

Analysis for the Development of Marine Renewable Energy Industry in China

Libo Chen^{1, a}, Xin Li^{1, b}, Weijia Ma^{2, c}, Haifeng Wang^{1, d}, Changlei Ma^{1, e}

¹ National Ocean Technology Center, Tianjin 300112, China;

² Industry Development and Promotion Center, Ministry of Industry and Information Technology, Beijing 100846, China.

^aocean86@163.com, ^blixin_t@126.com, ^cmaweijia@idpc.org.cn, ^dhaiyangneng2012@163.com, ^enotcmachanglei@163.com

Corresponding author: Weijia Ma. Funded by 2019YFE0102500

Abstract. Marine renewable energy is a new type of energy that is inexhaustible, clean, low-carbon and renewable. China is rich in marine renewable energy. It is of great significance to promote the development of marine renewable energy industry since it can strengthen the construction of ecological civilization, facilitate the implementation of the “Carbon Peaking and Carbon Neutrality” strategy, ensure energy security, and drive the development of the marine economy. Europe, the United States and other countries attach great importance to the development of the marine renewable energy industry. In recent years, they have constantly increased financial investment and policy support for this industry, and boosted its integrated development together with the blue economy including offshore wind power and marine aquaculture, which served as an important reference for China to develop the marine renewable energy industry. China’s marine renewable energy industry is at the critical stage of industrialization, and it is necessary to accelerate related work such as policy support, technology R&D, and scale application, so as to lay the foundation for driving our marine renewable energy industry to the growth stage.

Keywords: marine, renewable energy, industry development.

1. Introduction

In narrow sense, marine renewable energy refers to the renewable energy derived from sea water, mainly including tidal current, wave, tidal range, ocean thermal and salinity gradient energy. In broad sense, it also includes energies such as offshore wind, offshore solar, submarine geothermal and other energy exploited by the space of ocean. Marine renewable energy can be utilized in form of power generation, seawater desalination, seawater cooling and so on[1]. This paper mainly studies the development and utilization of marine renewable energy in the narrow sense.

2. Significance of Developing Marine Renewable Energy Industry

The advantage of marine renewable energy is green and cleaning. China has rich marine renewable energy resources with great potentials. The 14th Five-Year Plan for National Economic and Social Development points out “promoting utilization scale of marine energy”.

2.1 Objective Requirements for Ecological Civilization Construction

The marine renewable energy industry is a green and low-carbon industry, which could make a positive contribution to the construction of the ecological civilization. Meanwhile, through the development of the marine renewable energy industry, the electricity demand of coastal areas, especially remote islands can be met effectively.

2.2 Important Measures to Implement “Carbon Peak and Carbon Neutrality” Strategy

Marine renewable energy development and utilization are planned in several documents released by relative ministries, including the National Marine Plan for Medium and Long-term S&T

Innovation to 2035, the Implementation Plan Promoting High-Quality Development of New Energy in the New Era, and the Act Plan for Green and Low-Carbon Innovation of Power Equipment.

2.3 Inevitable Choice to Ensure Energy Security

Energy security provides important support for national security, especially for China as a developing country. Marine renewable energy has a huge development potential. In the medium and long term, the installed capacity of marine renewable energy in China is expected to exceed 30 GW. Marine renewable energy will become an important renewable energy and it is the inevitable way to strengthen the native energy security.

2.4 An Important Way for Developing Marine Economy

The global marine renewable energy has a promising market[2]. The global marine renewable energy industry will achieve to the level of 100 billion, even to trillions before 2050. In the medium and long term, the scale of China's marine renewable energy industry will worth hundreds of billion Yuan. It will emerge as an important marine industry.

3. Development Trend of International Marine Renewable Energy Industry

The international tidal range energy technology is already commercialized. However, the utilization of large-scale tidal range energy would occupy the coastline resources and have an important effect on the marine ecological environment for the conventional tidal barrage.

The international tidal current energy technology would be industrialized in the near future, a number of tidal current energy demonstration power plants with stable operation have been built, with a maximum power per turbine of 1.5 MW. The international wave energy technologies are still at the demonstration stage, and some of such technologies have been demonstrated for a long time, several power generation devices of hundreds of kW under different principles are undergoing sea trial. The power generation and comprehensive utilization potential of ocean thermal energy conversion (OTEC) technology have been verified[3,4].

3.1 Guided by Medium and Long-term Development Goals

Since 2020, the EU, USA and UK have successively announced goals for developing marine renewable energy industry in 2030. The total installed capacity of tidal current and wave energy would reach 2.5 GW. International Renewable Energy Agency (IRENA) predicted that the total global installed capacity of marine renewable energy would reach 10GW by 2030.

