MW HKZ 1 & 2 and the 760MW HKZ 3 & 4 wind farms. These will now use 11 MW turbines. The contract will be to supply a quantity of 134 turbines.[7]

Rolling Hills: MidAmerican Energy Co. has selected SGRE as supplier and installer for this 429-megawatt wind facility located in Iowa. This repowering project will use 163 SG 2.7-129 and 18 SWT-2.3-108 turbines.[8]

West Bakr, Egypt: This 250 MW project is owned by Lekela. SGRE will install 96 SG 2.6-114 turbines through a turnkey EPC contract.[9]

TBEA Group Changji Project China: SGRE will install 42 turbines with each rated at 4.8 MW, as well as provide operation and maintenance services for five years at this 200 MW project. This is the second order that SGRE has received from TBEA.[10]

Neart na Gaoithe, Scotland: SGRE has announced the firm order to supply wind turbines for this 448-MW offshore project, being developed by EDF Renewables in Scotland. The company will install 54 of its SG 8.0-167 DD turbines.[11]

Orsted Formosa 1: Ørsted is developing this 128 MW offshore wind farm in Taiwan. This project has two phases: Two SGRE 4 MW wind turbines were installed in October

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[4] https://www.cpexecutive.com/post/worlds-largest-offshore-wind-farm-begins-operation/
[5] https://finance.yahoo.com/news/dominion-energy-selects-siemens-gamesa-141900493.html
[6] https://steelguru.com/power/siemens-gamesa-to-install-turbines-at-hywind-tampen-wind-project-in-norway/551975
[7] https://reneweconomy.com.au/siemens-gamesa-sends-newly-launched-11-mw-offshore-turbine-to-dutch-project-24490/
[8] https://www.cpexecutive.com/post/siemens-gamesa-to-repower-429mw-iowa-wind-farm/
[9] https://steelguru.com/auto/siemens-gamesa-helps-egypt-250-mw-west-bakr-wind-project/550779
[10] https://steelguru.com/power/siemens-gamesa-grow-its-business-in-china/550221
[11] https://www.powermag.com/press-releases/siemens-gamesa-celebrates-strength-of-the-wind-with-firm-448-mw-scottish-offshore-order/

2016 for the first phase and the second phase, completed in October 2019, includes 20 SGRE 6 MW wind turbines. [12]

Alfanar Global Development, India: SGRE has been awarded a contract to supply 206 SG 2.2-122 wind turbines with a total capacity of 453MW for two wind farms in the Bhuj district in the Indian state of Gujarat, alongside Saudi Arabia's Alfanar Global Development.[13]

Gulf Wind: Pattern Energy Group Inc. announced on Jan 6 that it has closed financing and started construction on the repowering of its Gulf Wind facility located in Kenedy County, Texas. Repowering this facility will consist of removing the current wind turbines and replacing them with 118 new SGRE SWT-2.3-108 turbines, which will generate 271 MW of capacity. A majority of the energy from this facility will be sold via a 20-year power purchase agreement with Austin Energy.[14]

4.2. GE Renewable Energy (GERE)

Maasvlakte-Rotterdam, the Netherlands: Dutch utility Eneco has started to purchase power produced by the prototype of GERE's Haliade-X 12 MW wind turbine. The energy produced by the Haliade-X is being sold by Future Wind. The turbine has a height of 260 meters and a blade length of 107 meters.[15]

Dogger Bank Wind Farms will become the world's largest offshore wind farm when built. Today the developers unveiled GERE as its preferred turbine supplier. This project will use the 12 MW Haliade-X turbines. Dogger Bank Wind Farms is a 50:50 joint venture (JV) between Equinor and SSE Renewables. The overall wind farm comprises three 1.2 GW projects located in the North Sea, approximately 130km from the UK's Yorkshire Coast.[16]

China: With 2019 drawing to a close, GERE has now secured 1,215 MW in orders or commitments in the onshore wind sector in China for 2019. Commitments include:[17]

