China Council for International Cooperation on Environment and Development (CCICED)

Special Policy Study on
Global Ocean Governance and Ecological Civilization

CCICED Task Force Report
Offshore Renewable

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EXECUTIVE SUMMARY

Ocean renewable energy (ORE) is notable as an emerging sector on the maritime industry. China, the world's biggest energy consumer, is stepping up its push into renewable energy, proposing higher green power consumption targets, also in the ORE area. Achieving the needed renewable energy transition will not only mitigate climate change, but also stimulate the economy, improve human welfare and boost employment worldwide.

Each ORE technologies (wind, wave, current, tidal range, ocean thermal) are under consideration in different stage of development, and will presents its own unique challenges. ORE, specifically offshore wind, sees a rapid growth in installed capacity and environmental, socio-economic and technical challenges needs to be considered. The cost of electricity from ORE (offshore wind) is cut to 0.8 Yuan/kWh (USD$0.12/kWh) in 2019 and will further drop to 0.75 Yuan in 2020. Achieving this cost of electricity is a challenge to offshore wind industry, but provides an even bigger challenge to other ORE technologies. Understanding and assessing the environmental impact of ORE installations, operations and decommissioning is substantially challenged due to e.g. baseline data, socio-economic and diverse developing technologies. Development of ORE affects or is also affected by numerous stakeholders. Understanding who the stakeholders are and how they are engaged in the process is necessary for improving the responsible development of ORE technologies. Key stakeholders include fishermen, community members, regulators, developers, scientists, and tourists and so on that depend on the specific ORE project and the specific location. The seabed off China's east coast is characteristic of soft, silty soils which are unlike soil conditions in other countries contemplating ORE growth. This causes difficulty with regard to foundation type and installation techniques. Furthermore, the technical challenges for the offshore wind industry are much greater to other regions, where the weather conditions (Typhoon) more impactful on turbine performance. China's current legal system of environmental consideration related to ORE activities is limited and further regulations need to be developed.

China is particularly active in developing offshore wind technologies, an area which is set to become an important sector for the global energy future, whilst also demonstrating wave and tidal energy technologies. The Chinese government has made a commitment that the proportion of non-fossil fuel energy will account for 20% by 2030, and operational installed capacity of ORE (offshore wind) in 2019 reached 3.7GW in total, with another 13GW under construction and over 41GW permitted. The development of ORE, offshore wind, in China has reached a turning point in 2018, moving towards zero-subsidy. China's first auction for offshore wind projects in 2019 achieved a price of electricity at 0.75 Yuan/kWh, lower than the guide price of 0.8 Yuan/kWh. China has become also one of the few countries in the world that have mastered the technology of large-scale tidal current energy development and utilization.

ORE is a fast growing ocean economy which is advancing the goals of low-carbon and circular economy. Although offshore wind reached only recently a policy turning point, whilst other ORE technologies are at an early stage of development, there are encouraging signs that the investment cost of technologies and the price of electricity generated will decline further towards commercially viable energy generation. Enhancing knowledge of the ORE technologies potential impacts is crucial to inform future growth plans and inform effectively licensing for ORE activities. Ongoing review of environmental impacts associated with the

growing ORE sector and emerging ORE technologies will ensure that the best and most up-to-date information is available to decision makers, developers and stakeholders. Furthermore, the opportunity of integration emerging ORE technologies into military applications, electricity generation for remote community's freshwater generation or aquaculture applications, could be further opportunities. ORE technologies offer opportunities for China to develop a new industry, create jobs and take advantage of opportunities within its competency to global markets.

Recommendations

- Industrial supporting policy mechanism should be established and improved.
- Scale of ORE utilization should be promoted.
- Financial or venture capital communities as well as private capital should be encouraged by governmental policies.
- Offshore wind should be accelerated whilst environmental and socio-economic impacts assessed.
- Tidal current energy research and development should be encouraged by government as expected to be next type of ORE
- Mechanisms to accelerate commercial realisation of ORE technologies ORE technologies (wind, wave, current, tidal range, ocean thermal) should be supported by the government.
- Increase Offshore Wind deployment addressing many strategically important goals such as decarbonisation, security of supply, and new business opportunities.
- Enable RD&I to address challenges to reduce costs further to reach parity with other energy technologies.
- Enhance capacity to accelerate innovative and resilient technology development.
- Strengthening the global export and market opportunities.
- Engage at an early stage with stakeholders include fishermen, community members, regulators, developers, scientists, and tourists.
- Integration emerging ORE technologies into wider applications such as military applications, electricity generation for remote community's freshwater generation， hydrogen production or aquaculture applications.
- Grow ORE industry, create jobs and take advantage of opportunities within its competency to global markets

1 Marine Renewable EnergyINTRODUCTION TO OFFSHORE RENEWABLE ENERGY (ORE)

Ocean renewable energy (ORE) is notable as an emerging sector on the maritime industry. China, the world's biggest energy consumer, is stepping up its push into renewable energy, proposing higher green power consumption targets, also in the ORE area. Achieving the needed renewable energy transition will not only mitigate climate change, but also stimulate the economy, improve human welfare and boost employment worldwide.

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1.1. ORE is a fast growing ocean economy which is advancing the goals of low-carbon and circular economy. Although offshore wind reached only recently a policy turning point, whilst other ORE technologies are at an early stage of development, there are encouraging signs that the investment cost of technologies and the price of electricity generated will decline further towards commercially viable energy generation. Enhancing knowledge of the ORE technologies potential impacts is crucial to inform future growth plans and

inform effectively licensing for ORE activities. Ongoing review of environmental impacts associated with the growing ORE sector and emerging ORE technologies will ensure that the best and most up-to-date information is available to decision makers, developers and stakeholders. Furthermore, the opportunity of integration emerging ORE technologies into military applications, electricity generation for remote community's, freshwater generation or aquaculture applications, could be further opportunities. ORE technologies offers opportunities for China to develop a new industry, create jobs and take advantage of opportunities within its competency to global markets.Sustainable Development Goals

The Ocean Economy in 2030, a major report issued by the Organisation for Economic Cooperation and Development (OECD) in 2016, estimates the gross value added (GVA) of the Blue Economy at more than US$3 trillion by 2030, (at 2010 prices) and at 2.5% of total global GVA. Within this, ocean energy is notable as an emerging sector, defined by the key role in which cutting-edge science and technology plays in the delivery of projects and technology. There are significant areas of collaboration and overlap between ocean energy development and the development of our existing maritime infrastructure and capacity. E.g. the UK maritime sector contributes £14.5 billion to the UK economy, and directly supports an estimated 186,000 jobs.

The UK as the leading ocean energy developer has proposed a three interlinked support models, which fit with the current stage of technology development and Government policy, to bring ocean energy to a cost competitive position and allow for progression of technology and projects. The proposed Innovation Power Purchase Agreement (IPPA), can be used to support technology developers to deliver projects of up to 5MW whilst protecting consumers from costs by providing off-takers a tax rebate when buying marine energy. This would allow marine projects to sell their power over the market rate, with the off-takers reclaiming excess costs against tax, with this cost declining over time.

The Innovation Contract for Difference (iCfD) is a bridging mechanism that enables utility scale projects in the current CfD mechanism. This would allow for a new 'pot' within the CfD framework for all new technologies such as wave, tidal stream, and Advanced Combustion Technologies to compete among themselves.

By establishing a route to market for ocean energy, through the IPPA, it is expected marine projects will be able to deliver energy at a cost of around £150/MWh. With activity in an export market and by developing projects domestically, tidal energy is projected to reach target costs of less than £100MWh after 1GW of deployment.

China, the world's biggest energy consumer, is also stepping up its push into renewable energy, proposing higher green power consumption targets. Improving economics and firm policy support guide China's ambitions for renewable energy development. According to the 13th Renewable Energy Development Five Year Plan (2016-2020) by the National Development and Reform Commission (NDRC), the goal is to increase the share of non-fossil energy in total primary energy consumption to 15% by 2020 and to 20% by 2030, and this target cannot be achieved without the promotion of offshore renewable energy.

The country's 13th Five-Year Plan calls for 5 GW of offshore wind capacity to be installed by 2020 and for 10 GW more to be in the construction pipeline, split among the coastal provinces so as to help develop local supply chains. In 2019, the NDRC has adopted a competitive bidding scheme for offshore wind capacity in an effort to drive down costs. Around 2030, offshore wind is supposed to reach cost parity with coal-fired generation in LCOE terms, a critical milestone that supports continued long-term growth in China.

Regarding other types of ocean energy, the State Oceanic Administration (SOA) released the "13th Five-Year Plan for Marine Renewable Energy (2016-2020)", which sets out the key principles, specific actions and enablers needs to deliver upon China's potential in marine renewable energy. By 2020, 4 marine renewable energy demonstration districts will be built; the total installed capacity of marine renewable energy will be more than 50 MW. To date, China has committed above RMB 1.3 billion to marine renewable energy RD&D since 2010.

1.2. Technology Readiness Level and Development timeline

Technological and commercial maturation occurs over several phases, or Technology Readiness Levels (TRL), from concept design to commercial deployment at sea. Moving from one phase to the next requires increased level of investment for deployment, leading to technological and hence economic improvements. To assess and analyze the different steps to industrial roll-out, the following phases and criteria have been identified.

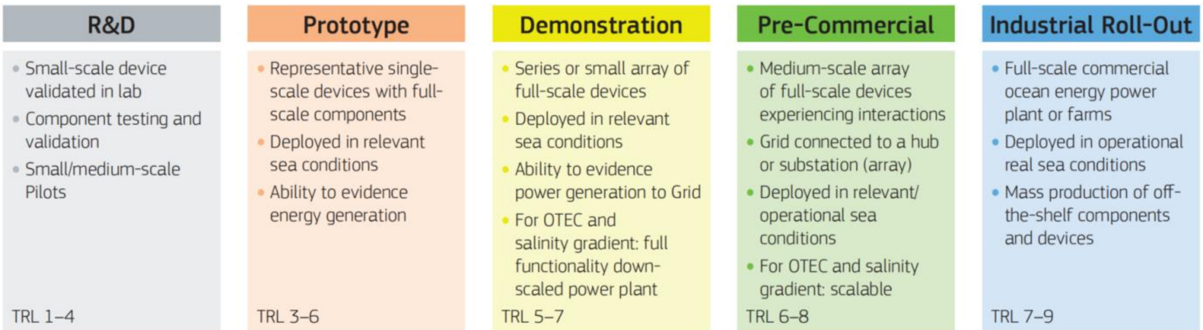


Figure 1. Phases of Technology Readiness Levels (Source: Ocean Energy Strategy Roadmap)

A timeline for the development (see Figure 2) of the five ocean energy technologies throughout these phases has been predicted in the Ocean Energy Strategy Roadmap [1]. It gives guidance as to where technologies currently are and when they could reach the next phase of development.

Addressing the current barriers to project deployment, while providing significant short- and long-term stable and predictable investment conditions are essential. Inaction will delay industrial roll-out, or in a worst case scenario result in a loss of accumulated knowledge.

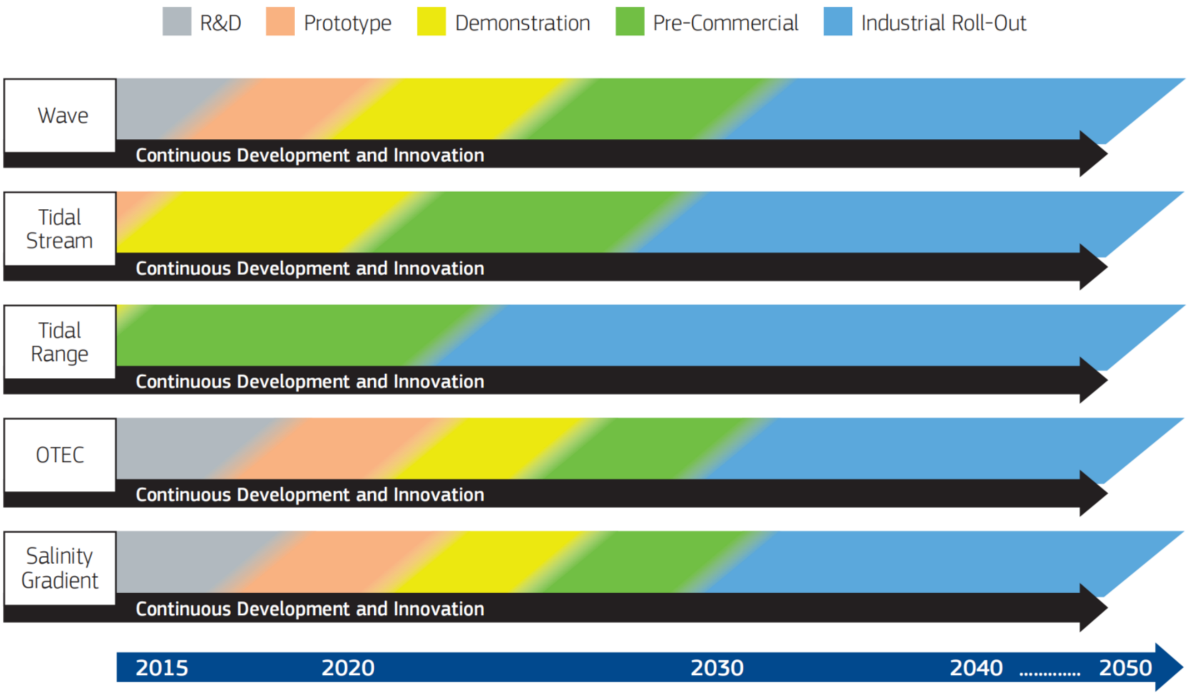


Figure 2. Timeline for the development phase of ocean energy technologies (Source: Ocean Energy Strategy Roadmap

1.3. Overview of Ocean Energy technologies

Ocean energy comprises five distinct technologies i) wave energy, ii) tidal current, iii) tidal range, iv) salinity, and v) ocean thermal energy conversion. The variations in ocean resource and location will require different technological concepts and solutions.

Ocean energy is abundant, geographically diverse and renewable. Developing technology to exploit its potential offers opportunities for Europe to develop a new industrial sector, create jobs and capitalise on its first mover status to cultivate significant export opportunities. The industry association, Ocean Energy Europe, estimates that 100GW of wave and tidal energy capacity can be deployed in Europe by 2050. This industry target is consistent with recent studies on the practical deployment potential of ocean energy in Europe. The global market for ocean energy could see 337GW of installed capacity by 2050, a third of this would be in Europe.

Today 45 % of wave energy companies and 50 % of tidal energy companies are from the EU. The right support over the coming decade could enable an European market worth a potential €653bn in investments between 2010 and 2050, and an annual market of up to €53bn.

1.3.1. Wave energy

Wave energy converters derive energy from the movement of waves and can be located flexibly – on the shoreline, the nearshore or offshore at depths of over 100m – to harness the available energy most efficiently. A range of full-scale prototypes have been deployed, however, further technology development, testing and demonstration are required prior to commercialisation and industrial roll-out.

Wave energy converters (WECs) have progressed significantly over the last decade, from scaled testing to full-scale prototypes. Field demonstrations have shown the importance of further R&D focusing on subsystems and components with an increasing number of innovative concepts.

The learnings from this phase will allow the development of whole wave energy systems through improvements of sub-systems and components as well as deployment methodology. Subsequently, the most promising consolidated concepts should be demonstrated in farms for a total of a further 100MW by the mid-2020's.

