Compare Industrial Development Between China and America: Centered on Wind Turbine Production

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Abstract. With the impact of climate change on the planet, wind energy has become a key part of the shift from fossil fuels to clean energy. Over the past decade, the wind energy industry has experienced rapid growth, with the production of wind turbines expanding to meet the growing demand. This expansion is not only a testament to advances in wind turbine design and manufacturing technology, but also a global commitment to increasing the share of renewable energy in the overall energy mix. On the one hand, wind energy, as a renewable energy source, plays a crucial role in reducing carbon emissions as it is capable of generating electricity without producing harmful emissions or depleting natural resources. Unlike fossil fuels, wind energy is abundant, widely distributed and sustainable in meeting the world's energy needs. Wind energy helps to reduce carbon emissions, improve air quality and minimize water consumption compared to conventional methods of power generation.

Keywords: wind energy, clean energy, wind turbines, manu-facturing technology.

1. Introduction

In recent years, the global demand for renewable energy has surged, driven by both policy initiatives and market dynamics. Governments worldwide are setting increasingly ambitious renewable energy targets, providing incentives for wind farm development, and investing in the necessary grid infrastructure to support wind power. Furthermore, as the cost of wind energy continues to decline, it is becoming more competitive with traditional energy sources, which further accelerates its adoption. This trend highlights the growing recognition of renewable energy as a viable solution to the dual challenges of energy security and climate change.

Against this backdrop, the global wind energy market will play a pivotal role in shaping the future energy landscape. Continuous improvements in wind turbine technology, coupled with the expanding global wind energy capacity, suggest that wind power will remain a key player in the transition to a low-carbon economy. This introduction paves the way for a closer look at what's influencing the worldwide wind energy market, the progress in wind turbine technology, and the wider effects of relying more on renewable energy sources.

In the following thesis, we'll mainly focus on comparing the US and Chinese wind turbine production industries to examine the probable reasons that account for the Chinese leading figure in this sector. According to the background information, wind turbine production sector's developing situation varies from country to country, and it is beneficial for constructing the future developing guidance of the industry.

Moreover, Onshore wind is a proven, mature technology with an extensive global supply chain. Onshore wind has evolved over the last five years to maximize electricity produced per megawatt capacity installed By comparing the wind power industries in China and the United States, can be better understood in the research and development of wind power technology, policy support, market application and other aspects of the two countries, which can provide useful reference and inspiration for the development of wind power industries in both countries, for example, China can improve its own wind power technology by learning from the U.S. experience in technological innovation and efficiency , and the U.S. can also benefit from China's huge market size and cost advantages. Such comparative analysis is conducive to promoting the cooperation and exchanges between the two

countries in the field of wind power generation, to jointly promote the development and application of global wind power generation technology.

Through reading this paper, the reader can gain valuable insights into the current status as well as the future outlook of the wind turbine industry in China and the United States.

For one thing, we'll abstract authentic data and genuine cases to compare and contrast the differences in wind turbine production industry between the US and China. Specifically, We'll use SWOT analysis in specific manufacturers that occupy the leading position of producing wind turbine in their domestic market, by introducing their market share, productivity, and manufacturing scale; we'll obtain an agglomeration of information about their producing capacity, which can reveal their accordingly manufacturing capacity.

Additionally, the paper will outline current policies that support recent innovations and the various forms of financial aid provided to leading companies. Following this, the analysis will focus on the specific challenges and constraints faced by the U.S., while also comparing these with China's distinct advantages, which stem from its robust industrial development. This approach allows for a comprehensive evaluation of strategies and potential shortcomings that should be taken into account in the progression of industry.

What's more, by presenting amendments that accounted for each countries' current problems, we'll anticipate the future states rationally, and conclude with our personal viewpoints of the industries' development between the US and China.

2. Case Description and Start of Analysis on the Problem

2.1. U.S. Wind Turbine Production Status

Today, the United States is the second largest producer of wind turbines globally, holding a ~7% share of the global wind turbine production market. Wind is currently the 4th largest renewable energy source in the country, with a total produced and installed capacity of ~149 gigawatts, providing enough energy to power ~46 million homes.

Since 2005, an average of ~3,000 onshore wind energy units have been produced in the United States each year. This produced capacity is spread out across 41 states, with states towards the middle of the country having the highest numbers installed. Texas currently makes up more than 20% of its total capacity as the leading state, having 239 active wind energy-related projects that have produced more than 15,300 wind turbine units to date. As of 2023, offshore wind in the United States has a total capacity of 52.6 gigawatts under development, estimated to be completed and operational soon.

