Ocean Energy Development under the Background of Carbon Emissions Peak and Carbon Neutrality in China

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Abstract. The ocean energy resources are abundant in China. The technical potential in Chinese coastal area is more than 70 GW. Thus, the utilization of ocean energy resources is very important for the energy saving and the mitigation of climate change. The Renewable Energy Law implemented since 2010 and the special fund program for ocean energy established in 2011 has advanced great progress of ocean energy technology research, development and demonstration in recent years in China. The ocean energy technologies in China have achieved rapid development under the support of the Ministry of Finance, the Ministry of Natural Resources, the Ministry of Science and Technology and so on. The accumulated capacity of ocean energy is in the international advanced level, but the ocean energy industry is still in early stage. The carbon emissions peak and carbon neutrality strategy put forward in China requires the transition to green energy and electricity, which also provides crucial opportunity for the development of the utilization of ocean energy resources in China. The paper introduces the status of ocean energy technology and industry in China firstly. Then the problems in the development of ocean energy are analysed. The potential of utilization of ocean energy is estimated to support the carbon emission reduction. Finally, the vision and main tasks are given.

1. The abundant ocean energy resources in China

Oceans are a source of abundant renewable energy potential. Ocean energy technologies – including wave, tidal range, tidal current, ocean thermal energy conversion and salinity gradient energy – can make full use of the enormous potential in line with overall sustainable energy and economic development. Thus, ocean energy could drive a vigorous global blue economy in the years ahead.

Table 1. Technical potential (Cf=30%) of ocean energy in coastal area in China

| Energy Source                      | Installed Capacity (GW) | Electricity Generation (TWh/yr) |
|-----------------------------------|-------------------------|--------------------------------|
| Tidal range                       | 23                      | 63                             |
| Tidal current                     | 2                       | 15                             |
| Wave                              | 15                      | 129                            |
| Ocean Thermal Energy Conversion   | 26                      | 225                            |
| Salinity gradient                 | 11                      | 99                             |
| In total                          | 77                      | 531                            |
The ocean energy resources are abundant in China. The technical potential in the coastal sea ($\leq 20$ km) is more than 70 GW, as shown in table 1, the figure 1 and figure 2. Among which, the Ocean Thermal Energy Conversion (OTEC) potential is calculated in all of the South China Sea. Thus, the utilization of ocean energy resources is essential for the energy safe and saving and the mitigation of climate change.

![Figure 1. Tidal current energy potential in coastal area in China](image1)

![Figure 2. OTEC potential in the South China Sea.](image2)

2. Ocean energy technologies status in China
The Renewable Energy Law implemented since 2010 and the special fund program for ocean energy established in 2011 has advanced great progress of ocean energy technology research, development and demonstration in recent years in China. The ocean energy technologies in China have achieved rapid development under the support of the Ministry of Finance, the Ministry of Natural Resources, the Ministry of Science and Technology and so on. The accumulated capacity of ocean energy (mainly for the tidal range stations, the tidal current energy stations and the wave energy stations) is in the international advanced level, but the ocean energy industry is emerging and still in early stage. The tidal current energy and the wave energy is more matured. So, the tidal current energy technologies and the wave energy technologies are analysed.

2.1. Tidal current energy technologies status in China
The universities are key players in the research of tidal current energy technologies in China. For example, the Harbin Engineering University (HEU), Zhejiang University (ZJU) and Northeast Normal University (NNU) have started the development of MRE turbines more than twenty years ago. The companies engaged in tidal current energy sectors in China are relatively less, among which the LHD Corp. and Three Gorges Corporation are leading. The Wanxiang-I with 70 kW capacity and Wanxiang-II with 40 kW capacity are developed by HEU, the 5 kW horizontal-axis turbine for powering the marine instruments is developed by NNU, the 25 kW, 60 kW, 120 kW and 300 kW
horizontal-axis turbines are developed by ZJU. Now, the maximum rated power of tidal turbines in China is 650 kW.

2.1.1. ZJU turbines. ZJU have developed a series of horizontal-axis turbines from 5 kW to 650 kW (Figure 3) since 2005. The first 60 kW turbine developed by ZJU was deployed near Zhairuoshan Island since May 2014, and then a 120 kW turbine and a 300 kW turbine were deployed in succession (Figure 4). The maximum conversion efficiency is more than 40%.

![Figure 3.650 kW ZJU turbine in test](image)

2.1.2. HEU turbines. The 70 kW Wanxiang-I floating vertical-axis turbine was developed in 1996, and then the 40 kW Wanxiang-II bottom fixed vertical-axis turbine was developed in 2002. In the support of the special fund program for ocean energy, HEU developed the Haineng series tidal turbines and deployed them in Daishan sea area. For example, the vertical-axis Haineng I with two 150 kW turbines in one platform was developed and tested since 2012 (Figure 5). The efficiency is about 30%.

![Figure 4. Platforms for ZJU turbines test](image)

![Figure 5.Haineng I 300 kW tidal turbine in test](image)
2.1.3. LHD turbines. In 2009, LHD Corp. developed the pathway of “fixed fence from sea surface to bottom and modular turbines” to utilize the tidal current energy. The first platform to host 3.4 MW turbines and the second platform to host 4.1 MW turbines were deployed in Xiushan channel in Mar 2016 and Jan 2021. The first two 300 kW and two 200kW vertical axis turbines were deployed in July 2016, the second two 200 kW vertical axis turbines and the first 300kW horizontal axis turbine were deployed for demonstration in 2018 (Figure 6). The total accumulative power is 1.7 MW till now and the generation reached 2100 MWh till May 2021.