The high cost of wave energy is still a key issue for the sector. Compared to the current levelised cost of energy (LCOE)of 75well below £90/MWh for offshore wind, the LCOE from wave energy remains considerably higher, and is estimated at around £350/MWh. The commercial development of offshore wind lagged onshore wind by approximately 15 years and was built on 30 years of onshore wind development from demonstration to the first commercial wind farms of the 1990s. This pathway to a commercially viable sector, which today is cheaper than new gas and nuclear electricity generation, was supported by policy and financial support structures, feed-in tariffs and contracts for difference (CFD). Further efforts are needed to achieve the necessary cost reduction for wave energy, and it is not clear whether existing technologies will be able to meet LCOE targets. However, some developers believe that progress is constrained through socio-economic as opposed to technical challenges. To address this, evidence is needed on the environmental and social impact of wave energy development. ETIP Ocean delivered a 'Report on presentation of stakeholder engagement results workshops' in 2018 which clearly clarified the prioritised challenges within wave energy from the aspects of technology, financial, environmental and socio-economics. Furthermore, ETIP Ocean suggested actions to be taken to overcome the challenges and their responsible stakeholder(s).

Wave energy has seen a significant demonstration of wave energy converter concepts but to date none of the concepts has made it to commercial maturity. The required balance between reliability, performance, survivability and LCOE is variable for the different technologies and experience from one specific prototype is not directly relevant to all the wave sector, making progress more difficult.

In order to advance and realise commercial viability the Ocean Energy Strategy Roadmap concludes:

- Prioritise subsystems and components. Research, development and innovation in wave energy should focus on key components and sub-systems, tested both individually and as part of the whole device.

- Power take-off (PTO) systems. PTO systems require near full-scale demonstration in real sea conditions for validation.

Wave energy harvester technologies

Wave energy harvesting technologies can be broadly classified into three different systems. These include oscillating water column, oscillating bodies, and overtopping type structures. These technologies are mainly in the development phase with oscillating water columns having received the majority of the focus of research and development. To date a number of full-scale oscillating water column harvesters have been constructed either as prototype proofs of concept or as working power generators. A brief description of the main technologies and some of the better-known examples are outlined below.

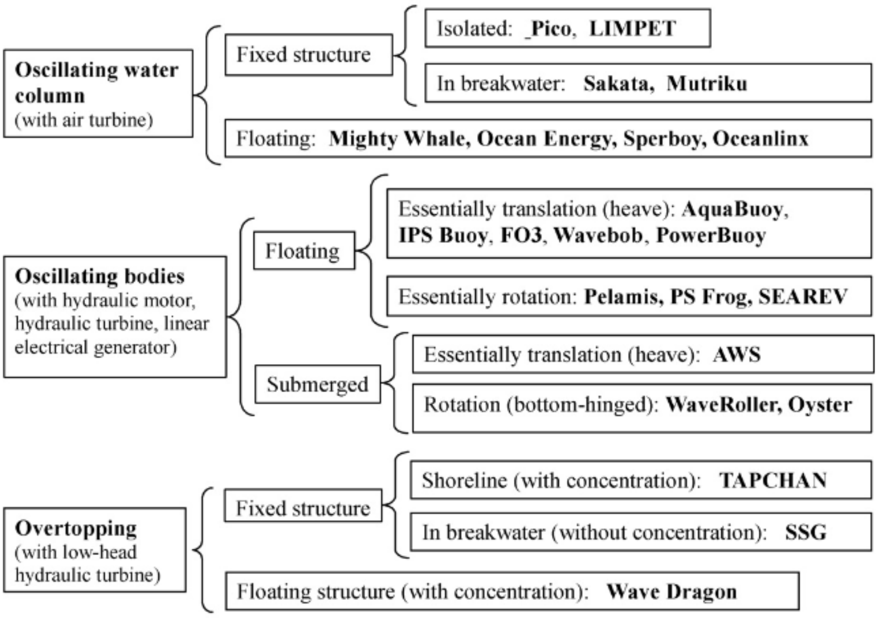


Figure 3. Wave energy technologies (Falcao 2010)

Oscillating water column

The oscillating water column consists of a partly submerged chamber with an opening below the water line on the wave impingement side of the structure. Inside the chamber, an air column is trapped above the water surface. As the incident wave ebbs and flows into the chamber, the water surface rises and falls, this drives the trapped air column out through an orifice usually located in the chamber roof. As the wave recedes away from the structure, the water surface inside the chamber falls and this draws air into the chamber. A certain type of turbine known a self-rectifying turbine that can spin up irrespective of the airflow direction is connected with the orifice. In this manner, the cyclic exhalation and inhalation phase can channel air through the turbine to generate electricity. Oscillating water columns have been constructed as fixed structures located on the shoreline or as floating platforms deployed in deeper water locations

Oscillating body

These types of generators have a very wide range of variations. They may be broadly classified as either floating or submerged. Thereafter they are grouped according to their motion response. With regards to floating oscillating bodies, the simplest type is a spar buoy type in which the main displacement direction is heave motion. The buoy is usually bottom fixed and the kinetic energy from its motion is converted into electrical energy either through a piston type hydraulic pump, spring type component or through linear magnetic generator. Submerged typed heaving bodies usually work in a similar manner. They are generally fixed to the seabed in shallow water locations. As the wave passes over the body, the larger pressure differential pushes down upon a top plate thus driving power take off system similar to the floating heaving body generators

Other floating type oscillating bodies rely on pitch motion (sometimes combined with surge motion). Examples include the Pelamis, the Edinburgh Duck, and the Searev wave energy converter. These are all floating type structures and use various methods to convert the wave energy into electrical energy. The most common type of submerged oscillating bodies are in the form of a bottom fixed flap that is oriented perpendicularly to the predominant wave direction. These flaps can either be totally submerged or surface piercing. The motion of the flap usually drives a hydraulic ram to convert the kinetic energy into electrical energy.

Overtopping convertors

In this type of wave energy convertor a reservoir is constructed with a parapet wall close to the prevailing wave height. Then as the waves impact the wall and overtops it, the water is collected in the reservoir. The floor of the reservoir is at a level that is higher than the mean sea level. Then potential energy form the stored water is converted to electrical energy through the use of low head hydraulic turbines. The reservoirs can be constructed either as onshore installations or as large floating platforms that trap the waves within a reservoir.

Wave energy- Current status and global demand

Global electrical energy consumption for 2018 was estimated to be in the range of 23000 TWh, (IEA, 2019). Of this amount, only about 22% was supplied by renewable energy resources, (Melikoglu, 2018). Furthermore, wave energy only contributed a miniscule proportion of this total. In 2014, the total global installed ocean energy power capacity was nearly 530MW. This figure is predicted to rise to 640 MW by 2021 (this includes all forms of ocean energy), (Melikoglu, 2018).

It is predicted that by 2040, the renewable energy sector will grow to contribute 29% of the global electricity consumption and wave energy should be leveraged to provide a greater share of this proportion (EIA, 2017). The total available global wave energy resource is estimated to be up to 29500 TWh/year, (Rusu and Onea, 2018). Therefore, wave energy alone has the potential to supply the present global power demand. To this end, it is necessary to further develop the wave energy sector as a viable, cost effective, clean source of renewable energy. Currently, the work to bring wave energy technology to commercially viable status is ongoing and as of 2018, there were in excess of 100 projects ongoing around the globe. However, further research needs to be undertaken to improve the cost efficiency and to enhance the durability of the structures to withstand the harsh environment in which these devices are deployed. Below there is a breakdown of some of the regional efforts to bring wave energy harvesting technologies to a market ready stage.

European countries with an Atlantic coastline also have accessible wave resources and are developing wave energy, including France, Ireland, Spain, Portugal, Denmark and Norway. Globally high levels of resource can be found in North America, Chile, Australia, China, Japan and Korea. EMEC has summarised a list of 244 wave energy developers globally, with 23 active technologies in the UK and the largest number based in the US.

Globally, most developers are still at the early research stage. The US and China are particularly active in developing wave energy technology. In the US, Northwest Energy Innovations tested a half-scale device at the US Wave Energy Test Site (WETS) in 2015 and a full-scale system was deployed in 2018. US Ocean Power Technologies (OPT) has a contract to supply Oil & Gas Company, Premier Oil, with one of its PowerBuoy systems for deployment in an oil and gas field in the Central North Sea. US Columbia Power Technology has plans for open-water demonstration of their WEC at WETS in 2021. In China, many WECs are being developed and tested, including the Guangzhou Institute of Energy Conversion 100 kW ‘Sharp Eagle’ WEC, which was deployed in Wanshan Islands in 2015, with its next generation 260 kW version combining wave, solar and desalination deployed in 2018.

The global potential for wave energy is clearly recognised and many countries have active and ambitious programmes for wave energy development. The UK, as an early sector leader, has accumulated most experience from the deployment of various WEC prototypes, and with strategic investment could retain this advantage in what is set to become an important global sector for our energy future.

References

1. IEA (2019), "Global Energy & CO2 Status Report 2019", IEA, Paris https://www.iea.org/reports/global-energy-and-co2-status-report-2019.
2. Mehmet Melikoglu, Current status and future of ocean energy sources: A global review, Ocean Engineering, Volume 148, 2018, Pages 563-573, ISSN 0029-8018.
3. EIA, 2017. EIA International Energy Outlook 2016-Chapter 5 Electricity, Report Number: DOE/EIA-0484(2016), Release Date: May 11, 2016 The U.S. Energy Information Administration (EIA) (2017).
4. Eugen Rusu, Florin Onea, A review of the technologies for wave energy extraction, Clean Energy, Volume 2, Issue 1, June 2018, Pages 10–19, https://doi.org/10.1093/ce/zky003
5. IRENA (International Renewable Energy Agency) (2014), Wave Energy: Technology brief, International Renewable Energy Agency, June 2014.
6. EPRI, 2011. Mapping and Assessment of the United States Ocean Wave Energy Resource. EPRI, Palo Alto, CA: 2011. 1024637.
7. IEC (Industrial Economics, Incorporated), (2014). Marine Sector Analysis Report: Marine Renewable Energy (Report No. SC 14-327). Report by Industrial Economics Inc.
8. Marine Renewables Canada (2018). 2018 State of the Sector Report: Marine Renewable Energy in Canada. Report by Marine Renewables Canada.
9. António F. de O. Falcão, Wave energy utilization: A review of the technologies, Renewable and Sustainable Energy Reviews, Volume 14, Issue 3, 2010, Pages 899-918, ISSN 1364-0321.

1.3.2. Tidal Energy range

Tidal range uses the difference in sea level between high and low tides to create power. Tidal range technology uses the same principles as conventional hydropower, and requires a barrier to impound a large body of water, driving turbines generating electricity. Tidal range is the more established ocean energy technology, with several projects generating power around the world.

With a long coastline, China has abundant tidal range resources. According to the results of "908 survey" in 2004, there are 171 potential sites that can build tidal range plant of more than 500 kW along coast of China, with a theoretical installed power of about 22.83 GW totally.

In the development of tidal range energy, from 1955, China began to build small tidal range plants. Till the 1980s, China built more than 70 of them, becoming the country with the most tidal range plants in the world. However, some of above plants were built in the political movement, which was restricted by times background and lacked rigorous scientific support. Most of these plants were shut down after only a few months or even a few years due to improper site selection, equipment failure, navigation conflict, sedimentation and other reasons. Among them, there were 8 plants operating for a long period (10 ~ 30 years) in China, which are shown below. The total installed power of these plants exceeded 6 GW and the annual generating capacity exceeded 10 GW·h. Unfortunately, most of these plants have also been shut down so far due to the significant decline in economic benefits and the restrictions on feed-in tariffs. Only two tidal range plants, Jiangsha and Haishan in Zhejiang Province, are still in operation.

Table 1 Basic information of tidal range plants in China

Tidal range Plant	Location	Operation Year	Install power /MW	Tidal range /m	Operation mode
Shashan	Zhejiang	1959	0.04	N/A	N/A
Yuepu	Zhejiang	1971	0.15	3.6	Ebb only
Haishan	Zhejiang	1975	0.25	4.9	One-way
Liuhe	Jiangsu	1976	0.15	2.1	Two-way
Baishakou	Shandong	1978	0.64	2.4	One-way
Jiangxia	Zhejiang	1980	4.10	5.1	Two-way
Xingfuyang	Fujian	1989	1.28	4.5	Two-way
Wanguozishan	Guangxi	N/A	N/A	N/A	N/A

At present, Jiangxia is the largest tidal range plant, as shown below, in China with an installed power of 4.1 MW, ranking fourth in the world. Since it was connected to the grid in 1980, this plant has been in good operation, experiencing many technical improvements with the support of many government departments. In 2016, a 700 kW two-way tidal turbine was developed and tested, as shown below, the maximum efficiency of the turbine is 88.7% for forward generation and 83.2% for reverse generation.

1.3.3. *Tidal Energy current*

Tidal stream turbines harness the flow of the currents to produce electricity. Tidal turbines can be fixed directly to and mounted on the seabed, or tethered/moored to the seabed and buoyant, floating on surface or in mid water.

The UK is currently home to 22 tidal device developers. Scotland is delivering the world's first tidal arrays. The MeyGen (www.meygen.com) project is the largest tidal current project under development in Europe. When fully constructed, the project will deliver 398MW of tidal power. In its first stage (Phase 1A) the project has deliver the installation of four 1.5MW turbines offshore as well as the construction of the onshore infrastructure. Three of the turbines were supplied by Andritz Hydro Hammerfest and one Lockheed Martin-designed turbine supplied by Atlantis.

Orbital Marine's SR2000 tidal turbine, a 2MW floating device, produced outstanding performance results whilst deployed at EMEC, including a load factor of more than 38% in the first 24 hours of continuous operation. Over its test programme the SR2000 exceeded projected performance, producing over 3,200MWh of electricity, more than the total generation of every marine energy device before this date.

Tidal stream technology is at a stage along its development path which requires full-scale demonstration projects supported by the right policy and economic conditions. It is expected that the demonstration farms phase will be underway by 2020, by which time around 100MW of capacity could be deployed in Europe alone. The tidal stream sector should therefore strive to deploy ten farms of 20MW to 30MW with devices laid out in several arrays across Europe by the mid-2020s.

China has a long coastline of up to 18,000 km, along which the large number of headlands and channels are usually with strong tides. These areas are rich in tidal current resources and have the potential of resource development. This part summarize the current situation of China's tidal energy technology from three aspects: resources, policies, research status.

Resources

In terms of resources, China has conducted three national assessments, which were conducted in 1986, 2004 and 2010 respectively. The results of which are shown as below.

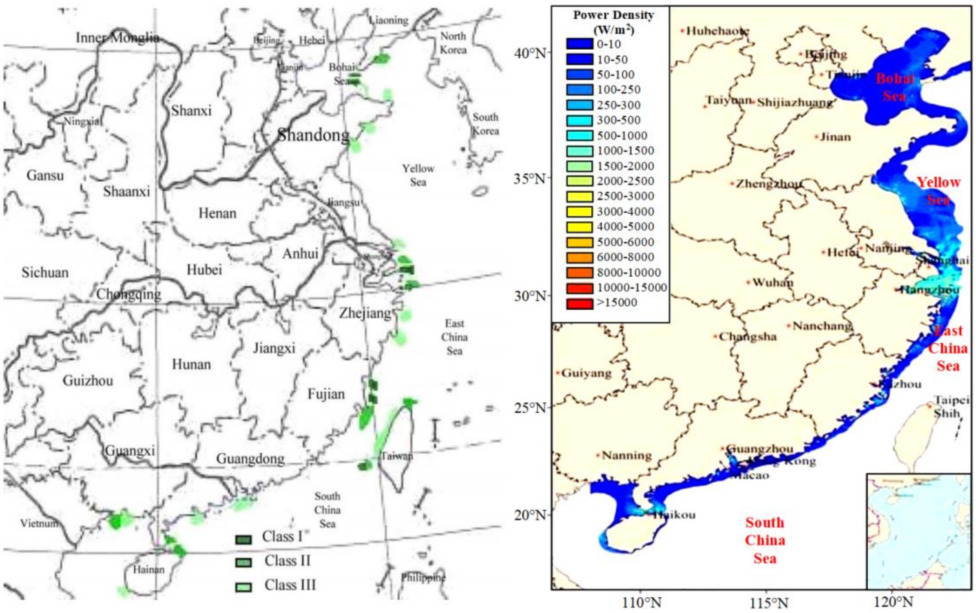
Table 2 National surveys of ocean renewable energy

No.	Execution Time	Assessment department	Assessment areas	Tidal current energy resource reserves
1	1986	MWCEP① and SOA ②	130 channel	13.96 GW
2	2004	SOA②	99 channel	8.33 GW
3	2010	SOA②	75 channel	5.56 GW

① Ministry of Water Conservancy and Electric Power

② State Oceanic Administration

According to the three national assessments, the tidal current resources in China are mainly distributed in the East China Sea, especially in the Zhoushan Archipelago, where tidal energy resources account for more than half of the national total. Other areas, including Qiongzhou Strait, Chengshantou and other areas also have sporadic distribution, as shown below. Although the above assessment results have some differences due to assessment methods, the total amount of tidal current resources in China is undoubtedly considerable.



