The Evolution and Practice of Offshore Wind Energy in China

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Abstract. Offshore wind power stands as a notable exemplar of environmentally friendly energy sources. Among global players, China emerges as a trailblazer in the realm of offshore wind energy, as evidenced by its remarkable aggregate capacity. This exposition delves into China's ongoing strides in offshore wind energy by dissecting its facets in terms of policy orientation, natural endowments, demographic dynamics, technological prowess, substantial investments, and pivotal subsidies. The elucidation of natural resources, population dynamics, fiscal commitments, and supportive subsidies serves to unveil the rationale underpinning China's resolute commitment to fostering this burgeoning industry. Through an insightful exploration of policy frameworks and technological innovations, this article cogently illustrates the trajectory of China's progress, delineating the present state of the offshore wind energy sector within its boundaries. Leveraging a tapestry of official governmental policies and pertinent scholarly literature, the narrative succinctly encapsulates the present developmental panorama and pragmatic implementation of offshore wind energy initiatives in China. It unequivocally asserts that China's endeavors in offshore wind energy are characterized by meticulous planning and a strong governmental mandate, thus positioning the industry for a promising trajectory of growth and advancement in the foreseeable future.

Keywords: Offshore wind power; clean energy; policy.

1. Introduction

Nowadays, the form of global warming due to excessive carbon emissions has become increasingly serious, countries are developing clean energy to mitigate carbon emissions. As a kind of clean energy, offshore wind energy has a development prospect that cannot be ignored. According to IRENA Renewable Capacity Statistics 2023, globally, the market size of offshore wind energy reached $10.9 billion in 2022 and will reach $28.8 billion in 2028, exhibiting a growth rate of 16.1% during the next 5 years [1]. Offshore wind refers to building turbines on the ocean and using them to generate electricity [2]. Unlike onshore wind farms, offshore wind energy farms are situated in coastal areas, making their electricity productivity speed more consistent and efficient. The potential of offshore wind energy has become an attractive option for countries striving to reduce their dependence on fossil fuels and combat climate change. In China, the development of offshore wind power is in the world's leading position. China has by far the most offshore wind capacity, which is 31,205 MW(Megawatt) in 2022 with a 17% growth rate compared to 2021 [3]. One of the factors causing the rapid development of offshore wind power in China is the government's support of policies. In China, policies on offshore wind power are stable and continuous. China has included the comprehensive development of offshore wind energy in its latest Five-Year Plan. In addition, China has invested in state-owned enterprises to develop offshore wind power. In terms of innovation, the Chinese government also promotes international technical and intellectual cooperation on the topic of offshore wind energy, which facilitates China's scientific research on offshore wind energy and technological exchanges with the rest of the world. China's unique distribution of natural resources has also helped the country to develop offshore wind energy. China's wind power energy supply is mainly located in the northwest, while demand is concentrated along the eastern coast. Therefore, the development of offshore wind energy can help China to solve the problem of the different distribution of energy supply and demand. The population distribution of China is an integral part of the factors contributing to the development of offshore wind energy in China. First, China's population base is the second largest in the world. For China, offshore wind energy, which can generate electricity day and night, is ideal. Second, China's population and high demand for electricity are located in the

eastern coastal areas, which reflects the fact that offshore wind power can save some of the cost of electricity consumption in coastal areas compared to onshore wind power. China's practice of offshore wind power generation is also inseparable from government support in technology and cost. So far, the diameter of China's turbines for offshore wind energy has been expanded, which has increased the capacity for power generation. In addition, China has reduced its overall offshore wind supply chain costs by lowering the cost of raw materials. Investment and subsidies will be discussed from both governmental and societal perspectives. In this article, China's offshore wind policy, natural resources, population size and distribution, technology and costs, as well as investment and subsidies are presented in detail to illustrate China's current offshore wind development and practices.