Take tidal current energy in UK as an example, in the support of the Renewables Obligation (RO) Certificates, the British government provided a feed-in tariff of more than 2 ¥/kWh for "MeyGen A" demonstration plant built in 2016. In 2022, in the support of the Contracts for Difference (CfD) scheme, UK provided a feed-in tariff of 1.5 ¥/kWh for tidal current projects with more than 40MW which will be completed before 2027. It can be said that the incentive policy of higher electricity price enabled UK to lead the world in the utilization of tidal current energy.

3.2 Keep on Increasing Financial Investment to Accelerate Technological Industrialization

In recent years, the USA has several amended laws and regulations related to the marine renewable energy. In 2019, the Energy Independence and Security Act of 2007 was amended, through which the annual budget ceiling of marine renewable energy for the U.S. Department of Energy's Water Power Technologies Office (WPTO) was raised to US \$160 million.

3.3 Facilitate the Continuous Decline of Levelized Cost of Energy (LCOE)

Take the construction of the tidal current energy power plant as an example, the installed capacity of MeyGen A tidal current energy demonstration power plant was 6 MW, and the LCOE exceeded 2 ¥/kWh. The installed capacity for the second phase under construction is 28 MW. The

LCOE will drop to 1.5 ¥/kWh, with about 25% reduction. It can be seen that, driven by technological progress and large-scaled utilization, the LCOE for tidal current energy has dropped rapidly[5,6], which would facilitate the large-scaled utilization of tidal current energy.

3.4 Achieve Integrated Development with Other Marine Industries

European Marine Energy Center in the UK established a subsidiary to generate power for hydrogen production with tidal current energy. In 2020, it enabled the world's first commercial hydrogen-powered aircraft to take off in the Orkney Islands. Over the past five years, the USA has supported dozens of projects including wave-powered seawater desalination, power supply for marine monitoring equipment and so on. India has built seawater desalination devices by OTEC on several islands, with a capability to produce 100 tons of fresh water each day.

4. Foundation and Problems for the Development of Marine Renewable Energy Industry in China

The marine renewable energy resources are abundant in China and have a huge potential for emission reduction. A number of representative technologies have obtained preliminary foundation for commercialization.

4.1 Resource Foundation

According to the resource investigation and evaluation, the theoretical installed capacity of coastal marine renewable energy resources in China is about 697GW, and technical exploitable amount is more than 70GW.

China's installed capacity of wave energy, tidal current energy, and OTEC would be expected to exceed 30GW in 2060s. If the annual utilization hour is 2,000 hours, the annual electricity generated will exceed 60 billion kWh, accounting for nearly 1% of China's annual output in 2021. The CO₂ emission reduction would be more than 50 million tons per year.

4.2 Technical Foundation

China leads the world in terms of the installed capacity of marine renewable energy. Until 2022, China's cumulative installed capacity was about 10.4 MW, ranking fourth in the world (Table 1), and the annual grid-connected energy output was about 7 million kWh, which was mainly generated by the tidal range energy. The cumulative installed capacity of tidal current energy and wave energy was about 6 MW, accounting for more than 37% of that operated internationally.

Table 1. Global Ranking of Installed Capacity of Marine Energy (by the end of 2022)

	South Korea	France	UK	China	USA
Tidal range plant	254MW	240MW	0	4.35MW	0
Tidal current plant	1MW	2.5MW	8.4MW	4.73MW	0.2MW
Wave energy plant	0	0	2.5MW	1.26MW	0.8MW
OTEC plant	1MW	0	0	0	0.1MW
In total	256MW	242.5MW	10.9MW	10.4MW	1.1MW

The Technology Readiness Level (TRL) of tidal current energy technology is about Level 7 in China. More than 20 turbines have completed sea trial and the maximum power reached MWs level[7]. The MWs demonstration plant operated by Zhejiang Zhoushan LHD Energy Co., Ltd. achieved grid-connected power generation in the sea area of Zhoushan Xiushan Island in August 2016. At present, its total installed capacity is 3.3 MW, and its performance indicators including continuous grid connection time are internationally advanced. In November 2017, Zhejiang

University deployed 650 kW horizontal axis tidal current energy generating units in the sea areas of Zhairuoshan Island.



Fig. 1 LHD tidal current plant

The TRL of wave energy technology in China is about Level 6. According to the characteristics of China's wave energy resources, low-power wave energy converters have been mainly developed. At present, about 30 devices have completed sea trial[8], and the maximum power per unit reached 1MW. Preliminary technology is now available for providing power to remote Islands, and the application of wave energy to supply power for aquaculture net cages has been explored.