(a)Maximum spring tidal velocity（2）Average power density

Figure 4. Distribution of tidal current resources (Class I: Vm⩾3.06; Class II: 2.04⩽Vm < 3.04; Class III: Vm < 2.04).

Policies

In terms of policies, SOA issued guidelines and policies on development of tidal energy resources and marine energy generation technologies in December 2016, and continued to invest a large amount of funds in the development and utilization of tidal current energy. By the end of April 2017, China had invested nearly 150 million USD in more than 100 marine energy projects to support the research on the development and utilization of such energy, among which the input of tidal current energy and wave energy accounted for more than half of the total investment. In addition, a number of national tidal current energy test sites are under construction, including tidal stream energy test site in Zhoushan, Zhejiang and National shallow sea comprehensive test site, which are expected to be operational by 2020, as shown below.

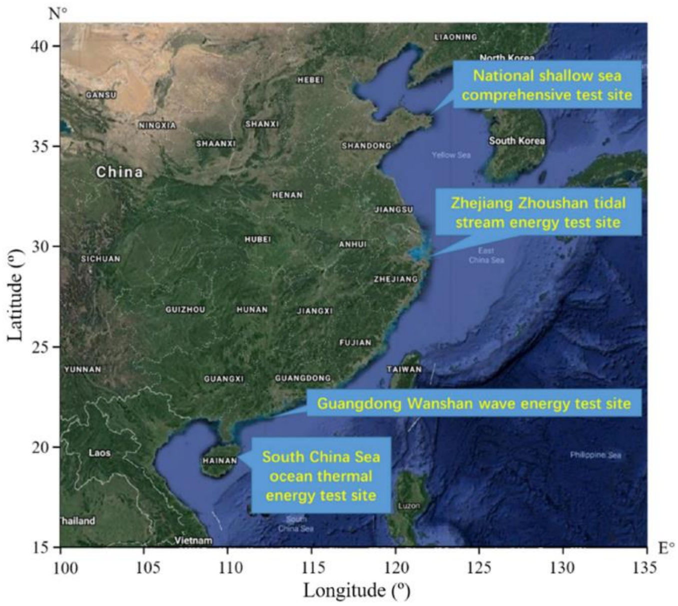


Figure 5. Marine renewable energy test sites

Research status

So far, many research institutions and companies has been carried out a lot of researches on tidal current energy technology. In Zhoushan Archipelago, Zhaitang island, Chengshan Cape and other tidal current energy resource areas, field measurements have been conducted, with a number of demonstration projects and sea trials of full-scale TECs. According to the analysis results, researches on this technology in research institutions mainly focuses on Zhejiang University (ZJU), Harbin Engineering University (HEU) and Ocean University of China (OUC), etc; in companies mainly focuses on LHD Co., China National Offshore Oil Corporation (CNOOC) and China Guodian Corporation (CGDC), etc.

In terms of device development, there are mainly four types of TEC developed in China, including horizontal-axis turbine, vertical-axis turbine, oscillating hydrofoil and vortex-induced vibration TEC. The specific development is as follows,

Horizontal-axis turbine. In this type device, the main research institutions include ZJU, Northeast Normal University (NENU) and OUC. At present, the maximum installed power of a single turbine has reached 650 kW, and the rotor diameter exceeds 15 m, as shown below. The power efficiency of these devices, which have been tested at sea in recent years, has exceeded 40%.

(a) 600 kW of ZJU (b) 300 kW of NENU

Figure 6. Horizontal-axis turbine

Vertical-axis turbine. In this type device, the main research institutions include HEU. At present, the maximum installed power of single turbine has reached 150 kW and the rotor diameter has reached 6 m, as shown below.The power efficiency of such devices, which have been tested at sea in recent years, has exceeded 25%.

Figure 7. Vertical-axis turbine of HEU

Other types. A number of other type devices are being developed and tested, including vortex-induced vibration TEC**Feil! Fant ikke referansekilden.** and oscillating hydrofoil. However, compared with horizontal and vertical-axis turbines, such devices have a low development maturity and are mostly in the stage of laboratory testing and numerical simulation.

In general, since May 2017, a total of 6 tidal current energy projects have been accepted and 3 new tidal energy projects have been supported. The overall technology is close to the international advanced level. China has become one of the few countries in the world that have mastered the technology of large-scale tidal current energy development and utilization. By the end of 2018, total installed capacity of TECs is 2.86 MW, and cumulative generating capacity exceeded 3.5 million kW·h

1.3.4. Salinity

Salinity gradient power generation utilises the difference in salt content between freshwater and saltwater, found in areas such as deltas or fjords, to provide a steady flow of electricity via Reverse Electro Dialysis (RED) or osmosis. Deployment potential is significant around Europe, however, further technology development is required to bring salinity gradient to maturity.

Salinity gradient is in the R&D phase, with up-scaling to megawatt prototypes expected around 2020. While still research driven, the technology could grow rapidly and become increasingly commercial. The development of a 50MW demonstration plant by mid-2020s is a necessary step towards subsequently deploying a first full-scale (200MW) plant. If successful, module salinity gradient storage solutions could be developed and used worldwide in combination with other renewable energy systems by 2030.

1.3.5. OTEC

Ocean Thermal Energy Conversion (OTEC) exploits the temperature difference between deep cold ocean water and warm surface waters to produce electricity via heat-exchangers. OTEC is suited to oceans where high temperature differences will yield the most electricity. A number of demonstration plants are being developed in EU overseas territories opening up export opportunities.

The construction of a 14MW OTEC project (NEMO) in Martinique, France, demonstrates the potential for the EU to develop a technology and know-how for export around the world's tropical regions. Moreover, the potential for high average availability factors could rapidly lead to significant reductions in cost of energy.

The OTEC sector should connect up to 20MW of scaled prototypes by the early 2030s, leading to the demonstration of full-scale power plants of around 100MW.

Subsequently, OTEC technology could be rolled-out industrially taking advantage of the export markets.

1.4. Offshore Wind Technologies

1.4.1. Fixed Offshore Wind

Offshore wind power or offshore wind energy is the use of wind farms constructed in waters, usually in the ocean on the continental shelf, to harvest wind energy to generate electricity. Over the past 25 years offshore wind technology has developed rapidly, with the first commercial plant beginning operation in Denmark in the early 2000s.

The commercial development of offshore wind has so far been based on bottom-fixed foundations. The use of relatively low-cost monopile foundations has been the offshore wind industry standard for the majority of the projects installed in water depths of less than 50 m. Monopiles are the most popular foundation choice, but there is a variety of foundations being utilized, including jackets, multi-piles, gravity bases, and suction bucket foundations.

The global offshore wind market grew nearly 30% per year between 2010 and 2018,benefitting from rapid technology improvements. Over the next five years, according to the IEA about 150 new offshore wind projects are scheduled to be completed around the world, pointing to an increasing role for offshore wind in power supplies.

Technology innovation has led to an increase in turbine size in terms of tip height and swept area contributing to larger production. The tip height of commercially available turbines increased from just over 100 metres (m) in 2010 (3 MW turbine) to more than 200 m in 2016 (8 MW turbine). Through technology innovation, turbine original equipment manufacturers have been able to limit the rise in turbine cost and manage the increase in mass to allow turbine growth to continue upward in the next decade.

Figure 8. Fixed Offshore Wind

1.4.2. Floating Offshore Wind

With floating structures, wind power can expand into new deep-water areas, often further from shore, opening vast new areas and markets currently unavailable for offshore wind. Floating structures are also less intrusive to the sea bed than bottom fixed structures, and provide the potential for increased standardisation and mass-production.

Floating offshore can harness untapped wind resources located in regions with water depths exceeding 50-60 m where traditional fixed-bottom offshore wind installations are not economically attractive. The industry is adapting various floating foundation technologies that have already been proven in the oil and gas sector. There are three main concepts for floating foundations: spar-buoy, semi-submersible and tension leg platforms.

In recent years, there have been significant developments in floating offshore wind

projects including the commissioning of the world's first multi-unit installation in 2017 the 30 MW Hywind in Scotland. A number of smaller demonstration projects were installed in in the past year in France and Japan. In addition, at least ten new pre-commercial scale projects in Europe are in the pipeline (WindEurope, 2017), including the 25 MW WindFloat Atlantic in Portugal and the 50 MW Kincardine in Scotland (IEA). In Norway Equinor has decided to build a floating wind farm of 88 MW to deliver power to existing O&G installations together with the owners of these installations.

2 MARINE RENEWABLE ENERGY SYSTEMS AND THE 2030 AGENDA FOR SUSTAINABLE DEVELOPMENT

2.1. Ocean Energy Technologies

2.1.1. Europe

Europe is regarded as one of the key players in the development of wave energy and it has been suggested that the next step on the road to commercialisation is the demonstration of wave energy farms in the range of 10 megawatts (MW). Due to the limited commercial deployments of prototype wave generation devices in the past, the estimates for levelised cost of electricity (LCOE) of wave energy technologies in 10 MW demonstration projects is in the range of EUR 330-630 per megawatt-hour (/MWh) (IRENA, 2014). However, as research and development advances and with the deployment of additional installations, the projected LCOE for wave energy in 2030 is estimated to be in the range of EUR 113-226/MWh for harvesters with capacities in excess of 2 gigawatts (IRENA, 2014). In order to continue the proof of concept work the sector will continue deployments of prototype WECs in small arrays of 10 MW, close to shore or on specific testing sites (European Commission, 2020).

To achieve reasonable profitability will require additional research on the constituent elements comprising the harvester installations. Not only is it necessary to improve the output efficiencies but also, the technology must be made more robust to extend the design lifetime duration. Presently a large number of studies are being under taken to augment the power take off systems that may currently account for up to 22% of project life costs. In particular, the focus is on efficiency improvements in air turbines (currently 50-60% efficient), (IRENA, 2014), and in the hydrodynamic performance of the fluid structure interactions. Another solution to reduce costs and to make the wave energy sector more attractive to potential investors is through cost sharing endeavours wherein the wave energy harvester is combined or integrated with another structure or technology. For example, current studies are being undertaken to determine the feasibility of integrating wave energy harvesters with floating wind turbine platforms or combining harvesters with coastal protective structures such as breakwaters. In this manner, the installation and maintenance costs can be offset or vastly reduced. Europe is one of the global leaders in the development of wave energy technology; this is partly due the high wave energy density along its west coast. Nevertheless, other regions such as China, the US and Australia are investing considerably in the development of wave energy ((European Commission, 2018) . Some of the better-known wave energy plants or technologies developed within Europe are outlined in Table 1 below.

To address the technical challenge, in the UK the Wave Energy Scotland (WES) funding scheme is regarded as a powerful tool that could be used more widely by governments and funding authorities. The WES 'Novel Wave Energy Converter Projects' competition winners, 'Blue Horizon' from Mocean Energy, and Archimedes 'Waveswing' from AWS Ocean Energy, will both be tested at EMEC in 2020 (Mwasilu F, Jung J W, 2018). The Australian company Bombora secured £10.3m of Welsh Government European Funding in 2018 to deploy their WEC in Pembrokeshire, Wales (Bombora, 2019). WaveSub, from Welsh company Marine Power Systems, is supported by a £12.8m grant from the Welsh Government to test a full scale WaveSub at sea in 2022. Most of the devices aforementioned are designed for large scale in-grid generation, but alternative smaller scale off-grid requirements are also being investigated. Albatern are working with aquaculture companies to supply power to working fish farms using their 7.5 kW 'WaveNet' WEC to replace diesel generation (Albatern, 2016) . Mocean Energy developed 'Blue Star' to power a range of sub-sea applications, from subsea control systems to fully autonomous underwater vehicles and has attracted funds of £200,000 from Scottish Enterprise and the Oil and Gas Technology Centre in Aberdeen for the development.

Although still dominated by start-up wave energy companies, other engineering firms and utilities are entering the market. Saipem and Wello Oy have signed a memorandum of understanding to enhance the Penguin WEC2 technology. Utilising their long experience in offshore engineering, Saipem will support Wello Oy to optimize the installation procedure and operability of their WEC. CorPower have signed a Strategic Collaboration Agreement with Simply Blue Energy to develop a number of significant wave energy projects off the coasts of the UK and Ireland. With the experience of offshore wind, Simply Blue Energy will also investigate the development and deployment of combined floating wind and wave energy farms. This is to explore opportunities to reduce costs and increase output by dovetailing the variations in resource availability between wind and wave energy.

Country	year	Project	capacity
Denmark	2003	Wave Dragon	Prototype
UK	2004	Pelamis	750kW
Portugal	2004	Archimedes Wave Swing2	2MW
Finland	2009	WaveRoller	300kW
Scotland	2011	Oyster	800kW
Spain	2011	Mutriku power plant	296kW
UK	2016	Oceaunus2	162kW

Table 3. European wave energy projects

2.1.2. China

China has attached great importance to the development and utilization of Marine Renewable Energy. Since 2010, in total, 114 projects have been approved and three marine energy test fields and demonstration bases have been built. This has been achieved with the support of the special fund for Marine Renewable Energy at a total cost of 1.3 billion yuan. Since May 2017, 6 wave energy projects have passed acceptance checks and 4 new wave energy projects have been approved for financial support. A number of technologies with small power generation capacity have been developed and of these, about 30 devices completed the sea trials. By the end of 2018, China's wave energy plant installed capacity was rated at over 0.2 megawatts and over 150,000 kW·h of electricity was produced.

As one of three test demonstration bases, the Wanshan Wave Energy Test Field and Base will be built as a public testing system, in which private firms can develop their technologies. The devices that will undergo testing include three Sharp Eagle WECs with rated capacities of 350 kW and one imported WEC with a rated capacity of 50 kW.

2.1.3. USA and Canada

According to a recently published report, the bureau of ocean management (BOEM) has approved a large wave energy test site in Oregon (IEC, 2014). Funding is provided by the Department of Energy (DOE). This will be a grid-connected facility where consortia can develop their prototype designs. Other current projects that are being financed by the DOE include Columbia power technologies' development of a largescale wave energy-harvesting device in Washington State and CalWave Power Technologies design of advances submersible Wave energy convertors. Some further wave power schemes and the details of their electrical power generation capacity are outlined on Table 4 below.