2. China Policy

2.1. Stability and Continuity

The Chinese government's policy towards offshore wind energy is stable and consistent and can be sorted out through the major events of policy promulgation from 1993 until now. China's earliest policy on offshore wind power can be traced back to the 1993 "Wind Power Industrial Programme", which reduce the value-added tax by half for wind power projects. After that, in 2008, China enacted "The Wind Base Programme". Seven wind-rich sites in China have been selected to develop offshore wind power, with a target of 138 GW(Gigawatt) by 2020. The feed-in tariff is a national policy whereby the government sets a higher than market price for new energy sources as a way to promote the development of clean energy. China enacted a feed-in tariff in 2009. This feed-in tariff has four different categories, ranging from CNY (Chinese Yuan) 0.51/kWh to CNY 0.61/kWh. Besides, this feed-in tariff applies for the entire operational period, which is usually 20 years. In 2020, China issued "Suggestions on Promoting the Healthy Development of Non-Water Renewable Energy Power Generation", in which the document states that there will be no more subsidies for new offshore wind projects after 2021. The Chinese government enacted "A New Feed-in Tariff Regulation" in 2021. In this document, new wind power can participate in on-grid spot market transactions, and provincial authorities decide on-grid offshore wind electricity prices. Most recently, Green Power Trading Rules (2022) encourage offshore wind power operators to join power purchase agreements with benefits. In addition to these regularly issued documents and policies, China has included the development of offshore wind energy in its authoritative national-level Five-Year Plan. The Five-Year Plan is an authoritative policy issued by the Chinese government, and there have been 13 Five-Year Plans to date. It is usually a meeting within the government to decide on the important events that will lead to the achievement of the goals for the next five years. In China's thirteenth five-year plan, the construction of offshore wind farms in Jiangsu and Fujian has maintained a rapid development speed, Liaoning, Zhejiang, Hebei, and other provinces are also actively accelerating the pace of development which together account for 15% of the whole installed capacity of offshore wind power [4]. In the "14th Five-Year Plan" Renewable Energy Development Plan, put forward "actively promote the large-scale development of offshore offshore wind power" and "promote the deep and distant sea offshore wind power technology innovation and demonstration of application". The 14th FYP process is a turning point from installed capacity to shares of renewable energy sources in electricity generation. 18% wind and solar PV electricity generation were set, as well as the restrictions of offshore wind project permitting [5]. Since the 14th FYP process, laws, national strategies, and action plans are developed for the power sectors with more flexible timeframes. All in all, China's ambitions on developing offshore wind are encapsulated in its FYPs and supported by other provincial, and local strategies. These continues policies with quick and firm cooperation of all stakeholders contribute to the leading position of Chinese offshore wind power industry.

2.2. The Power of State-Owned Enterprises

In developing offshore wind energy, China has fully utilized the role of state-owned enterprises. Unlike ordinary businesses, SOEs in China are subordinate to the government, rather than relying on

or deferring solely to the company's own profits or losses to choose how they operate. State-owned enterprises can serve as experimental platforms for the commercial development of wind power in China. In China, the Shanghai government announced in 2022 that three SOEs (State-owned enterprises) had won the project for Jinshan offshore phase I at a fixed tariff rate of 0.302 yuan/KWh [6]. Despite the fact that no subsidies will be provided for the project that goes online after 2021, the local government will still provide support to the sector. The investment for this project is 3.1 billion yuan and copes with the "North-South Transformation" concept. Similar to other cases, rapid innovation systems have the advantage to raise money for important national goals and give governments the freedom to experiment and take advantage of markets to split risks and maintain competition [5].

2.3. International Cooperation

China desires to attain global leadership in offshore wind technology through policy-driven international cooperation which is a key strategy. The sharing of knowledge through officially agreed-upon contracts, business, and unofficial individual exchanges is essential if offshore wind research is to be of the highest quality and have the most potential for reaching markets and reducing costs. The Beleolico project (2022), the nation's first offshore wind energy development, serves as a prime illustration. Ming Yang, a Chinese provider of equipment, improves the flow of knowledge and technology between European businesses and contributes to international collaboration under the "One Belt and One Road" Initiative [7]. Along with technical cooperation, the Chinese government is encouraging the growth of wind energy around the world by joining intergovernmental organizations, such as the CWEA (California Water Environment Association), which has arranged for 28 domestic wind power firms, academic institutions, and research centers attend IEA (International Energy Agency) wind TCP (Transmission Control Protocol) tasks by the end of 2021[8].