Though the exact cost of producing wind energy units varies based on several factors in different states, costs generally hover around ~$1 million per megawatt of capacity. Producing the average onshore commercial turbine ranges from $2-4 million, typically with 2-4 megawatts capacity each. Offshore turbines tend to cost much more to produce and install as the installation process is more difficult and they must be made to withstand rougher conditions at sea. These can cost upwards of $10 million per unit to produce, having capacities ranging from 6-12 megawatts.

2.2. Policies In U.S.

The Inflation Reduction Act (IRA) was signed by President Biden in 2022, marking the most significant action that Congress has taken on clean energy and climate change in the country's history. This act mainly focuses on supporting the renewable energy sector through government spending and providing additional capital to firms in the form of production and investment tax credits. Tax credits are government-issued credits that companies are able to use to offset tax, allowing them to have access to more capital for innovation and expansion. Production tax credits are given to companies based on the number of kilowatt hours of electricity they are able to produce, encouraging them to spend more on producing renewable energy units. Investment tax credits are given to firms based on the amount of capital they invest in renewable energy development. This incentivizes companies to invest more in the industry, pushing up innovation and efficiency of production.

The IRA extends the existing renewable energy production tax credits for wind energy and turbine production through 2024, which previously expired at the end of 2021. Eligible wind projects that satisfy the minimum wage requirements receive an inflation-adjusted production tax credit of 2.6 cents per kWh for the next 10 years. Though this tax credit doesn't directly affect the production of wind turbines, the incentive to produce more electricity using wind energy encourages more wind turbines to be produced, indirectly supporting the wind turbine production industry. For projects beginning construction by the end of 2024, the IRA also provided up to 30% of the cost of installed equipment in investment tax credits. This is a significant reduction in the cost of production and would allow firms to significantly up their production efficiency.

2.3. China Wind Turbines Production Status

Like in the rest of the world, Chinese development of turbine production first began in the 1980s. However, the industry didn't see much development as coal had been the dominant energy source at the time, being both more efficient as well as less expensive. This was until climate change really began gaining traction in the late 1990s, and the Chinese government began to recognize the significance of the renewable energy industry's role in solving this problem. It led officials to eventually implement the country's National Renewable Energy Law in 2005, marking the beginning of the industry's development in China.

Since then, the Chinese wind turbine production industry has grown more than 340 times, from 1.27 gigawatts of capacity produced in 2005 to more than 440 gigawatts of capacity produced in 2023. This represented a ~65% share of the global wind turbine production market, making China the 1 producer of wind turbines globally.

Costs of producing wind turbines in China have seen a significant decline over recent years. In 2018, the average cost per megawatt of capacity installed was ~$700,000. Since then, government subsidies and additional technological improvements have continued to push the cost of production down, and as of 2022, the average cost of Chinese wind turbines sits at ~$350,000.

2.4. Policies In China

China's government began developing its wind industry early on. Though early policies weren't as significant, the fact that China began its development in the industry earlier than most other countries played a crucial role in building its foundation as a global leader today.

China's first significant renewable energy policy was the National Renewable Energy Law in 2005. This marked the beginning of China's renewable energy development, setting targets, implementing the feed-in tariffs, and providing financial support to all non-fossil fuel projects. At the same time, one of the main goals that the Chinese government hoped to accomplish was to in a way, forcefully integrate renewable energy into the country's energy mix by requiring electricity grid operators to purchase all available energy within their coverage area that are generated through renewable sources. This law laid the foundation for China's renewable energy development, utilizing a more aggressive approach to position China in a leading position.

2.5. Comparison

Whether it is in the form of subsidies or tax reductions, we see that both countries' governments are generally supportive of the wind turbine production industry and are giving relevant firms support financially. The Chinese government is taking a more aggressive approach in terms of policies that support the wind turbine production industry. Apart from providing financial support to firms in the form of subsidies, the Chinese government forcefully integrates the industry into the country's infrastructure by setting market requirements and implementing feed-in tariffs. This is a viable option for China as the country is run by a more authoritarian political system where the government has more control of the market. This makes it possible for the government to "pick winners" and provide more support to certain industries. On the other hand, it is harder for the government to have as much of an impact in the United States as the country's market ideology follows a more laissez-faire

approach, focusing more on the private sector without as much government intervention (Zhang et al., 2020). Therefore, any attempt to aggressively push the industry in the United States would be subject to criticism by opposing political groups and would not be the ideal choice.