PROJECT STAGE	NUMBER OF PROJECTS	TYPES OF PROJECTS	CAPACITY (MW)	PROJECT TITLE AND DESCRIPTION
Issued Preliminary Permits	5	1 tidal 1 wave 3 inland	8.2	n/a
Pending Preliminary Permits	16	4 tidal 5 wave 7 inland	3969.0	n/a
Projects in Pre-Filing for License	3	2 tidal 1 wave	25.1	• P-12665 New York East River (NY) Tidal Pilot (0.2MW) • P-13015 Muskeget Channel (MA) Tidal Pilot (4.9MW) • P-14616 Pacific Marine Energy Test Center South Energy Test Site (OR, Outer Continental Shelf) Wave Test Center (20MW)
License Issued	1	1 wave	1.5	P-12713 Reedsport OPT Wave Park (OR) Wave Commercial (1.5MW)
License Issued for Pilot Projects	4	3 tidal 1 river	2.5	• P-12611 Roosevelt Island (NY) Tidal Pilot(1.5MW) • P-12690 Admiralty Inlet (WA) Tidal Pilot (1.0MW) • P-12711 Cobscook Bay (ME) Tidal Pilot (0.3MW) • P-13305 Whitestone Poncelet (AK) In-River Pilot (0.1MW)
Source: FERC 2014.				

Table 4. Wave energy Projects in the US, (IEC, 2014).

The extractable wave energy potential along the Canadian coastline is estimated to be 10-16 GW, (Marine Renewables Canada, 2018). The West Coast Wave Initiative project (WCWI) is one of the leading ventures for the development of wave energy in Canada. The project is committed to increasing the contribution of wave power to the overall proportion of renewable energy consumed. NeptuneWAVE, has recently developed and deployed a 200 kW wave energy harvester in 2018 off the West coast of British Colombia in Canada.

2.2. Offshore Wind Energy Technologies

2.2.1. Global/EU

While offshore wind provides just 0.3% of global electricity supply today, it has a large potential and is expected to play an important role in the broader energy system.

Offshore wind market projections show accelerated growth, with cumulative capacity ranging from 165 to 225 GW by 2030, and long-range predictions for 2050 in the order of 500 GW (BNEF) to 1000 GW (IRENA).

Over the past years Europe has been where by far most of the of offshore wind installations have taken place. However, over the next years, Asian countries will represent an increasing share of the activity and is expected to be dominating the markets in the longer term.

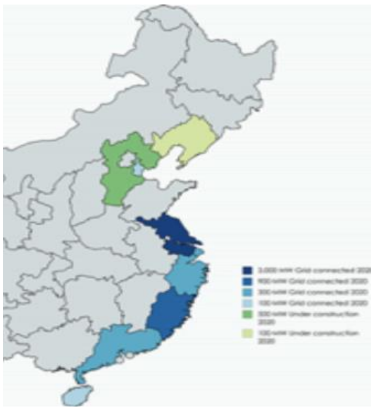
According to the IEA European Union and China account for 70% of the global offshore wind market to 2040, but a number of countries will enter the market and increase their capacity

2.2.2. China

The Guangdong, Jiangsu and Fujian provinces represent over 80% of development in the next two years. Jiangsu and Fujian in particular represent the immediate market. However, other regions such as Guangdong, Shandong and Zhejiang are expected to be GW-scale markets by 2020-2025, and the OSW sector is expected to emerge in a range of other provinces by 2020, including Hainan, Hebei, Liaoning, Shanghai and Tianjin. National targets for the regions are outlined in the China 2020 Offshore Wind Development Plan. These are outlined below.

Provinces have also set out regional OSW development plans, many of which are significantly more ambitious than national targets. For example, Guangdong province has developed the Guangdong Sea Wind Development Plan (2017-2030). This sets a target for a total installed capacity of 12 GW by 2020 (of which 2 GW will be operational) and an ambitious target of 30 GW installed by 2030.

Notably, Shandong province is not named within the national targets, but there are significant provincial targets in place. The Shandong province OSW development plan is targeting 28.6 GW, but the timing on delivery of this is unclear. Given the level of activity in OSW in this province, there is potential that the national plan will be adjusted to include this.



Region	Currently operational (2018) (MW)	Grid con-nected by 2020 (MW)	Under con-struction by 2020 (MW)
Tianjin	-	100	200
Liaoning	-	-	100
Hebei	-	-	500
Jiangsu	1,400	3,000	4,500
Zhejiang	200	300	1,000
Shanghai	300	300	400
Fujian	150	900	2,000
Guangdong	1,200	300	1,000
Hainan	-	100	350
TOTAL	2,170	5,000	10,050

Figure 9. China 2020 offshore wind development targets (NEA, 2016)

Key provinces:

1. JIANGSU

Jiangsu is the most prominent Chinese province in the OSW wind sector. It boasts the largest operational capacity to date (1.4 GW) as well as the largest national target for development by 2020. This represents 60% of the national target. Ten projects, totalling 2.75 GW (as of April 2018), have been approved for construction during 2018-2019 with construction expected to begin before September 2019.

There is a fairly well-established supply chain in the province, including turbine manufacturer Goldwind’s industrial base. Due to the significant build-out of projects to date, there are relatively high-level local capabilities in the construction and installation supply chain, including developers and design engineers. However, as the build-out rate increases, it is expected that bottlenecks may appear for which overseas support may be required. Jiangsu is expected to remain the most prominent province in OSW until post-2020, when other provinces are likely to reach similar capacities.

2. FUJIAN

Fujian target installed capacity rises from 0.9 GW and 1.1 GW under construction in 2020 to 7 GW installed by 2030. As of March 2018, only 0.15 GW is operational, with 0.4 GW under construction. However, five more projects are due to begin construction in 2018 with another 12 projects approved for construction.

Initial development in the region has been slower than anticipated due to challenging seabed conditions and typhoons. A report commissioned by ORE Catapult suggests that as a result there is a strong appetite in the region for inward investment by European companies who can help address these issues, accelerate the market and build local capabilities.

China Three Gorges is the leading developer in the region. There is extensive industrial capability within the region and a key provincial company, the Fujian Shipbuilding Industry Group, is positioning itself to take advantage of opportunities within its competency. The region is considering a centralised O&M hub in Putian.

3. GUANGDONG

Guangdong’s offshore wind sector is expected to undergo significant growth after a relatively slow start. OSW development in the province began in 2016, with the construction of its first demonstration project. It has a very high level of ambition in OSW. It has announced plans to approve or begin the construction of 10 projects totalling 3.65 GW in 2018. As of March 2018, 1.6 GW of this was in construction. The Guangdong Sea Wind Power Development plan also aims for 12 GW to begin construction by 2020.

Projects are planned for both shallow (<35 m) and deep water (30-50 m) sites. In total, 15 projects are in planning in shallow water sites and 8 in deep water sites. When added to the 1.6 GW in construction, this represents an enormous total of over 66.85 GW, which alone represents more capacity than the UK's target of 50 GW OSW by 2050.

Guangdong is highly focused on becoming an industrial base for OSW in China. Activities and economic development are focused around the city of Yangjiang. Yangjiang has an existing manufacturing base, mainly focusing on metal manufacturing (particularly knives and scissors). The mission went to Yangjiang as part of a wider UK OSW delegation visiting the city. The existing cluster of OSW industry in the region includes major developers such as the Three Gorges Group, CGNC, China Energy Conservation Group and Guangdong Electric Group, and turbine manufacturers such as Mingyang Smart Energy's industrial base for OSW.

References

1. IRENA, 2014. Ocean Energy Technology Brief. https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2014/Wave-Energy_V4_web.pdf.
2. European Commission, 2020. An EU Strategy to harness the potential of offshore renewable energy for a climate neutral future. https://ec.europa.eu/energy/sites/ener/files/offshore_renewable_energy_strategy.pdf.
3. European Commission, 2018. Low Carbon Energy Observatory. https://publications.jrc.ec.europa.eu/repository/bitstream/JRC118296/jrc118296_1.pdf.
4. Mwasilu F, Jung J W. Potential for power generation from ocean wave renewable energy source: a comprehensive review on state-of-the-art technology and future prospects. IET Renewable Power Generation, 2018, 13(3): 363-375.
5. Albatern, 2016. Albatern and AquaBioTech Aquaculture & Wave Energy Combination. http://maribe.eu/wp-content/uploads/2016/11/b-4-albatern-and-abt-final-report-abt.pdf.
6. Bombora, 2019. Wave Marine Energy Device and Onshore Infrastructure. https://cdn.naturalresources.wales/media/689423/chapter-1-mwave-introduction.pdf.
7. National Energy Administration (NEA), 2016. The 13th Five-Year Plan for Wind Power Development. http://www.nea.gov.cn/135867633_14804706797341n.pdf.

3 TECHNOLOGY-SPECIFIC PRIORITY NEEDS

3.1. Installation/ O&M / Decommissioning

The installation, operation and maintenance of ORE equipment is an important part of engineering application. As the installation and operation of ORE equipment has become a challenge to be solved considering the constraints regarding costs for installation and in-service maintenance. China is expecting its oil and gas base to adapt to take over offshore installation and maintenance roles, as has happened in Europe. A number of companies are already developing experience in the sector, including the Chinese Offshore Oil Engineering Co, Nantong Ocean Water Conservancy Engineering Co and Jiangsu DoaDa Heavy Marine

Industry. Take the current situation of offshore wind (OSW) in China: to date, a number of Chinese OSW sites have used an “assemble at port” technique, whereby the turbines are assembled shore-side and then shipped assembled to the installation site. This requires large bespoke vessels and very calm conditions. As turbines get bigger, sites get further offshore and demand for vessels increases, it is expected that Chinese developers will move to an “assemble offshore” approach, as typically used in Europe. In addition, as the majority of Chinese sites are very near-shore, a shore-based CTV (crew transfer vessel) approach is typically adopted. European operators have been forced into other strategies, such as SOV (service operations vessel) as development sites move further offshore.

3.2. Testing & Demonstration

A demonstration strategy is a key part of an overall risk-based consenting approach as demonstration projects provide an opportunity for addressing some of the scientific uncertainty surrounding the licensing of marine renewable developments. The proposed Atlantic Demonstration Strategy seeks to move the ocean energy sector from a state where there is limited or no empirical data to sound science consenting through the collection of empirical data. It will provide a long-term strategy for the demonstration of ocean energy developments in the Atlantic Area and will build on the current pioneering projects in this area and consider what support will be required to enable further demonstration projects across the Atlantic Area. The demonstration strategy should seek to provide answers to the environmental unknowns for ocean energy technologies and to promote the use of best available techniques such as use of sonars, videos, tagging and strategic survey. It should also consider support for further demonstration of monitoring techniques / technologies.

The proposed demonstration strategy will not only assist in the consenting of future marine renewable developments, but also assist future demonstration strategy projects by providing a protocol through which empirical data can be collected in the future to characterise the likelihood of collision risk impacts from tidal turbines and other ocean energy technology developments. Without this progressive research, it will prove difficult to consent with confidence further marine tidal turbine developments where there is potential for significant marine mammal interactions, without the potential for onerous restrictions which risks making future projects unviable.

Concerns with respect to the potential impact of tidal turbines and other ocean energy developments on marine mammals arise from the potential for mortality or injury through collision with turbine rotors or other moving parts within an ocean energy development array. To evaluate these risks there is a clear need to improve understanding about whether animals can perceive the impact risks associated with these devices and whether they take appropriate macro, meso and micro avoidance action to avoid collisions.

A series of geographically discrete and technology specific sites will also be considered as future demonstration strategy projects to trial ocean energy development environmental performance and/ or the effectiveness of mitigation techniques such as the use of acoustic deterrent devices to deter marine mammals (and fish) from entering ocean energy arrays. See Table below for a preliminary list of potential sites for consideration.

The demonstration work, proposed at the MeyGen site in the Pentland Firth, Scotland will provide initial empirical data on animal movements which will form the basis of an understanding of close range encounters including collision and avoidance rates and an analysis of marine mammal behaviour responses to an operating tidal turbine.

The proposed strategy will provide much needed empirical information on key environmental unknowns, including the likelihood that marine mammals will avoid/collide with tidal turbines. These data will be used to produce empirically derived estimates of collision risk for operating tidal turbines at the micro and possibly meso scale which will form the basis of advice to decision makers on parameterising collision risk models for future assessments, and will ultimately inform the consenting of marine renewable developments.

Given the sector wide benefits of such learning, collaborative funding of such studies should be explored. Provision of public sector funding will, in addition, help ensure unrestricted dissemination of results and analysis reporting to establish species avoidance and other impact assessment methodology reporting. A demonstration strategy approach should reduce the burden on early or initial developers which socialize the costs of intensive monitoring, the development of monitoring devices and the collection, analysis and conversion of empirical data to underpin the production of impact models and methodologies. The overall Demonstration Strategy should also be used to better explore if meso and macro avoidance is being applied by marine animals and if mitigation techniques are required and how these can be field tested and applied.

To reduce the risk of significant device failures in the demonstration phase, device sub-systems and components should be tested and effectively validated prior to use on full-scale devices. To address this, Wave Energy Scotland put in place a programme for wave devices allocating funding through a phase-gate process: each stage of development is only funded once the stage before is fully tested and validated.

A similar approach could be used at EU level to stimulate advances in less mature ocean energy technologies that are not yet demonstration ready, by funding critical component and early stage device development and testing before full-scale demonstration.

The demonstration stage is characterised by multiple grid-connected devices or fully functional down-scaled plants deployed in real sea conditions. Usually considered “R&D Phase 2”, this is the demonstration phase and does not have to be commercially viable. OTEC and salinity gradient plants at this stage will be scalable.

From this stage onwards, wave and tidal devices are installed as pre-commercial arrays suitable to inform future large commercial farms. These arrays optimise space usage and resource extraction, and should be connected to a hub or substation feeding electricity to the shore.

In the demonstration and pre-commercial phases, considerable uncertainty about both revenue from power production and maintenance costs means financial risk remains high and transition to a pure revenue support dominated mechanism is premature. Upfront capital to support investments therefore, remains essential.

This upfront capital no longer needs to be grant-only. It can take the form of public equity, public debt, repayable loans or even access to low cost finance (e.g. zero or low interest loans) provided lending criteria are suitable for high-risk projects.

Revenue-based support schemes can and should commence to give long-term visibility and confidence to investors and reduce the cost of capital. Short-term or short-lived support schemes do not give market players the visibility required for long-term energy investments.

3.3. Reliability/Condition monitoring/survivability

In general, perception of technical risk is dependent on how confident the investors are that marine energy devices will perform their required functions under stated conditions for a specified period of time. In order to achieve this reliability, it is important not only to predict the life of a product, but also to investigate and take into account the sources of variability and their influence on the service life. Similar to any other industry, reliability design for marine renewable technologies had been addressed in reliability and robust design methodologies as well as methodologies like design for six Sigma, design for variation and failure mode avoidance.

There are also specific design guidelines that focus on reliability of wave and tidal technologies. Reliability is identified as a key aspect in ‘Guidelines on design and operation of wave energy converters’ in the development of wave energy devices. A specific framework is given in ‘State of the Art Descriptions and Tasks for Structural Design of Wave Energy Devices’. Several methods are being used in reliability assessment, such as Life Cycle Costing (LCC), Fault Tree Analysis (FTA), Reliability Block Diagram, Failure Modes and Effects and Criticality Analysis (FMECA) and Reliability Centred Maintenance (RCM). However, the specific guidance for marine renewable devices such as wave and tidal are still only provide on a generic level that require further development.

In the meantime, the wave and tidal renewable energy industry is still consider to be at the pre-commercial stage, field testing and demonstration at various scales will be a primary focus for the sector in the foreseeable future. This require test centres to put in place a rigorous testing programme whereby the reliability of the relevant emerging technologies can be tested and independently verified before they move onto large scale array deployments.