3. National Resources and Environment Drives

China's development of offshore wind energy can also be attributed to the geographic disparity in the distribution of energy in China. 70% of China's coal and wind resources are generated in its western areas, and 80% of water energy resources are in the southwest, while the eastern power demand accounts for more than 47% of the country's total. With the development of clean energy in the East, the imbalance between supply and demand will be reduced, also alleviating the seasonal instability of west-to-east power transmission and the pressure of channel construction by realizing local consumption of energy [9]. In addition, China's tight land resources mean that offshore wind is important for China. In economically developed areas such as the Yangtze River Delta/Pearl River Delta, land resources are tight, industrial, and residential electricity demand is strong, and the available area for onshore wind power is limited. Concentrated PV has a lot of land requirements and using marine resources is the only way [5]. For offshore wind resources in China, the Taiwan Strait has China's highest density. Nearshore locations such as Shanghai, Jiangsu, and Guangdong have seen the majority of offshore wind power installations. China also has deep water locations, particularly along the Southeastern coasts. Which can be used with floating offshore wind technologies to produce wind energy. The global warming climate is also promoting the development of offshore wind energy in China. In 2019, China's CO2 emissions ranked first in the world, with emissions of 9.8×109 t. While global CO2 emissions have stagnated, China's emissions have been growing and bringing pressure to reduce them. Offshore wind development helps to limit the use of coal-fired power near large population centers in the eastern part.

4. Population Size and Distribution

China's large population base provides a market for offshore wind energy development. The annual operating hours of offshore wind power can reach up to 4,000 hours, which is 20% to 40% more than the annual power generation of onshore wind power [9]. The extensive available time and capacity of offshore wind power can feen the domestic market quite well.

Most of China's population is located in coastal cities. The demand for electricity in these cities is much higher than in other cities. Offshore wind power can provide electricity to coastal cities more efficiently than other energy sources that require onshore or underground transportation. The development of offshore energy can save costs and meet the characteristics of China's population distribution, which leads to the concentration of electricity consumption in coastal areas.

5. Technology and Cost

The advanced technology in China can be reflected in the diameter of the rotor. The maximum unit capacity of new wind turbines rises to 18 MW in 2022, a 7 MW increase from 2021, while the average capacity is 11.47 MW [10]. So far, China has been able to localize 100% of all the equipment needed for offshore wind turbines. This is the world's first 16 MW offshore wind turbine developed by Goldwind in collaboration with dozens of companies, universities, and research institutes. This innovation has laid a solid foundation for the development of the offshore wind power industry. In addition, China's offshore power generators are moving from the offshore to the deep sea. According to a news release from the Chinese government, the Haiyang Guanlan, a deep-sea floating wind power platform, is already in use. This is a floating wind power platform that operates in an area more than 100 kilometers from the coastline and in water depths of more than 100 meters. The completion and commissioning of "Haiyang Guanlan" have increased China's ability to independently develop offshore wind power from water depths of less than 50 meters to more than 100 meters [11]. The cost of the supply chain decline. The investment cost of floating offshore wind power in China is $5319~ 5,599/kW, which is less expensive than the prices in other countries because of technical advancements and the decline in the price of raw materials [12]. In 2022, China’s levelized cost of electricity (LCOE, or the average net present cost of generating power over a generator’s lifespan) dropped to 65.7/MWh or $21 less than the rest of the world [13]. Offshore wind power projects' unit costs have been below $2,099/kW from 2020, eventually bringing in the parity era [14]. However, difficulties persist, such as the significant reliance on carbon fiber textiles needed for imported blades [15].