3. Continuation of Analysis on the Problem and Suggestions:

From solely longevity of wind turbine production development, the US, without doubt, can be regarded as precursor of this industry, but in fact, the leading position was taken by China, intriguingly. Moreover, from singular natural wind energy resources, according to Wang (2011), Chinese onshore wind energy technical exploitable quantity is $(2.97\times10^8 + 23.8\times10^8)$KW, while the offshore potential theoretic exploitable data is 7.58×10^8; on the other hand, according to *The US National Renewable Energy Laboratory*, the US's exploitable wind energy is about 11×10^8KW, and its offshore wind energy potential is 4.15×10^8KW, so it is difficult to declare a more competitive one due to the owned resources. So, this unexpected result, that said, should be influenced by many other factors rather than single developing time-scale (Bošnjaković et al., 2022).

From the policy perspective, the divergent regime can account for the current situations of this factor, partially. In China, for one, the development of the wind turbine production and whole wind energy industry was mainly influenced by the central government's attitude. Historically, before the central government created *The National Energy Leading Group* and implemented *2005 Renewable Energy Law*, the Chinese government lacked the most distinguished leading institution to guild the wind energy development, and the loose policies made the local governments mean to get rid of the control by the central government, for example, *the 49.5MW Phenomenon*: according to the correlated legislation, only those wind turbines' capacity exceed the 50MW should report to the central government to receive permissions, and those below the standard could be decided by the locals. In addition to Sufang Zhang (2013), according to a report from Sinohydro Engineering Consulting Group Corporation, it pointed out that in 2009, in 187 permitted wind farm projects, 111 of them are all 49.5MW. To solve the problem, the Chinese government published *2005 Renewable Energy Law*, which ensured wind energy will be compulsorily combined into the grid and its fully acquisition (Zhang et al., 2020). Then, the Chinese government instituted *The National Energy Commission* to collect scientific suggestions from the labs, supervise the local governments, and provide pinpoint suggestions to the local government. With the massive aids provided by the central government, Chinese wind turbine production sector can obtain a prosperous development. In America, on the other hand, according to Wu (2013), In the United States, renewable energy development is largely influenced by bipartisan political, federal and state politics. Specifically, with Wu's conclusion, When the president of the United States is a Democratic party, and both the House and Senate when the majority was Democrats, renewable energy grew rapidly; as president in the Republican Party, and when the majority of the House and Senate is Republican, renewable energy development in America is relative slow, or even backward (only when the two parties are equivocal, other factors become more important factor) (Energy Association, 2023).

For example, when the House and Senate were all occupied by the democrat in 1992, the US government published the famous *Energy Policy Act of 1992*, which emphasis on creating new taxes and direct subsidies for energy efficiency and renewable energy technologies. The main reason for the difference would be the distinct aims of the two parties, the Republicans want to increase their national wealth to boost their energy supplies, while the Democrats are more focused on controlling energy prices. And Li (2012)'s citation of Daniel Yergin: On energy and environmental issues, American's bipartisan system always like this, the Federal and State government often "fight" with each other. In other words, in the Federal government, it is much easier to reject a proposal rather than pass it, and the politicians will be influenced by the energy lobby groups from the oil and gas companies that holds great fortune and power, and the politicians are facing the winner takes all situations, so they may choose to shelve the renewable energy proposals like wind energy. On the other hand, the majority of people are mainly focused about their living conditions and more job

opportunities, so they will urge the state government to protect the environment (Zhang, Andrews-Speed, & Zhao, 2013). So the policies published by the different government are often controversial and meagre (Jin et al., 2014).