![Figure 6. LHD 1.7MW turbines in the platform in demonstration](image)

2.2. Wave energy technologies status in China
The universities and research institutions are key players in the research of wave energy technologies in China. For example, National Ocean Technology Center (NOTC), Guangzhou Institute of Energy Conversion, Chinese Academy of Sciences (GIEC CAS), and Shandong University (SDU) have been engaged in the research and development of wave energy converters (WEC) for more than 30 years in China. More than 40 WECs have been deployed for demonstration or test till the end of 2020, including the 8 kW gravity pendulum-type WEC and 30 kW floating pendulum-type WEC, the sharp eagl-type WECs, the point absorber-type WECs and the Oscillating Water Column-type WECs.

2.2.1. GIEC WECs gridded for remote islands. GIEC has been engaged in the development of sharp eagl-type and Oscillating Water Column-type WEC technologies since 1980s. More than 700 navigation buoy with OWC modules of 10W, 60W, 100W capacity have been manufactured till the end of 2020. GIEC then developed the sharp eagle WECs with the features of a wave-absorbing body like the head of an eagle mounted in a semi-submerged boat. The “Wanshan” sharp eagle-type WEC (100 kW), “Xiandao” sharp eagle-type WEC (200 kW), “Zhoushan” (Figure 7) and “Changshan” sharp eagle-type WEC (500 kW) were deployed near Wanshan Island and South China Sea in 2015, 2017 and 2020 respectively. The efficiency is about 20%.

2.2.2. GIEC WEC for fish-farming. In order to couple blue economy sectors with the ocean energy, which would provide an important pathway to improve the quantity of WECs, GIEC combines sharp eagle-type WEC technology with aquaculture in one platform, which is also a potential offshore tourism site. The “Penghu” WEC (60 kW) has been deployed near Wanshan Island since 2019.
2.3. **OTEC technology**

The First Institute of Oceanography (FIO) developed a 15 kW closed-cycle OTEC prototype in 2012, using the temperature difference between the cold seawater and the hot discharge from a coastal power plant. NOTC developed a 200W power supply module for marine observing devices using the OTEC technology since 2011.

3. **Potential of ocean energy to support the carbon emission reduction strategy in China**

The carbon emissions peak and carbon neutrality strategy put forward in China requires the transition to green energy and electricity, which also provides crucial opportunity for the development of the utilization of ocean energy resources in China. The amount of carbon emissions is about 10 billion tons in 2020 in China. It is estimated that the amount will increased to about 1.16billion tons to the peak in 2030.

According to the resources potential for ocean energy in China, the technical potential in the coastal area is more than 70 GW, among which, the technical potential of the wave energy, the tidal current energy in coastal area and OTEC in South China Sea is more than 40GW. The technical potential of the wave energy and the tidal current energy in exclusive economic zone is estimated to be more than this figure.

Generally, the annual equivalent available hours for ocean energy devices is about 2000. If the accumulated installed capacity of ocean energy reach 30GW before 2050 in China. The emission reduction is more than 50 million tons of carbon dioxides.
4. The challenge and opportunity for ocean energy in China

4.1. The challenge for ocean energy in China

4.1.1. Low Technology Readiness Level (TRL). Most of the developed tidal current turbines and wave energy converters are in sea trial phase in China. The TRL for tidal current turbines is about 7 and TRL for wave energy converters is about 6 in China. The low TRL for ocean energy can not attract enough companies and private investment to engage in the ocean energy sector.

4.1.2. Immature Market. The number of ocean energy demonstration projects is limited, neither the standards of devices designs and manufacturing nor the incentive policies for ocean energy have been established to form a relative mature market in China.

4.2. The vision and main tasks for ocean energy in China.

4.2.1. Ocean Energy Development Long-term Roadmap. A long-term development plan oriented to ocean energy industry is very important in China, which would provide confidence for ocean energy sector sustainably. So, it is necessary to launch a national ocean energy roadmap guiding the development of the overall industry for next 10-20 years under the background of carbon emissions peak and carbon neutrality strategy.

4.2.2. Feed-in Tariff for ocean energy. The current feed-in tariffs should improve to more than 3yuan per kilowatt for ocean energy station in the first ten years in operation. Then the price could decrease to a certain level in the next ten years. Which would provide enough time and experience to improve the TRL of ocean energy in China.

4.2.3. Couple blue economy sectors with ocean energy. The blue economy is expected to grow, and in doing so, ocean energy is well placed as a potential solution to decarbonise sectors such as desalination, space cooling, shipping, and tourism, as well as emerging sectors such as aquaculture, green hydrogen generation, ocean observation instruments and underwater vehicle charging.

4.2.4. De-risk ocean energy projects and unlock the RD&D funding. Ocean energy project risk assessment should create awareness on the technology reliability and raise trust among investors, who may be reluctant to provide financing in this sector. Ocean energy technologies are in major need of funds to push technologies towards the commercial stage.

4.2.5. Build marine spatial planning and evaluate environmental impact. The comprehensive marine spatial planning is very important to boost the roll-out of ocean energy. We should reserve adequate space for R&D and commercialization of ocean energy. In addition, marine spatial planning should go hand in hand with social, economic and environmental impact assessments.

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