6. Investments and Subsidies

6.1. Government Investments and Subsidies

Government policies and subsidies have helped China grow its offshore wind industry. The National Development and Reform Commission and the National Energy Administration have consistently approved policy subsidizing measures from the pilot stage in 2005. The offshore wind project subsidy intensity fluctuated from 46.7% to 57.1% during the benchmark energy price stage from 2010. 2020 marks the end of central government intervention in the subsidy strategy for market development. Given that both OEMs and developers are under intense pressure to assure high-quality and inexpensive development while satisfying profit standards, the policy has been modified to use a province-local subsidy structure. For offshore wind generation, under the 14th Five-Year Plan, the installed offshore wind power capacity in Jiangsu, Guangxi, Guangdong, Zhejiang, Tianjin, and Shandong provinces and cities will expand by 43.28 GW, 5.25 times the 8.25 GW increase in the 13FYP. Since 2020, China's renewable energy market has reached grid parity, and electricity produced by renewable sources will be compensated similarly to electricity produced by coal-fired power plants [16]. Additionally, the Chinese government's significant investment in energy research

and development (R&D), which is particularly focused on low-carbon energy R&D, favors the offshore wind business in China. In 2020, it spent $4.1 billion on R&D for low-carbon energy, which was 15% of the global total [17].

6.2. Investments in Society

Social investments in China's offshore wind power sector are coming in one after another because to the country's stable supply chain, political climate, and local and international market conditions. The federal government encouraged private equity and entrepreneurial capital to engage in green projects in 2017 [18]. The Zhanjiang Xuwen 600MW Offshore Wind Farm Project will immediately address the funding demands resulting from banking institutions' lack of capital investment. The project has received repeated funding contributions totaling more than 2.7 billion yuan from China Southern Network Capital Holding Company, which also offered a solid financial guarantee [19]. Goldwind Technology, the industry leader in wind power systems, committed tens of billions of dollars in the design of coastal wind power industrial bases in order to take advantage of the potential presented by the fast expansion of the domestic offshore wind power market. By the end of the first quarter of 2023, the business had received orders from abroad totaling 4.53GW, an increase of 65.7% year over year [20].

7. Conclusion

Based on a multifaceted analysis of China's offshore wind development and practice, China is a world leader in this field, with a favorable policy environment and development prospects. China's policy is coherent, as can be seen by the frequent promulgation of government documents on offshore wind starting in 1993 and continuing through 2022. These documents support the development of offshore wind in a number of ways, such as feed-in tariffs, subsidies, reduced prices, etc. More authoritatively, in China's last two Five-Year Plans, there have been references to goals regarding offshore wind development. In the 13th Five-Year Plan, China set several densely populated coastal cities as locations to focus on offshore wind energy and invest in the program. In the 14th Five-Year Plan, the importance of further developing offshore wind energy is again mentioned. The 13th and 14th Five-Year Plan have helped China stabilize the importance of developing offshore wind energy in the future. China has also played a governmental role in supporting the development of the industry by encouraging the development of state-owned enterprises, promoting international cooperation, and in a variety of other ways. In addition to its policies, China strongly supports technological innovation in offshore wind energy and has achieved milestones at this stage. China's technological development for this industry is planned and targeted. China has now secured larger turbines and has plans to move from offshore to deeper waters. Due to technological advances, China has succeeded in controlling the supply chain costs of the industry. In this article, three reasons why China is developing offshore wind energy are discussed. The first is that there is a mismatch between supply and demand in the distribution of natural resources in China, with supply mainly in the West and demand in the East. The second is that China's population and power-intensive cities are mainly located along the coast, which is where offshore wind energy can be supplied. The third point is an investment in subsidies from both government and society. Overall, the development and practice of offshore wind energy in China is currently planned and being practiced. Policies show that the government is expanding the scale of offshore wind power generation and trying to further commercialize the industry through state-owned enterprises. Technological advances and abundant financial support in the form of investment and subsidies are driving the industry in China.

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