The renewable energy industry is constantly improving in order to cover the increasing demands in power consumption. Companies are competing to take advantage of any evolving opportunity presented. Nowadays one of those remarkable competitive advantages focuses on maintenance management, such as operating and maintenance costs, availability, reliability, safety, service lifetime, etc. emerge. In the offshore wind industry, technologies such as condition monitoring systems (CMS) are increasingly being employed to detect and identify failures/faults at the earlier stages, maximising productivity performance, logistical arrangements and minimising possible downtime. The industry also expects the deployment of CM systems would contribute to the extension of the operational life of renewable energy devices such as wind turbines beyond their nominal design life, which is estimated to be around 20 years.

Despite wind renewable industry's huge success, it is still a significant challenge for wind farm owners and operators to accurately estimate the remaining service life of their assets. The data required for such analyses is generated by the on board condition monitoring systems (CMS) and structural health monitoring (SHM) systems. Towards the end of life, this data will be critical to make the business case for life extension.

Conventional condition monitoring (CM) and structural health monitoring (SHM) techniques have been relatively well established in offshore wind turbines. However, it's challenging using current SHM technology within sophistic CM system to predict the turbine operating performance and remaining service life because of harsh offshore weather and complex marine environment. With the trend of increasing power capacity and size of wind turbines, the enhancement in advanced technologies of asset health monitoring of reducing component failure, increasing efficiency and operation endurance are more attractive for the offshore wind industry

3.4. Data/Knowledge sharing

Knowledge management plays a significant role in many different kinds of industries to deal effectively with changes, increasing their productivity and paving the way to development and innovation. Following successful data-sharing from earlier generations of offshore wind farms, Ørsted A/S also shared data from a wind farm featuring 6MW turbines. The aim with sharing wind farm data with technical universities is to further improve wind farm design and inspire future engineers to join the green energy industry. Sharing this data has led to improvements of wind-flow modelling and monitoring of wind turbines.

3.5. Spatial availability/Infrastructure

Sound infrastructure is the foundation for promoting technological development. At present, China's infrastructure is increasingly mature, but it needs to be further improved. Historically much of the design work for partial ORE equipment like wind turbines and windfarm infrastructure in China was outsourced to, or licenced from, European design houses and this is still the case to some degree. However, China is building mature ORE infrastructure at a rapid pace. For example, specific cities, such as Yangjiang, and provinces such as Shandong and Guangdong, are investing heavily in developing the infrastructure to support inward investment in OSW. These include science parks and industrial areas as well as providing tax and funding incentive for setting up facilities in the region. China is adapting wind turbines and other infrastructure for Chinese wind and seabed conditions at the same time.

3.6. Grid integration/Transmission

Devices, farms and plants must be able to deliver grid compliant electricity. A key missing technological component, fundamental to the development of ocean energy on a large scale, is a central power electronic hub to collect and efficiently transmit electricity from multiple devices to shore through an export cable.

3.7. Barriers/ Game changers (technical [mooring, PTO, materials, manufacturing, etc.))

There are no insurmountable barriers to delivery of the Chinese OSW market. There are a few issues that may have the potential to slow development. These are outlined below.

		China North	China South	Similarity between installed UK projects and Chinese sites
SITE CONDITIONS	Ground conditions	The northern Chinese development region is dominated by soft mud.	The southern provinces have a challenging combination of very deep mud combined with hard rocky out-crops.	Low
	Water depth	Current OSW developments are in relatively shallow water. The initial rounds of developments were generally in <10 m of water and the current round of development is generally in water <30 m. In China, 30-50 m is considered deep water.		Medium
	Distance from shore	The initial round of development has been very nearshore and in the intertidal zones. There is an inevitable move to development of projects further offshore but planned areas are typically <20 km offshore.		Medium
	Wind regime	Average wind speed is low compared to the UK, typically 6.5-8.0 m/s at 80 m height. No issues with typhoons.	The southern provinces of China are subject to typhoon during the annual typhoon season. Average wind speed is higher than in the northern provinces. The Fujian Strait has the highest average speeds in China, at 9-12 m/s. Compared to 9-10 m/s in the UK.	Low
	Geology	Occasional earthquakes.	Southern China is subject to occasional earthquakes.	Low

Figure 10. China site conditions barriers (Innovate UK, 2018)

3.8. Storage (hydrogen, batteries, etc)

Renewable energy harvested offshore faces the same issue faced by most renewable energy resources - intermittency. This applies in equal measure to offshore wind, offshore solar power and power from tidal stream sources. Energy storage has the potential to solve the imbalance problem by absorbing power from renewables when demand is low and supplementing power from renewables when the demand exceeds what can be supplied from the renewable resources. Hydrogen is among the most promising solutions for offshore energy storage. A plan to convert power from offshore wind to hydrogen and store it on the seabed is underway by a multi-company project team that hopes to have a full-scale pilot running off Norway by 2025. It aims to see turbine-level electrolysis feeding seabed hydrogen tanks where output from offshore wind farms can be stored. Fuel cells would then re-electrify the hydrogen to provide a clean source of power for offshore oil and gas platforms, with shipping and seafood among other potential target markets for green electricity produced. 'Green hydrogen' is increasingly being seen as a key tool of the energy transition, potentially offering an large-scale option to store and transport renewable power output.

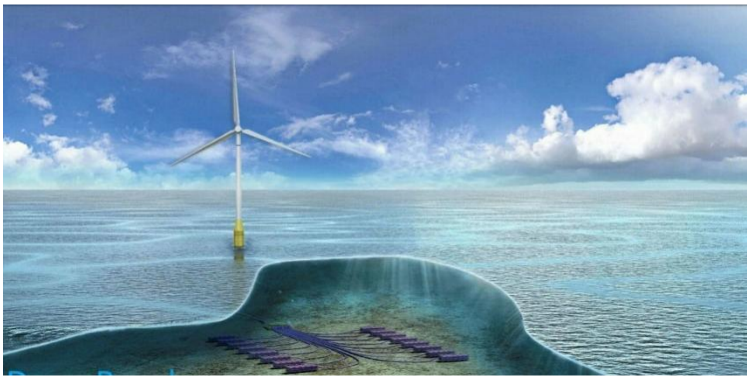


Figure 11. 'Deep Purple' seabed hydrogen storage for offshore wind plan (TechnipFMC, 2019)

4 CROSS-CUTTING TECHNOLOGIES (AS/AI)

4.1. Multi-platforms/combination of technologies

Closer collaboration between the UK and China OSW sectors on innovation has the potential to provide significant opportunities for stakeholders in both countries. As discussed, Chinese stakeholders are keen to use both European technology and experience to both accelerate the Chinese OSW market and better position themselves to access a global market. The Chinese market can potentially offer UK innovators a route to overcoming many of the key barriers faced when commercialising OSW technology in the UK; in particular:

• Finance for later stage development and large-scale demonstration

• Access to OSW turbine manufacturers

• Access to sites/turbine for demonstration.

Through collaboration, Chinese stakeholders can provide a route to the market for UK technology companies.

The diagram below shows the key steps required to bring innovation to market and how the core capabilities of the UK and China map against these. It highlights where the UK can support Chinese OSW technology development and vice versa, and where there is opportunity for co-development.

References

1. Innovate UK, 2018. China Offshore Wind Expert Mission 2018. https://admin.ktn-uk.co.uk/app/uploads/2019/06/2018-China-OSW-Expert-Mission-Report-public.pdf.

2. TechnipFMC, 2019. Deep Purple. https://energyvalley.no/wp-content/uploads/2019/04/Deep-Purple-.pdf.

5 LINKAGES BETWEEN THE MARINE RENEWABLE ENERGY SYSTEMS

5.1. Synergies in delivery mechanisms

It is challenging to draw parallels with, and identify synergies in, delivery organisations in OSW in China and the UK. Innovation policy is highly centrally-controlled and the funding and enabling organisations control budgets many times larger than equivalents in the UK. There is also little in the way of public facilities dedicated to offshore renewable such as we have in ORE Catapult in the UK, although public and private research institutes do exist around wider subject areas and are carrying out work in OSW.

However, regional development agencies, equivalent to Scottish Enterprise and LEPS do exist within the provinces. Mechanisms also exist from MOST, NSFC and regional development agencies for issuing competitive calls for specific innovation or research challenges, similar to those delivered in the UK. Like the UK, the majority of innovation in OSW in China is delivered from within private companies.

Rather than drawing parallels between two quite different innovation landscapes, if assessing delivery mechanisms, it is helpful to review the existing successful mechanisms for innovation collaboration between the UK and China.

5.2. Existing mechanism for innovation collaboration between China and the UK

There is a long-standing positive relationship in innovation between the UK and China and a number of existing initiatives relate to, or could potentially relate to, OSW. The following initiatives were identified during the mission. This is not an exhaustive list.

（1） Joint Strategy on Science, Technology and Innovation

In December 2017, MOST and the UK's Science Minister signed a high-profile collaboration agreement, the UK-China Joint Strategy on Science, Technology and Innovation Collaboration. The strategy outlines a framework for future cooperation between the two countries to jointly tackle global challenges and drive economic growth over the next ten years.

It covers research through to commercialisation across a range of jointly identified challenges, including renewable energy.

（2） Flagship Challenge Programme

One of the core mechanisms for the delivery of the UK-China Joint Strategy Science, Technology and Innovation Collaboration is the Flagship Challenge Programme. In 2018 this focused on agri-security. However renewable energy is a potential Flagship Challenge area.

（3） UK-China Research and Innovation Partnership Fund

As outlined in section 3.2 the UK-China Research and Innovation Partnership Fund is a funding programme that supports collaboration between Chinese and British R&D organisations that issued a call in 2016 to focus on Offshore Renewable Energy Systems.

（4） Industrial Advisory Group (IAG)

The IAG is a working group co-hosted by the UK (Renewable UK) and China (CREEI) that includes representatives of OSW turbine manufacturers, developers and other stakeholders. It meets regularly to discuss shared knowledge challenges and opportunities for collaboration including joint approaches to other global markets.

(5) UK-China Technolology Growth Accelerator

In early 2017, the Offshore Renewable Energy Catapult (ORE Catapult) and TUS Wind, part of TUS Holdings, signed an agreement to establish a UK-China Technology Growth Accelerator. This programme aims to increase technology cooperation between the two countries and support UK SMEs and universities in accessing the Chinese OSW sector.

Specific initiatives under the agreement include:

- UK-China collaborative R&D projects
- An incubator to support SMEs developing technology to access the Chinese market
- Development of an OSW science park in Shandong province
- Collaboration on a 300-500 MW demonstrator project, incorporating 10-15% UK content.

TUS has dedicated a £229 million venture capital fund to support this activity. ORE Catapult is tasked with identifying the most promising UK companies who could benefit from this investment.

Focus areas	Potential for collaboration	Reason for rating
Floating wind	Medium	The UK has a reputation for being ahead in floating wind development. The level of interest in floating is rapidly increasing in both the UK and China.
Fixed foundations and structures design	Medium	The UK has good capabilities in this area, but much of our experience to date is not relevant in the Chinese market as seabed conditions are very different. There is a high level of interest by Chinese developers to use UK expertise. However, feedback suggests that state-run research institutes are keen to develop designs and standards in using domestic capabilities.
Next generation drive train	High	There is an appetite amongst Chinese manufacturers to adopt European technology for the next generation of drive trains. While the majority of the established OSW drive train supply chain is not in the UK, there has been considerable interest from Chinese manufacturers in more innovative concepts from SMEs and new-entrant players. This could be a valuable route to market for these companies.
Next generation drive train manufac-turing	Low	China has extensive experience in the manufacture of large-scale in-dustrial machines.
Development of turbines for low wind regimes	Low	Limited turbine design experience available in the UK. High competences and existing relationships in Denmark and Germany.
Design for typhoon survival (turbine and support structures)	Low	The UK has no experience in the design of turbines for storm conditions. There is potential to supply support for the design of material and support structures.
Large rotor design	High	The UK supports significant expertise in blade design and composite materials, which is supported with a world-leading understanding of testing for very large rotors.

Table 5 innovation between the UK and China (Innovate UK, 2018)

5.3. Areas of technical synergy

In general, there is a good synergy between what the UK can offer and what the Chinese OSW market needs and a reasonable synergy between what the UK can offer and what the Chinese OSW stakeholders want.

Broadly, there are four technical areas of interest for Chinese OSW stakeholders repeatedly observed during the mission:

1. Large OSW turbine development.
2. Reducing costs in the development and installation of wind farms.
3. Adapting wind turbines and other infrastructure for Chinese wind and seabed conditions.
4. Development of policy and supporting mechanisms to stimulate the OSW market.

In addition to the four areas listed above, the UK has a very strong base in innovation in O&M for OSW. However, this does not appear to be a priority area for Chinese stakeholders as their focus is on getting turbines in the water and learning from this experience. It is expected that as wind farm operators take operational control of a large number of wind turbines over the next three to four years, the level of interest in this topic will grow considerably.

The potential technical areas of interest, identified by Chinese stakeholders during the mission, were assessed qualitatively. These are summarised in the table below.

Next generation power electronics design	Medium	Some capability in the UK and interest in Chinese stakeholders but not flagged as a major area of interest.
Power electronics manufacturing	Low	Higher level of expertise in China than in the UK.
Blade and drive train testing design	High	High level of competence in the UK and high level of interest from Chinese stakeholders.
Techno-economic modelling	High	The UK's leading role in cost of energy analysis and cost reduction mechanisms was highlight by MOST as an area of particular interest.
Support mechanisms	High	
Wildlife impact monitoring and assessment	Medium	Some level of interest from Chinese stakeholders; wildlife issues have been a barrier to development. Good UK capability.
Installation of wind farms	High	Chinese stakeholders are very keen to learn about achieving lower costs for the installation of wind farms and to understand the UK's experience to date.
Piling technologies	Medium	Both the UK and China have a good level of capabilities in sub-sea civil activities. China has significant challenges in this area.
O&M operations	Medium	The UK has a high level of expertise but at present this is not a focus area for China.
Condition monitoring and diagnostics	Medium	UK has a good level of capability. Interest from Chinese stakeholders but not a priority area at present.
Integration of intermittent renewables onto grid	High	Initial interest in this area was demonstrated by Chinese stakeholders, although it is not likely to become a priority area until a higher level of OSW penetration on the grid is achieved. However, the UK is ad-dressing this issue and is likely to maintain its position as a world-leader in this area.
Data science	High	Interest from MOST and a key development area in the UK.
Wind farm design optimisation	High	High level of interest from Chinese and a good capability in the UK in both the public and private sector.

Table 6 potential technical areas of interest (Innovate UK, 2018)

References

1. Innovate UK, 2018. China Offshore Wind Expert Mission 2018. https://admin.ktn-uk.co.uk/app/uploads/2019/06/2018-China-OSW-Expert-Mission-Report-public.pdf.

6 THE ROLE OF STANDARDS AND CERTIFICATION

6.1. Standardisation of the industry leading to certification.

Standards and certification are present in any industry and are key for facilitating commercialization (including financing and insurance) through the establishment of technical requirements that reduces the probability of failures to an acceptable level considering safety, environment and economic targets and by the action of an independent and competent third party (certification body).

The more mature the industry is, the more prescriptive the standards and procedures tend to be. For industries and sectors dealing with innovation, such as wave and tidal, the application of risk-based standards and adaptation of suitable standards from other industries are the way forward to expedite the development of technology in a consistent and effective way. Also, it is very difficult to develop standards that are able to cover with very clear requirements and acceptance criteria very different technologies as it happens with wave and tidal.

Risk-based standards and certification processes have been applied in other industries before, sometimes mixing with prescriptive requirements. Some are only focused on safety and environment. For marine renewables, the focused is extended to economical consequences as the design, construction, installation, commissioning, operation and maintenance are governed by the essential requirements regarding safety, environment, survivability, reliability and performance at a LCOE that can be competitive with other renewable energy sources. It is interesting to emphasise that for floating wind, the risk-based approach is adopted to deal with the innovation and uncertainties (reference DNVGL-SE-0422)

6.2. Performance

6.2.1. Power

In general, any industry has to be capable to define how performance is measured. It is the same, and essential, for the renewable energy sector to establish a standard way to measure performance (for example power matrix, power curve) in a way that it correctly reflects how the technology performs under different metocean conditions. This is an essential aspect regarding derivation of LCOE.