Fig. 2 Nankun 1MW wave energy device

4.3 Industry Foundation

Considering the resources conditions, sea use conditions and technology foundations, China is well placed to industrialize tidal current energy and wave energy, and OTEC has a great potential for development.

The utilization standard mechanism of marine renewable energy of China has been improved. By the end of 2022, a total of 22 national standards and 11 industry standards had been implemented.

4.4 Existing Problems

4.4.1 Insufficient financial investment.

As the marine renewable energy industry is technology intensive, has a long R&D cycle, and poses great investment risk, it is difficult to attract large amount of continuous investment, which seriously hinders the development of the industry. Over the past five years, China has reduced investment in marine energy gradually. The annual average investment in China for marine energy R&D and demonstration projects is about 30 million Yuan.

4.4.2 Lack of incentive policies.

At present, there are still risks in offshore construction, and equipment operation and maintenance in the development and utilization of marine energy power plants. It is infeasible to undertake relevant development risks only relying on project construction units such as enterprises. It is urgent to formulate incentive policies in finance, insurance, financing, electricity prices, and sea utilization approval.

4.4.3 Breakthroughs need to be made in key technologies urgently.

In recent years, although China has made great achievements in the basic research of marine science and technology, and nearly reached the level of developed countries in some fields, it is still faced with such problems as weak basic research, inadequate independence in key technologies, insufficient competitiveness, and lack of key equipment technologies.

4.4.4 Weak ability to transform achievements.

At present, due to the low conversion of technological achievements of the marine renewable energy industry in China, most of such technological achievements are still in research institutes. It is difficult to attract enterprises to increase investment due to the lack of incentive policies and insufficient public services for the development and utilization of marine energy

5. Suggestions for Accelerating the Marine Renewable Energy Industry

China's marine renewable energy industry is at the critical stage of technology industrialization. Guided by President Xi Jinping Thought on Socialism with Chinese Characteristics for a New Era, we should fully, accurately, and comprehensively implement the new development philosophy, adhere to the problem-oriented approach and systems thinking, follow the innovation-driven approach, bear the world in mind, accelerate the development of the marine renewable energy industry, and provide robust support for achieving the Carbon Peaking and Carbon Neutrality goals and building a country with a strong maritime power.

5.1 Establish A Long-term Financial Support Mechanism

There is still great risk in the development and utilization of marine renewable energy, and no single entity can fully undertake it. Diversified capital investment mechanisms should be established such as finance, insurance, venture capital and financing to further alleviate risks for entities. Explore the central or local marine renewable energy industry funds, formulate medium and long-term development plans for the industry, and stabilize expectations for industry development.

5.2 Promote the Formulation of Incentive Policy System

According to the analysis of the operational data of existing tidal current energy demonstration projects in China, the LCOE is generally higher than 3 ¥/kWh, and it is urgent to reduce power generation cost through ongoing innovation and long-term engineering demonstration projects. The development experience in the tidal current energy industry of the United Kingdom shows that the electricity price incentive policy has played a decisive role. During this period, it is recommended to formulate and roll out feed-in tariff incentive policies for marine energy as early as possible. Such policies can be discussed case by case by the energy authorities, or approved by the Development and Reform Department of local governments. China should start the construction of the tidal current power plant with installed capacity of 10 MW as soon as possible.

5.3 Strengthen Efforts in Breakthroughs in Key Technologies

In the critical period for China's industrialization of marine renewable energy technology, we should keep on increasing investment in technology R&D. Develop and deploy low-cost and highly efficient marine renewable energy power generation equipment technologies, boosts the reliability of the power generation equipment and its survivability in the sea. The application fields of the marine renewable energy technology should be expanded in combination with applications such as deep sea development, offshore energy supply, offshore defense construction, desalination, and refrigeration.

5.4 Strengthen Public Service Capability

China should keep on supporting construction and operation of experimental sites for marine renewable energy, help R&D institutions to use indoor and outdoor infrastructure free of charge for testing, and drive ongoing technology improvement and optimization. The development of testing and certification mechanism for marine renewable energy equipment should be promoted to create marine renewable energy equipment brand for China. Provide support for the development of marine renewable energy standards and industrial coordinated development, accelerate the conversion of international marine energy standards into domestic ones. China also need to participate actively in and lead the formulation and revision of international marine energy standards, and help China's marine energy equipment to enter into the international market.

5.5 Carry Out International Cooperation

Encourage the introduction and R&D cooperation of marine technologies, make full use of global innovation resources, and jointly make and share international innovation achievements. Deepen international cooperation and exchanges in management, technology, talents and mechanisms, promote international cooperation in marine science and technology and industry innovation, and strive to increase industry R&D, manufacturing and marketing to internationally advanced level.

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