The market, for another, however, provides a counter effect than we simply thought. To be specific, backtracking the history of the innovation of the US wind turbine production market and renewable energy market, we can trace to the 1990s. Thus, the market-oriented electricity rate is much more advanced than China, but this caused the more competitive price in the market, which caused the profit margin to decline, and discouraged motivation of the investors. As Wu (2013) concluded: Marketization based reforms do not necessarily benefit from wind power of such renewable energy industry, which is like a decentralized competitive grid that is not necessarily conducive to the power transmission and distribution industry development. Besides, the energy lobby groups consisted by the petroleum, nuclear, gas, and coal energy industries, and their representations who taken most of the leadership in White House, Commercial Ministry, Energy Ministry, and Environmental Protection Agency. Accordingly, the innovations of facilities like wind turbines are hindered by these capitals; even though the wind energy production realm has its own lobby groups, and the PTC, policy that allow wind turbine production receive tax credit, was admitted by the US government, under the overwhelming pressure addressed by the traditional energy industry, the wind turbine production still encountered many obstacles in its way to thrive. China, on the other hand, the representational group of wind energy is CREIA, but it does not have much of the contribution to this sector, since the needed capital for entering the wind energy sector and wind turbine production are tremendous, it's hard to witness private companies compete in this industry. So the marketable structure is mainly dominant by the government in China, as Sufang Zhang (2013) stated, wind power SOE in China occupied nearly 80% of the wind turbine share in China; moreover, in order to be more competitive during the invitation for bids, those SOE typically offer a very low price for bids, a report stated that during the four-year-period bid, the final price was 0.373-0.519yuan per KW, while the estimated economically feasible one would be 0.566-0.703yuan per KW. The losses of these companies in these projects will be compensated by other projects they manage, while these bids cannot be afforded by the foreign companies like GE or Vestas, and thus the wind turbine production market in China has become monopoly that excluded other exotic companies, which only have 14% of the market share. Overall, the American wind turbine production industry is more dependent on market than China. Since China has fixed wind electricity price stated by the government, the US implemented RPS and PTC, which let the electricity price will be fluctuated by the market, and thus discouraged the investors to anticipate the future outlook of the industry. So the investment in this sector in the US are not potent enough to make the industry thrive (National Department of Energy, 2023).

4. Discussion

In order to improve the global competitiveness of the wind turbine industry, it is recommended to strengthen R&D investment and technical cooperation. Specifically, enterprises should increase R&D investment in new materials, intelligent control systems, and high-efficiency fan design (Wu, 2013). Through cooperation with universities, research institutes and other industry-leading enterprises, they can accelerate technological breakthroughs and shorten the application cycle of new technologies. In addition, promoting transnational technical cooperation and exchanges will help integrate global innovation resources and further improve the technical level and market adaptability of wind turbines (Renewable Energy Agency, 2023).

Optimizing the supply chain management of wind turbines is a key strategy to reduce production costs and improve product competitiveness. It is recommended that enterprises adopt advanced supply chain management technologies, such as Internet of Things (IoT) and big data analysis, to monitor all links in the supply chain in real time, so as to improve efficiency and reduce waste. Meanwhile, establishing closer partnerships with suppliers for joint sourcing and production planning can help reduce raw material costs (Wang & Shi, 2012). In addition, companies can consider localized

production to reduce transportation costs and tariffs and improve supply chain flexibility and responsiveness (Saidur et al., 2010).

In order to expand market share, U.S. wind turbine manufacturers should actively seek international market expansion and cross-border cooperation. First, companies can enter emerging markets such as Asia, Africa, and Latin America by establishing joint ventures or strategic partnerships to capitalize on the strong demand for renewable energy in these regions. Second, companies should participate in the development and implementation of international standards, thereby increasing their competitiveness in the global market. Finally, by working with international organizations, government agencies and non-governmental organizations (NGOs) to promote the use of wind turbines globally, they can enhance their brand influence and gain more market opportunities (Kerr et al., 2024).

5. Conclusion

Both the United States and China have established significant wind turbine production industries, but with different approaches and challenges. China dominates the global market with a 65 percent share, driven by aggressive government policies, lower production costs, and a strong domestic supply chain. In contrast, the United States, benefiting from advanced technology and innovation, holds a 7 percent market share but faces challenges due to higher production costs, dependence on imported raw materials, and lower integration with global supply chains.The SWOT analysis highlights China's cost advantages and market dominance, while noting that the U.S. strengths lie in recent policy incentives (e.g., Inflation Reduction Act of 2022), U.S. efforts in technological innovation, and the U.S. ability to reduce the cost of production. Act), U.S. strengths in technological innovation, and potential growth opportunities.