In the wind, wave & tidal and solar, this has been done through several technical committees under the IEC (International Electrotechnical Committee), representing the views and knowledge of the industry.

For wave and tidal, although technical specifications have been developed (IEC TS 62600-100:2012 and IEC TS 62600-200:2013) their implementation in full has been considered difficult and the limited experience does not help to adjust the technical specifications. This is one key aspect for commercialization of technology, that in the wind and solar sectors has been consolidate through technical work and experience through the years giving confidence to all stakeholders.

6.2.2. Other

IEC TC-114 has published two TSs addressing other aspects of performance: electrical power quality (IEC TS 62600-30) and acoustic characterization (IEC TS 62600-40). They are important to form the basis of impact of marine renewables in the grid and in the environment. So far, there is no much information on application of the TSs.

6.3. Resource Assessment

Equally to any other renewable energy sector, the resource available (wind, sun, wave, tidal stream) is to be carefully assessed to work the potential of energy that is available for conversion. In wave and tidal, this has been established in the technical specifications IEC TS 62600-101:2015 and IEC TS 62600-201:2015.

6.4. Technical Requirements

6.4.1. Risk-based process

The establishment of technical requirements based on risks and acceptable criteria compatible with the renewable sector has been developed for the Tidal sector (DNVGL-ST-0164) (also adopted in the TS 62600-2) in response to the multiple different technologies and business models. The multiple business models and technologies lead to different demands on reliability and lead to different risks.

The risk-based approach is based on the technology qualification process, as described in DNVGL-RP-A203 Technology Qualification, that has been adapted and adjusted for marine renewables and inserted into the certification process (DNVGL-ST-0163 and DNVGL-ST-0120 draft). This becomes the foundation for the risk-based content of the standard for tidal (DNVGL-ST-0164 Tidal Turbines). In the IEC, there is an on-going process to prepare and release the IEC TS 62600-4 that addresses technology qualification process.

The risk-based process starts with the definition of certification basis, followed by the technology assessment and execution of failure mode identification and risk ranking (FMIRR). The consolidation of the process is carried out in the certification plan that defines the actions to mitigate the risks. These actions include aspects related to the specific technology risks and uncertainties (for example use of tests, analytical studies, collection of data, etc.) and adjustment of requirements from relevant standards.

The Figure 2 and following text below describes the steps of technology qualification.

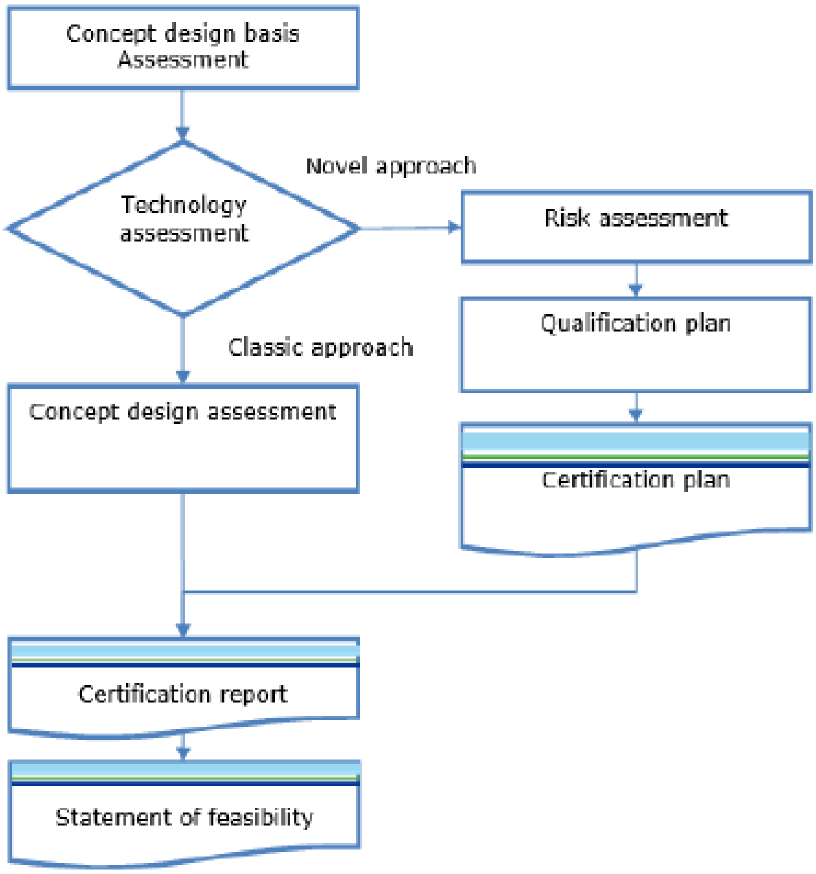


Figure 12. Technology Qualification [DNVGL-SE-0163]

Certification (Concept Design) Basis Assessment

The Certification Basis consolidates all targets, requirements, assumptions and methodologies essential for the design of the technology, among other codes and standards, design parameters, assumptions, methodologies and principles, as well as other requirements such as conditions for manufacturing, transportation, installation, commissioning, operation and maintenance. The certification basis specifies the principal input for the design process, in order to ensure that the final product can withstand the loads expected within the design lifetime while performing its duty. It defines the comprehensive range of boundary conditions that impact upon design and operation of the device / array.

Technology Assessment

The Technology Assessment is performed by dividing the technology into manageable elements in order to assess where the novel aspects lay, and to identify the key challenges and uncertainties.

Technology Assessment Steps

- Division of the technology into manageable elements
- Assessment of each element's life cycle into phases such as (but not limited to)
  - operation and maintenance

- fabrication and testing
- transportation and storage
- installation
- activation and commissioning
- decommissioning
- retrieval and abandonment

- Assessment of the technology elements with respect to novelty based on the technology assessment matrix
- Identification of the main challenges and uncertainties related to the new technology aspects. For complex systems it is recommended that the main challenges and uncertainties are identified by carrying out a high level HAZID (HAZard IDentification).

Definitions of technology assessment matrix

Application area

Application area may refer to the experience of the operating condition, or the environment, or the purpose for which the technology shall be used. A change to the normal operating environment or a different application / use of the technology will lead to increased uncertainty - the most uncertain case being where no experience exists within industry for a particular application of the technology in question. In such cases the category of “New” is inserted against “Application Area”. The least uncertain case is where there is appropriate documented knowledge for the use of the technology element under similar conditions and applications, in which case the category would be “Known”.

Technology Status

Technology status refers to the technology itself. A change in any of the elements of existing technology (parts, functions, processes, subsystems) will lead to increased uncertainty resulting in selecting the technology status “Limited Field History” or “New or Unproven”. The change may be related to hardware or software components of the technology. Change may be related to technology elements such as new architecture configuration, system interfaces, and increased reliability requirements. The increased uncertainty may change the overall performance of the technology and its acceptance criteria.

Technology Classes

Technology categorization does not consider the consequence of failure. As an example, category 4 may be assigned to a technology element whereas its failure may have little effect on overall system performance. If considered of value, the combination of technology categorization and consequence of failure - possibly in combination with other relevant factors for the technology - may be used to determine the technology criticality. Such criticality may be used to prioritize qualification activities

Each component falling in Class 1 or 2 are attributed one or several applicable standards as most of the failure modes and mechanisms of the component must be already covered by existing standards.

For each component falling in Class 2 and above, the inconsistencies between the attributed Standards' assumptions and the component's application area are identified and recorded as the "New aspects".

Application Area	**Technology status**		
	Proven	**Limited field history**	**New or unproven**
Known	**1**	**2**	**3**
New	**2**	**3**	**4**

1: No new technical challenges 2: New technical uncertainties

3: New technical challenges 4: Demanding new challenges

[source: DNVGL-SE-0163]

Failure Mode Identification and Risk Ranking (FMIRR) – Risk Assessment

The Failure Mode Identification is based on the Failure Mode and Effects Analysis (FMEA) that is a qualitative reliability technique for systematically analysing each possible failure mode within a hardware system, and identifying the resulting effect on safety, environment, operation and asset. The Risk Ranking is a quantitative procedure which ranks failure modes according to their probability and consequences (i.e. the resulting effect of the failure mode on safety, environment, operation and asset).

This activity brings a further understanding of the considered system, and increase emphasis on the areas upon which a detailed description of failures modes and mechanisms is expected in the subsequent process.

The consequence and probability classes as well as the risk matrix were defined as below.

Probability Classes

Clas s	Name	Description	Indicative Annual Failure Rate (up to)
1	**Very Low**	Negligible event frequency	1.0E-04
2	**Low**	Event unlikely to occur	1.0E-03
3	**Medium**	Event rarely expected to occur	1.0E-02
4	**High**	One or several events expected to occur during the lifetime	1.0E-01
5	**Very high**	One or several events expected to occur each year	1.0E+00

Table 7 probability classes [source: DNVGL-SE-0163]

Consequence Classes

Class	Description of consequences (impact on)				
	Safety	**Environment**	**Operation**	**Assets**	**GBP**
1	Negligible injury, effect on health	Negligible pollution or no effect on environment	Negligible effect on production (hours)	Negligible	1k
2	Minor injuries, health effects	Minor pollution / slight effect on environment (minimum disruption on marine life)	Partial loss of performance (retrieval not required outside maintenance interval)	Repairable within maintenance interval	10k
3	Moderate injuries and/or health effects	Limited levels of pollution, manageable / moderate effect on environment	Loss of performance requiring retrieval outside maintenance interval	Repairable outside maintenance interval	100k
4	Significant injuries	Moderate pollution, with some clean-up costs / Serious effect on environment	Total loss of production up to 1 month	Significant but repairable outside maintenance interval	1m
5	A fatality	Major pollution event, with significant clean-up costs / disastrous effects on the environment	Total loss of production greater than 1 month	Loss of device, major repair needed by removal of device and exchange of major components	10m

Table 8 consequence classes [source: DNVGL-SE-0163]

The risk matrix, considering the normal safety factor, has been defined as below:

Risk Categories

	Consequence				
Probability	**1**	**2**	**3**	**4**	**5**
5	Low	Med	High	High	High
4	Low	Med	Med	High	High
3	Low	Low	Med	Med	High
2	Low	Low	Low	Med	Med
1	Low	Low	Low	Low	Med

Where:

Low	tolerable, no action required
Medium	mitigation and improvement required to reduce risk to Low
High	not acceptable: mitigation and improvement required to reduce risk to Low (ALARP)

Table 9 risk categories [source: DNVGL-SE-0163]

6.4.2. Certification Plan

In the generic process, the Certification Plan is established at the conclusion of the technology Qualification (concept evaluation) process and includes the standards and certification levels agreed upon for the components and sub-systems, and the testing plan as defined by the recommended actions. The document contains the plan for all actions to be carried out during the certification process. The Certification Plan is compiled from the results of the Risk and Technology Assessments and subsequent results from the FMIRR and includes assessment of the applicability of existing requirements and new requirements.

6.5. Design requirements

6.5.1. Definition of Risk and Safety Philosophy

The safety philosophy to be applied to the renewables sector shall consider that safety to personnel is not necessarily the only consideration, with expectations from the different stakeholders and the balance between survivability, reputation, maintenance, repairs and production costs also being key aspects for consideration. An overall safety philosophy should be clearly established covering all phases up to and including decommissioning.

A Safety Philosophy should consider the following aspects and stakeholders:

• Risk to life (during installation and removal, access to device during in-service life, risk to navigation and others during in-service life).

• Environmental impact due to any fluid releases, anti-fouling coatings, bilge water, and location of site relative to sensitive environments (protected species or sensitive sites and visual impacts).

• Inspection and maintenance cost, risks during removal of equipment for inspection and maintenance.

• Safety level expected by the Authorities. This may include Authority requirements in other countries which are potential marketing targets for the device(s).

Additional aspects that will also define the philosophy to be used are:

• Balance between reliability, survivability and maintainability.

• Loss of production.

• Experience of developer, industry, concept (survivability of the device to extreme environment is very important in terms of impact on industry).

• Underwriter perception of risks and definition of premium value (during installation and removal, and in-service life).

• Financial or venture capital communities' perception of risk to the return on investment.

Three safety levels have been identified in the IEC/TS 62600-2, Part 2: "Design requirements for marine energy systems", as defined below:

Safety Level	Definition	Probability of failure
High	Operating conditions where failure implies high risk of human injury, significant environmental pollution or very high economic or political consequences	$< 10^{-5}$ per annum (p.a.)
Normal	For temporary or operating conditions where failure implies: risk of human injury, significant environmental pollution or high economic or political consequences This level normally aims for a risk of less than 10^{-4} per year of a major single accident. It corresponds to a major incident happening on average less than once every 10,000 installation years. This level equates to the experience level from major representative industries and activities.	$<10^{-4}$ p.a.
Low	Failure implies low risk of human injury and minor environmental and economic consequences	$<10^{-3}$ p.a.

Table 10 Design requirements for marine energy systems [source: DNVGL-SE-0163]

6.5.2. Standards

Technologies used in marine renewables result, normally, in a complex system with subsystems such as structures, moorings, power take-off, auxiliary systems (bilge, HVAC, cooling, ballast, lubrication), controls, electrical, communication, monitoring, etc interacting and contributing to the success of technology. Some more critical, others less critical. Thus, standards should address all the systems as well as the different phases that the technology goes through: from the design to retrieval and decommissioning / refurbishment.

The IEC TC-114 has publised the IEC TS 62600-2 Design requirements that mainly addresses the design of wave and tidal and the IEC TS 62600-10 Assessment of mooring system for marine energy converters (MECs) that addresses mooring design. All other systems are not covered.

The DNVGL-ST-0164, issued in Oct 2015, has provided content to cover the whole tidal energy converter and also the methodologies and safety philosophy considering a risk based approach. This is the target content that should be aimed at a standard for marine renewables:

- Risk based approach
- Design principles: Safety philosophy, Safety classes and target safety level
- Limit states – structures, Design by the partial safety factor method – structures, Design by direct simulation of combined load effect of simultaneous load processes – structures, Design assisted by testing - structures, Probability-based design- structures, Systems design
- Manuals for onshore and offshore works: Sea transport and offshore installation manual, Commissioning manual, Operating manual, Stability manual, Maintenance manual, Periodic inspection documentation
- Site conditions and characterisation
- Loads and load effects: Tidal turbine loads, Blockage and wake-induced loads, Design load cases (Power production, Power production plus occurrence of fault or loss of electrical network connection, Start up, Normal shutdown, Emergency shutdown, Parked (standstill or idling), Parked plus fault conditions, Transport, load-out, assembly, maintenance and repair), Multiple rotor specific load cases, Floating tidal turbines, Ice loads, Water level loads, Scour, Fatigue loads, Combination of environmental loads, Load effect analysis, Accidental loads, Deformation loads.
- Load and resistance factors: ULS (Ultimate Limite State), FLS (Fatigue), SLS (Serviceability) and temporary phases
- Materials for structures and blades
- Design and construction of steel structures
- Foundation and mooring system design
- Floating stability and watertight integrity
- Design and construction of blades
- Machinery systems and components: Pitch mechanism with bearing and actuator, Yaw system, Drivetrain, Auxiliary systems, Hydraulic system
- Protection and safeguarding
- Electrical systems: Electrical machines, Power transformer, Frequency converters, Medium-voltage switchgear, Back-up power supply system, Low-voltage switchgear,

controlgear and switchboards, Cables, lines and accessories, Lightning protection, Array cabling

- Corrosion protection
- Marine operations
- Maintenance
- Tests and measurements: Blade testing, Main gearbox, Generator, Transformer, Converter, Medium-voltage switchgear, Load measurements, Power performance measurements

The IEC TC-114 is developing the IEC TS 62600-3 ED1 Marine energy – Wave, tidal and other water current converters – Part 3: Measurement of mechanical loads that should be published in 2020. This will provide the requirements for measurement of loads in the marine renewables, essential to confirm that the analytical models are provide a safe prediction of structural and mechanical elements.