- An order for 33 2.7-132 turbines for HECIC's 100 MW Balagedai II Wind Farm in Inner Mongolia, scheduled for completion in 2020
- An order for 286 2.5-132 turbines for Huaneng's 715 MW Puyang Phase I and II wind farms in Henan, scheduled for completion in 2020
- An order for 114 2.5-132 turbines for Shenzhen Energy Corporation's 285 MW Yangzhou and Pizhou wind farms in Jiangsu, scheduled for completion in 2020

[12] https://steelguru.com/power/rsted-inaugurates-offshore-wind-farm-in-taiwan/552513
[13] https://www.constructionweekonline.com/257755-siemens-gamesa-saudis-alfanar-to-supply-wind-turbines-in-indias-gujarat
[14] https://www.prnewswire.com/news-releases/pattern-energy-starts-construction-on-repowering-of-gulf-wind-facility-in-texas-300981309.html
[15] https://www.cnbc.com/2019/12/18/prototype-of-ges-huge-wind-turbine-starts-sending-power-to-utility.html
[16] https://www.genewsroom.com/press-releases/ge-renewable-energy-haliade-x-turbines-be-used-dogger-bank-wind-farms
[17] https://www.genewsroom.com/press-releases/ge-announces-1215-mw-onshore-wind-total-wins-year-china

- Public tender award for 46 2.5-132 turbines for Huaneng's 115 MW Mianchi and Zhenping wind farms in Henan, scheduled for completion in 2020

Serra da Babilonia, Brazil: GERE announced that it has been selected by Rio Energy for the production, delivery, installation, and commissioning of 30 Cypress onshore wind turbines, that range from 4.8 MW to 5.1 MW. This is the second contract signed by GE and Rio Energy. The turbines are expected to be installed in the last quarter of 2020.[18]

Blåbergsliden wind farm, Sweden: - GERE has been selected by Holmen as the wind turbine supplier for the 143 MW project, which will use 26 Cypress onshore wind turbines. This represents GERE's second Cypress-equipped wind farm in Sweden. The deal includes a 25-year service contract. The construction of the project will commence shortly and will be fully commissioned and operational by the end of 2021.[19]

4.3. Vestas

Even though Vestas apparently receives large orders, they often do not identify the customers, especially for U.S. projects, whereas other manufacturers do this. Also many of their projects are under 100 MW, making them ineligible for this paper. Immediately below there are links to some press releases where they describe these projects:

https://renews.biz/57184/vestas-books-320mw-in-us-and-china/

https://www.rechargenews.com/wind/vestas-year-end-order-joy-spans-three-continents/2-1-730857

Walney Extension: See the first entry under section 4.1

Wind Energy Development Fund, Russia: Vestas has been awarded an order for 252 MW for three wind energy projects in Russia from Wind Energy Development Fund. The projects will comprise 60 V126-4.2 MW wind turbines. The contract includes supply, installation and commissioning of the wind turbines, as well as a 15-year Active Output Management service agreement. First operation is planned in the fourth quarter, 2020. [20]

Northwester 2, Belgium: The first turbine has been installed at the 219 MW Northwester 2. This is the first offshore wind park to use V164-9.5 MW turbines from MHI Vestas. The project will consist of 23 V164.9-5 MW turbines 50 km off the coast of Ostend. Northwester 2 is the fourth collaboration between Parkwind and MHI Vestas in Belgian waters, soon providing a combined output capacity of 765 MW.[21]

[18] https://www.genewsroom.com/press-releases/ge-announces-agreement-provide-30-cypress-turbines-rio-energy-brazil
[19] https://www.genewsroom.com/press-releases/ge-renewable-energy-supply-turbines-sweden-latest-cypress-equipped-wind-farm
[20] https://steelguru.com/power/vestas-secures-252-mw-order-for-three-wind-energy-projects-in-russia/554600
[21] https://steelguru.com/power/mhi-vestas-installs-first-v164-9-5-mw-turbine-at-northwester-2/554385