Future research on wind turbines could go in several directions. First, it is recommended to focus on novel materials and manufacturing processes to improve the efficiency and durability of wind turbines. For example, lighter and stronger materials are explored, as well as improved designs to reduce wind resistance and increase power generation efficiency. Second, as wind turbines scale up, research into better integration of smart sensors and monitoring systems for real-time data analysis and predictive maintenance will help reduce operating costs and extend equipment life. In addition, due to the wide geographic distribution of wind farms, optimizing the performance of wind turbines in different environments and reducing their potential impact on the ecosystem will also be an important direction for future research. Finally, with the changes in the global energy market, research on how to better integrate and optimize the location of wind energy in the power network, especially in conjunction with the application of energy storage technologies and smart grids, is key to ensuring the long-term sustainable development of wind energy.

Looking to the future, the U.S. wind power industry has great potential for development and a bright future. The efficiency of wind turbines will continue to improve as technology advances and production costs continue to decrease, which will allow wind energy to occupy a more important place in the U.S. energy mix. Government supportive policies such as tax credits and investment incentives will continue to drive the wind energy industry and promote more innovation and investment. At the same time, U.S. companies are expected to capture a larger share of the global wind energy market by strengthening international cooperation and expanding into global markets. However, in the face of fierce international competition and the diverse needs of the domestic market, companies in the industry will need to continue to make technological innovations and improve efficiency in order to maintain a competitive edge. Overall, the U.S. wind power industry is at a critical stage of development, and its future development will have a profound impact on U.S. energy security and the realization of global climate goals.

Authors Contribution

All the authors contributed equally and their names were listed in alphabetical order.

References

[1] Bošnjaković, M., Katinić, M., Santa, R., & Marić, D. (2022). Wind Turbine Technology Trends. Applied Sciences, 12(17), 8653. https://doi.org/10.3390/app12178653

[2] Energy Association (2023) Wind has one of the greatest potentials to increase countries renewable capacity growth.https://doi.org/10.1016/j.rser.2014.02.025

[3] Jin et al. (2014) Wind turbine manufacturing industry in China: Current situation and problems

[4] National Department of Energy. (2023, August 24). U.S. Department of Energy Projects Strong Growth in U.S. Wind Power Sector. Energy.gov. https://www.energy.gov/articles/us-department-energy-projects-strong-growth-us-wind-power-sector

[5] Renewable Energy Agency (2023) https://ourworldindata.org/grapher/cumulative-installed-wind-energy-capacity-gigawatts?country=USA~CHNInternational

[6] Saidur, R., Islam, M. R., Rahim, N. A., & Solangi, K. H. (2010). A review on global wind energy policy. Renewable and Sustainable Energy Reviews, 14(7), 1744–1762. https://doi.org/10.1016/j.rser.2010.03.007

[7] Saidur, R., Rahim, N. A., Islam, M. R., & Solangi, K. H. (2011). Environmental impact of wind energy. Renewable and Sustainable Energy Reviews, 15(5), 2423–2430. https://doi.org/10.1016/j.rser.2011.02.024

[8] Sonia Kerr,Kevin Baxter,Vivien Lebbon,Mark Thomton,Hla Myat Mon (2024) China leads global wind turbine manufacturers' market share in 2023 https://www.woodmac.com/press-releases/2024-press-releases/global-wind-oem-marketshare/International

[9] The US National Renewable Energy Laboratory. (2018). WINDExchange. Energy.gov. https://windexchange.energy.gov/

[10] Wang, F., & Shi, R. (2012, June 1). Energy Sustainable Development Scheme in China. Https://Www.diva-Portal.org/Smash/Get/Diva2:563836/FULLTEXT01.Pdf.

[11] Wu, J. (2013, January 29). Renewable and Sustainable Energy Reviews. Https://Www.sciencedirect.com/Science/Article/Abs/Pii/S1364032113000166.

[12] Zhang et al. (2020) China in global wind powerdevelopment: Role, status and impact

[13] Zhang, H., Yang, J., Ren, X., Wu, Q., Zhou, D., & Elahi, E. (2020). How to accommodate curtailed wind power: A comparative analysis between the US, Germany, India and China. Energy Strategy Reviews, 32, 100538. https://doi.org/10.1016/j.esr.2020.100538

[14] Zhang, S., Andrews-Speed, P., & Zhao, X. (2013). Political and institutional analysis of the successes and failures of China's wind power policy. Energy Policy, 56, 331–340. https://doi.org/10.1016/j.enpol.2012.12.071