6.5.3. Reliability

Standards are normally developed to match the required reliability of a technology / product. The requirements for survivability to ULS and FLS for structures and systems should be adjusted to support the required reliability of the overall product / technology. For established technologies, this is normally the case that also have available reliability data for components. This allows refine the configuration of the systems and improve reliability and improve performance with an acceptable level of investment.

However, where the technology is new, the matching of the requirements from the standards may not lead to the required reliability. And the limited amount of reliability data, the uncertainty in the data, does not allow a reliability assessment to be performed with a narrow level of uncertainty.

Although early indication on reliability can be obtained at prototype stage, the collection of reliability data is only relevant once the technology has achieved a level of production that allow for statistically relevant amount of data over a stable configuration. At that stage, the requirements from the standards should be updated considering the input from the collected data.

The selection of the adequate supply chain and workforce quality level is also very important for reliability. When a high level of reliability is required, well qualified workforce, using thorough manufacture, commissioning, testing and maintenance procedures and a supply chain of high quality level is demanded.

The multiple technologies in marine renewables make the process more complex as it is difficult to use reliability data from technologies that are operating in very different regimes.

It is an important priority to develop a cross industry programme to collect reliability data. ISO 14224:2016 Petroleum, petrochemical and natural gas industries — Collection and exchange of reliability and maintenance data for equipment provides a comprehensive basis for the collection of reliability and maintenance (RM) data.

6.6. Certification

The role of the third party (certification body) is vital for confirmation that the requirements from the standards have been fulfilled and that the product / technology can be considered compliant i.e. with the accepted level of risks. This facilitates decisions regarding investments, commercial transactions and acceptance from authorities. This leads in lower costs of serial production.

Although, technologies in marine renewables are very different and their business model are also variable, the certification process assure that the certified technology complies with the requirements from standards (bearing in mind that the requirements will differ depending on the risk of the technology). Thus, the buyers could compare the functions, characterisitcs that are attractive to them and check the balance with the LCOE.

For the technologies with innovation the risk-based approach is adequate to deal with the causes of the failures and its associated risks.

The IEC, through its Compliance Assurance Board, is developing the IECRE certification scheme that comprises of wind, solar PV, wave and tidal. The wind part of the scheme is operational, but the wave and tidal and solar are still under development.

So far, some certification bodies have been providing certification for solar and wave and tidal using their own certification schemes. DNV GL has provided certification to wave and tidal based on the DNV-OSS-312 since 2007. Later, from Oct 2015, the tidal energy converters were certified based on the DNVGL-SE-0163 using the standard DNVGL-ST-0164. The wave energy converters will be certified based on the DNVGL-SE-0120 that it is at a draft stage at the moment, with use of adapted suitable standards from tidal, wind and offshore. They are all risk-based with the technology qualification as the methodology.

For wind certification schemes for floating is given in DNVGL-SE-0422, project certification of wind farms in DNVGL-SE-0073 and DNVGL-SE-0190, type and component certification of wind turbines in DNVGL-SE-0441 and DNVGL-SE-0074.

Bureau Veritas has also developed certification requirements for marine renewables (floating offshore wind turbine, current and tidal turbine, ocean thermal energy converter and wave energy converter) based on the Guidance Note NI631 DT R00 E which also uses risk-based methodology although this is optional for prototype, type and project certification. The NI603 R01 Current and tidal turbines has been established with requirements for tidal energy converters.

Lloyd’s Register has developed LR Guidance Notes for Offshore Wind Farm Project Certification.

One strong recommendation is that it is important that all certification schemes are equivalent in terms of the requirements, degree of involvement, target safety levels and risks and delivered under accreditation to ISO 17065 from Accreditation Bodies.

References:

1. BV Guidance Note NI631 DT R00 E Certification Scheme for Marine Renewable Energy Technologies November 2016
2. BV NI603 R01 Current and tidal turbines May 2015
3. DNV-OSS-312 Certification of tidal and wave energy converters
4. DNVGL-SE-0163 Certification of tidal turbines and arrays
5. DNVGL-SE-0422 Certification of floating wind turbines
6. DNVGL-SE-0120 (Draft) Certification of wave energy converters and arrays
7. DNVGL-ST-0054 Transport and installation of wind power plants
8. DNVGL-ST-0119 Floating wind turbine structures
9. DNVGL-ST-0126 Support structures for wind turbines
10. DNVGL-ST-0145 Offshore substations
11. DNVGL-ST-0164 Tidal turbines
12. DNVGL-ST-0437 Loads and site conditions for wind turbines
13. DNVGL-ST-0361 Machinery for wind turbines
14. DNVGL-ST-0376 Rotor blades for wind turbines
15. DNVGL-RP-A203 Technology qualification
16. IEC TS 62600-2:2019 Edition 2.0 (2019-10-18) Marine energy - Wave, tidal and other water current converters - Part 2: Marine energy systems - Design requirements
17. IEC TS 62600-10:2015 Edition 1.0 (2015-03-27) Marine energy - Wave, tidal and other water current converters - Part 10: Assessment of mooring system for marine energy converters (MECs)
18. IEC TS 62600-30:2018 Edition 1.0 (2018-08-29) Marine energy - Wave, tidal and other water current converters - Part 30: Electrical power quality requirements
19. IEC TS 62600-40:2019 Edition 1.0 (2019-06-18) Marine energy - Wave, tidal and other water current converters - Part 40: Acoustic characterization of marine energy converters
20. IEC TS 62600-100:2012 Edition 1.0 (2012-08-30) Marine energy - Wave, tidal and other water current converters - Part 100: Electricity producing wave energy converters - Power performance assessment
21. IEC TS 62600-101:2015 Edition 1.0 (2015-06-05) Marine energy - Wave, tidal and other water current converters - Part 101: Wave energy resource assessment and characterization
22. IEC TS 62600-200:2013 Edition 1.0 (2013-05-07) Marine energy - Wave, tidal and other water current converters - Part 200: Electricity producing tidal energy converters - Power performance assessment
23. IEC TS 62600-201:2015 Edition 1.0 (2015-04-09) Marine energy - Wave, tidal and other water current converters - Part 201: Tidal energy resource assessment and characterization
24. ISO 14224:2016 Petroleum, petrochemical and natural gas industries — Collection and exchange of reliability and maintenance data
25. ISO/IEC 17065:2012 Conformity assessment — Requirements for bodies certifying products, processes and services
26. LR Guidance Notes for Offshore Wind Farm Project Certification

7 ENVIRONMENT

The international Renewable Energy Agency (IRENA) has revealed that increasing renewables to 36 percent of the global energy mix by 2030 would generate about half the emissions reductions needed to prevent global warming rising above 2 degrees Celsius. It also found that increasing renewables two folds by 2030 would increase global GDP by up to 1.1 percent, about $1.3 trillion, providing jobs for over 24 million people worldwide. International study provided compelling evidence that achieving the needed renewable energy transition would not only mitigate climate change, but also stimulate the economy, improve human welfare and boost employment worldwide.

Ocean renewable energy (ORE) currently only contributes a tiny proportion (far less than 1 percent) of the global renewable energy production due to the technological difficulties as well as the high cost. Meanwhile, the environmental impact assessment (EIA) of ORE' installation, operation, and decommissioning are also facing critical challenges, e.g. little baseline data and diverse developing technologies.

Chinese government has made a commitment that the proportion of non-fossil fuel energy will account for 15% of primary energy by 2020 and 20% by 2030, and the total installed capacity of ORE will exceed 50,000 kw by 2020. The development of ORE in China is unstoppable, benefitting and challenging.

7.1. Climate (carbon emission reduction)

Climate changes is a hotpot nowadays, which always is listed on the major issues by most countries and international communities. The international Renewable Energy Agency has revealed that increasing renewables to 36 percent of the global energy mix by 2030 would generate about half the emissions reductions needed to prevent global warming rising above 2 degrees Celsius. International report also found that increasing renewables two fold by 2030 would increase global GDP by up to 1.1 percent, about $1.3 trillion, providing jobs for over 24 million people worldwide. International study provided compelling evidence that achieving the needed renewable energy transition would not only mitigate climate change, but also stimulate the economy, improve human welfare and boost employment worldwide.

Based on World Resources Institute (2019), ORE as one of the five key ocean-based climate change mitigation solutions, will contribute to reduce 0.18-0.25 GtCO2e/year by 2030, and could contribute to reduce 5.4 GtCO2e/year by 2050 at its maximum potential, which accounting for nearly 10% of the total contributions under the 2℃ scenario (Table 7-1).

Looking into the two major forms of ORE which are offshore wind generation (OW) and other forms of ocean renewable energy (OORE), such as wave, current, tidal, salinity and thermal power: estimates of the potential for electrical energy generated by OW will be in the range of 650 to 3,500 TWh/year by 2050; and estimates of potential from OORE technologies will be in the range 110 to 1,900 TWh/year. It was found that if ORE technologies displace coal-fired power plants, CO2 emissions can be reduced by between 0.65 and 3.50 GtCO2e/year in 2050 in the case of OW, and by between 0.11 and 1.90 GtCO2e/year in 2050 in the case of OORE. Alternatively, if energy technologies with emissions equal to the present global mean for the electricity sector of 0.46 kg CO2e/kWh were displaced, OW could contribute a reduction of 0.30 to 1.61 GtCO2e/year, and OORE could avoid 0.05 to 0.87 GtCO2e/year in 2050 (Table 7-2).

The overall proportion of the world electricity generation from ORE although is currently less than 0.3 percent (IEA 2019), large projects in China, EU and majorities of the coastal nations are underway, and huge funds from UN organizations, national and local government as well as private companies are being invested in the full range of ORE options, including floating PV panels, tidal and wave power station and other strategies to meet sustainable energy demands, which is also generating side benefits in local coastal environment and community's wellbeing.

Table 11 Summary of Global Mitigation Potential Offered by Each Area of Ocean-based Climate Action

AREAS OF OCEAN-BASED CLIMATE ACTION	2030 MITIGATION POTENTIAL ($GTCO_2E$/YEAR)	2050 MITIGATION POTENTIAL ($GTCO_2E$/YEAR)
1. Ocean-based renewable energy	0.18–0.25	0.76–5.40
2. Ocean-based transport	0.24 – 0.47	0.9 – 1.80
3. Coastal and marine ecosystems	0.32–0.89	0.50–1.38
4. Fisheries, aquaculture, and dietary shifts	0.34–0.94	0.48–1.24
5. Carbon storage in the seabed (Action in this Area Requires Further Research Prior to Implementation at Scale)	0.25–1.0	0.50–2.0
Total	1.32–3.54	3.14–11.82
Total percentage contribution to closing emissions gap (1.5°C pathway)	4–12 %	6–21%
Total percentage contribution to closing emissions gap (2°C pathway)	7–19%	7–25%

Source: Hoegh-Guldberg. O., et al. 2019. ''The Ocean as a Solution to Climate Change: Five Opportunities for Action.'' Report. Washington, DC: World Resources Institute.

Table 12 Mitigation Potential of Offshore Wind and Other Ocean-based Renewable Energy Technologies in 2030 and 2050

OCEAN-BASED CLIMATE ACTION AREA	MITIGATION OPTIONS	DESCRIPTION		2030 MITIGATION POTENTIAL ($GTCO_2E$/YEAR)	2050 MITIGATION POTENTIAL ($GTCO_2E$/YEAR)
Ocean-based renewable energy	Scaling up offshore wind	Fixed and floating offshore wind installations	coal displacement	0.17–0.23	0.65–3.50
			displacing current generation mix	0.08–0.11	0.30–1.61
	Scaling up other forms of ocean energy	Energy carried by ocean waves, currents, tides, salinity, and ocean temperature differences	coal displacement	0.006–0.016	0.11–1.90
			displacing current generation mix	0.003–0.007	0.05–0.87
TOTAL			coal displacement	0.18–0.24	0.76–5.4

Source: Hoegh-Guldberg. O., et al. 2019. ''The Ocean as a Solution to Climate Change: Five Opportunities for Action.'' Report. Washington, DC: World Resources Institute.

7.2. Wellbeing (pollution reduction, community)

Besides climate change mitigation, ORE's possible positive ecological and social effects may include creating artificial shelters around the ocean devices for marine life, strengthening of energy supply and regional economic growth, employment and tourism for local community.

Case studies in Scotland, Canada, New Zealand and Australia reveal ORE contributed significantly for coastal community's economic growth and employment (Kerr, 2011), UK predicted that the marine energy sector will support a total of 22,600 jobs by 2040 (UK marine energy 2019). ORE also have become tourist attractions in their own right, providing jobs in tourism, e.g. La Rance tidal barrage, in Brittany, France, which is the oddest tidal installation in the world. The following case in China are showing the integrated ecological and social effects of development of tidal energy.

Jiangxia Station of tidal energy in Wenling, Zhejiang

In the Yueqing Bay area of Zhejiang Province, conventional energy is lacking, power supply is tight, abut the tidal energy is abundant. The development of tidal energy definitely plays a positive role in the development of the local economy. Jiangxia Tidal Test Power Station was first installed in 1970s, which is also the first two-way tidal power station in China. Specific benefits include:

Generating annual grid-connected power greater than 500x104 kWh, provided energy for the local people's production and life for nearly 50 years;

Cultivating 366 ha farmland by the reservoir, and the annual income exceeds 10 million RMB;

Forming a reservoir with a water area of 1.37 km2, which can be used for aquaculture and the annual production value of breeding in the reservoir area is 15 million RMB, and the benefits of the annual output value of cultivated farmland and seafood breeding areas are more than 25 million RMB.

ORE development appears to have low environmental impacts, but all aspects of the lifecycle of ORE systems, from raw material extraction, component manufacturing, construction, maintenance to decommissioning should be considered. Meanwhile, ORE projects could be long-lived, about 25 years in general and may be over 100 years for tidal barrages (Sustainable Development Commission, 2007), the long-term impacts should therefore be taken into considerations as well. The possible negative environmental impacts (Table 13). Taking deploying wave devices as an example, noise and vibration are likely to be most disruptive during construction and decommissioning, while electromagnetic fields around devices and electrical connection/export cables that connect arrays to the shore may be problematic to sharks, skates and rays that use electromagnetic fields to navigate and locate prey. Wave energy farms could also reduce swell conditions at adjacent beaches and modify wave dynamics along the shoreline. These aspects can be assessed through numerical and tank testing studies.

Table 13 Environmental Impacts of ORE

Types of ORE	**Wind energy, tidal energy, wave energy, ocean current energy, temperature difference energy, etc.**
Sources of environmental impacts	Ocean energy device itself, dynamic environment change caused by ocean energy device, ocean energy conversion effect, chemical, electromagnetic fields
Environmental receptors	Physical environment, biological habitats, biological species, fish and fishery resources, seabirds, marine mammals, biological systems and food chains

Types of environmental change	Quantitative change, community change, biological process change, physical structure / process change
Cumulative effects	Climate change, other human activities, etc.

Negative social effects may include visual amenity and loss of access to space for stakeholders, noise during construction, and other limited specific impacts on local communities, e.g. conflicts between developers and indigenous people (Kerr, 2011).

Overall, ORE is playing an increasing role in sustainable development. A study carried out by WRI showed that ORE has quite strong positive impacts on SDGs, only SGD7 (affordable and clean energy) and SDG14 (life below water) were found negative impacts caused by ORE development (Table 14).

Table 14 The relationships of ORE and the SDGs

Wilder Impact Dimensions		Ocean-based renewable energy
Economy	SDG7: Affordable and Clean Energy	
	SDG8: Decent Work and Economic Growth	
	SDG9: Industry, Innovation And Infrastructure	
	SDG11: Sustainable Cities and Communities	
Environment	SDG6: Clean Water and Sanitation	
	SDG12: Responsible Consumption and Production	
	SDG14: Life Below Water	
	SDG15: Life on Lan	
Society	SDG1: No Poverty	
	SDG2: Zero Hunger	
	SDG3: Good Health and Well-Being	
	SDG4: Quality Education	
	SDG5: Gender Equality	
	SDG10: Reduced Inequalities	

Governance	SDG16: Peace, Justice and Strong Institutions	■
	SDG17: Partners hips for The Goals	■

Positive impact score

LOW					HIGH

Negative impact score

HIGH					LOW

7.3. EIA/Technology Impact (technology impact)

At the beginning of 2010, Ocean Energy System (OES), an intergovernmental international organization, established a working group IV to study the environmental impact of developing and utilizing ORE. They strengthened the links between researchers in various countries, established the Tethys database to collect, sorted out and shared the research results of various countries in the field of environmental impact of ORE development and utilization with the objectives of 1) to expand baseline knowledge of environmental effects and, particularly, environmental monitoring methods, 2) to ensure that this information is widely accessible, 3) to make available any proven mitigation strategies, and 4) to foster efficient and timely government oversight and public acceptance. The project has gone through three phases, future efforts for Phase 3 will focus on developing the 2020 State of the Science report and completing the process of risk retirement. EIA would then have sound technical support globally and indeed it has already become an important part of ORE development in many coastal countries and regions.

China’s current legal system of EIA for ORE is limited to the stage of construction (Table 15), while the stages of planning and decommissioning are missing. it is also difficult to take into account the cumulative effects and long-term effects of various environmental impacts, and rarely considers the environment, society and economy as a holistic system. Strategic environmental assessment (SEA) is based on the policy, planning, plan environmental impact assessment, is the extension and expansion of EIA on the strategic level. It's on the systematic analysis of the problems related to the environment, optimal planning, sound government policy, and the implementation of social and economic benefits at the same time, which could help to eliminate or reduce major negative impact on the environment at the very initial stage of the plan. At present, SEA is still absent in the process of formulating ORE plans in China, and relevant research work remains blank. The measures on the development and construction of offshore wind power released in 2017 (Table 16) only states that the developer should prepare an EIA report and submit it to the related department for approval before proposing the rights to the use of sea areas. The audit of offshore wind power environmental issues relies excessively on a single environmental impact assessment. Before the institutional reform in

2018, offshore wind power was managed by the Sate Oceanic Administration and the National Energy Administration. The framework of the environmental review system for offshore wind power has been basically established. However, there are still a lot of specific provisions need to be filled. Especailly, in the project licensing process, due to the lack of local baseline data of ocean energy environmental impact research in China, it is impossible to scientifically define whether the project meets the requirements of functional zoning control, and it is also difficult to define the intensity of environmental impact.

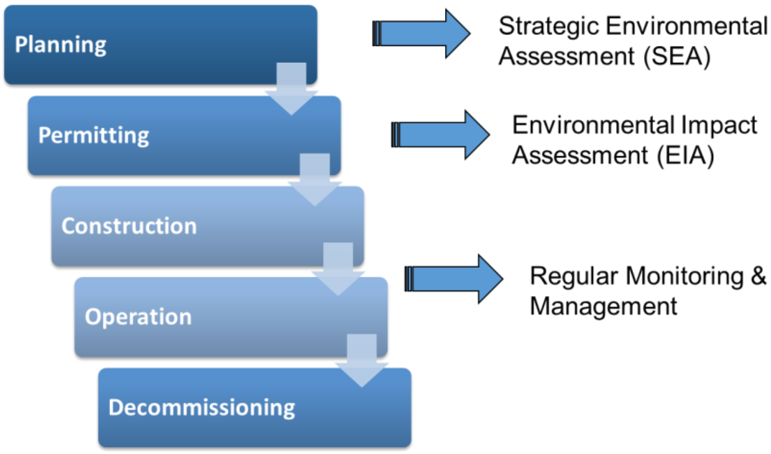


Figure 13 The lifecycle of ORE project

Table 15 Relevant laws on ORE and its EIA in China

Related laws	Issuing Authority
Law of the People's Republic of China on the Administration of Sea Areas (2002)	Standing Committee of the National People's Congress
Island Protection Law of the People's Republic of China（2010）	
Renewable Energy Law of the People's Republic of China (2009 Amendment)	
Energy Conservation Law of the People's Republic of China (2018 Amendment)	
Marine Environment Protection Law of the People's Republic of China（2017 Amendment）	
Law of the People's Republic of China on Environmental Impact Assessment (2018 Amendment)	
Fisheries Law of the People's Republic of China (2013 Amendment)	
Maritime Traffic Safety Law of the People's Republic of China	

(2016 Amendment)	

Table 16 Relevant regulations for EIA of ORE in China

Items	Issuing Authority	Issued Date	Types
Technical specifications for environmental impact assessment of offshore wind power projects	State Administration of Environmental Protection (dissolved)	2014.04.17	Department working documents
Provisions on Code of Conduct for Environmental Impact Assessment and Honest and Clean Administration concerning Construction Projects（2006）	State Administration of Environmental Protection (dissolved)	2006.01.01	Department Rules
The 13th Five-Year Plan of Environmental Impact Assessment Reform Implementation Plan	Department of environmental protection(dissolved)	2016.07.15	Department working documents
Administrative Regulation on the Prevention and Treatment of the Pollution and Damage to the Marine Environment by Marine Engineering (2018 Amendment)	State Council	Released in 2006, revised in 2018-3-19	Administrative Regulations
Management Regulations for Environmental Impact Assessment of Offshore Engineering (2017 Amendment)	State Administration of Environmental Protection (dissolved)	Released in 2008, revised in 2017-4-27	Departmental Regulatory Documents

7.4. Marine stakeholders (fishery, shipping, deep sea mining, tourism, O&G, etc.)

Development of ORE affects or is affected by numerous stakeholders. Understanding who the stakeholders are and how they are engaged in the process is necessary for improving the responsible development of ORE technologies. Key stakeholders could include fishermen, community members, regulators, developers, scientists, and tourists depend on various ORE projects located in different offshore area. For example, in the case of Tidal Power Development in Maine, U.S.A, key stakeholders are fishermen, community members, regulators, developers, and scientists. Fishermen and regulators are definitive stakeholders, with legitimacy, power, and urgency in the process. Tribes are considered dominant stakeholders; they have legitimacy and power, but their interests are, at this time, not viewed as urgent. Scientists are considered to have urgency and power. The developers viewed their stakeholder engagement strategy as open and transparent. Community stakeholders, regulators, and fishermen generally perceived the developer's approach as effective; they noted the company's accessibility and their efforts to engage stakeholders early and often.

In China, sea area shall be in the ownership of the state, which is cleared defined in <Property Law of P.R.C>. Stakeholder involvement therefore is relatively weak in China. EIA in China has employed the public hearing system in the stage of planning and implementation, which is mandatory for the developers to publicize the ORE projects and who need to seek the consensus from the representative stakeholders.

8 GOVERNANCE/INSTITUTIONAL STRUCTURES

8.1. Offshore Wind Deployment Stakeholders

The following section provides an overview of key stakeholder groups who will influence the development of the OSW industry in China. Different stakeholders are influential or active at different stages of the wind farm development. The key stakeholders at each stage are summarised in the figure below.

Table 17 The key stakeholders at each stage

Site leasing/ consent	Financing	Development	Turbine supply	Build	Operation	Power purchase
NEA						
State oceanic administration						
Provincial governments						
	Independent developers					
	Turbine manufacturers					
	State-owner utilities					State-owner utilities
	Grid companies					Grid companies
						Large energy users

Evidence from the mission suggested that the Chinese OSW development supply chain appears to be much more integrated than observed in European markets. While most organisations are identified as having a primary role in the sector, they are also active in other aspects of the OSW sector. For example, most of the major OSW turbine manufacturers that were engaged during the mission were also developing a significant portfolio of their own sites, as were the state grid companies. Likewise, some of the larger utilities have formed turbine manufacturing companies, primarily to meet their own project demand.

This integration is partly a function of the scale of the market – no developers in the UK would have a large enough secure development portfolio on their own to support a turbine manufacturer – and partly a function of the scale of the organisations operational in the OSW sector in China. They are able to absorb the cost and risk of both the development of sites and turbine technology. There are very few, if any, companies operating within the OSW market in Europe that could do this.

The table overleaf outlines key stakeholders operational in the Chinese OSW market at present.

Table 18 key stakeholders operational in the Chinese OSW market (Innovate UK, 2018)

State level agencies	**National Development and Reform Commission (NDRC)**	**National Energy Administration (NEA)**
	The NDRC is a highly influential administrative and policy development organisation with the Chinese government. It has extensive control over the development of the Chinese economy. Its role is to formulate policies for economic and social development within China.	NEA sets energy targets and policy and controls the subsidy support to energy generators. In the case of OSW, it controls the rate of the feed-in tariff and other support mechanisms.
	State Oceanic Adminstration (SOA)	**Chinese National Renewable Energy Centre**
	SOA manages the Chinese seabed, and its remit covers both use of the seabed for economic activities and environmental protection. It plays a key role in leasing and consent sites.	CNREC is the national institution that supports China's energy authorities on policy research, and industrial management and coordination of renewable energy.
	Design and engineering institutes	
	Design institutes in China play a key role in project development. They play a role in both planning and construction, particular on electrical balance of plant, foundation selection and design and, in some cases, design institutes take an EPC role. A key engineering institute for OSW is the China Renewable Energy Engineering Institute.	
Regional and local agencies	**Provincial-level agencies**	**City-level agencies**
	Provincial energy agencies and provincial oceanic authorities are responsible for provincial OSW development plans. These plans are integrated into a national plan. The initial agreement for development is usually conducted with provincial authorities. Provincial government also has the right to provide consent to projects, but anecdotal evidence suggests that central government still plays a significant role. Provincial economic development agencies also play a role in promoting economic activities around OSW in their province and supporting R&D in the region.	City-level economic development agencies are primarily focused on economic development within their city. Key activities for promoting OSW include the development of industrial areas and port facilities.

Industry	Developers	Investors
	Offshore wind development in China is dominated by state-owned utilities, but there are a significant number of new companies entering the sector, including the turbine manufacturers and state grid companies. The 'first mover' developers include: • China Longyuan Power Group • China Three Gorges • China Datang Corporation • China Guangdong Nuclear • China National Offshore Oil Corporation • China Hudian Group • Shenhua Group • China Huaneng Group. Chinese developers are aggressively targeting investment in UK projects (notably, China Three Gorges acquired a 30% stake in the UK's Moray OSW project) and have invested in overseas projects. Chinese developers, to date, have tended to operate individually rather than in development consortium.	Evidence from the mission suggests that passive financial investors have a very limited role in Chinese OSW development. There is also limited interest or opportunity from non-domestic investors in Chinese projects. Developers and operators are the primary investors and play an active role in the project. However, there is a very strong appetite for Chinese developers to invest in European projects and during the mission this was raised by most of the developers. China Three Gorges stated that for the first time they had taken a minority, passive stake in a windfarm (Moray), in order to gain experience in the European market.
	Supply chain	
	Wind turbine manufacturers	There is a large existing wind turbine manufacturing base (>20 operational) in China that has, to date, been primarily focused on onshore wind. Established Chinese manufacturers dominate the emerging OSW market in China, and this is expected to continue. Key turbine companies that are active in the Chinese OSW include: • CSIC • Envision Energy • Sinovel Wind Group Co • Goldwind • Mingyang Smart Energy • Shanghai Electric Wind Power Equipment Co. These manufacturers' OSW activities have, to date, been focused on the Chinese market. The turbines available and under development are too small to be competitive in the European or US markets; however, several have stated mid-term ambitions to enter the European market. All these manufacturers have substantial manufacturing bases in China.
	Turbine tier 2 and 3 suppliers	There is an extensive base of tier 2 and 3 manufacturers in China supplying the onshore wind turbine market, including all key components such as blades, gearboxes, generators and bearings. While these suppliers are not geared-up to supply the OSW sector, it is likely that they will continue to work with the key turbine manufacturers as they expand their offshore activities.

	Balance of plant	There is a limited supply chain for OSW wind balance of plant at present in China. However, there is a strong industrial base that has can adapt to the emerging market requirements. In particular, this will include: • Foundations: The existing marine and shipbuilding industrial base have the capabilities and facilities to fabricate the large steel structures required for OSW, for example, Jiangsu Jialing Heavy Industry Group and Zhejiang Kailing Shipyard[2]. • Vessels: There is a limited number of suitable vessels for OSW installation in China but, as mentioned, there is a strong shipbuilding base that should be able to adapt to supply suitable vessels and the market is large and stable enough to justify the commissioning of new vessels. • Submarine cables: China has a substantial base in capabilities in sub-sea cable manufacturing that should easily adapt for supply to the OSW sector.
	Installation and O&M contractors	China is expecting its oil and gas base to adapt to take over offshore installation and maintenance roles, as has happened in Europe. A number of companies are already developing experience in the sector, including the Chinese Offshore Oil Engineering Co, Nantong Ocean Water Conservancy Engineering Co and Jiangsu DoaDa Heavy Marine Industry.
	Specialist support services	The design institutes in China provide much of the specialist design and planning expertise to the OSW sector. However, European companies such a DNV GL and Atkins have been relatively successful in supplying specialist consultancy services to Chinese developers and turbine manufacturers.
Pressure/ lobbying groups and other stakeholders	Special interest organisations	OSW support/lobbying organisations
	No evidence was seen during the mission of any influential independent stakeholder groups.	There are trade organisations supporting the Chinese OSW sector. They play a vital role in organising events, best practice sharing and development of standards. The more high profile include: • Chinese Wind Energy Association (CWEA) • Chinese Renewable Energy Industries Association (CREIA) • China Wind Energy Equipment Association.

For the purpose of this report, stakeholders within the OSW R&D sector have been split between delivery organisations, which deliver R&D in OSW and enablers, which support innovation through funding or programme initiation and facilitation. The key sets of stakeholders identified during the mission are summarised overleaf.

8.2. Industry

The vast majority of high TRL R&D on OSW in China appears to be carried out by industry. This is typically within internal R&D departments, particularly of the turbine manufacturers, key developers and the grid companies. Historically much of the design work for wind turbines and windfarm infrastructure in China was outsourced to, or licenced from, European design houses and this is still the case to some degree. For example, Atkins is involved in the balance of plant design for a number of Chinese developers and Shanghai Electric has directly licenced 8 MW OSW turbine design from Siemens. Additionally, the more advanced companies, particularly the turbine manufacturers, have established satellite offices in Europe in order to access and transfer European knowledge back to China. For example, both Mingyang and Goldwind have established Danish R&D centres to access turbine design knowledge.

However, the domestic OSW R&D capability within these companies has rapidly increased over the last decade and the majority of design and development work is carried out in-house. As an example, Goldwind employed over 1,000 R&D staff in 2017, which is on a par with the more established European turbine manufacturers. The majority of significant wind turbine R&D facilities in China also sit within these companies.

Evidence was provided during the mission of significant government financial support to companies for commercial R&D activities including funding for testing facilities. For example, MOST put signifi-cant funding into Goldwind’s testing facilities.

Chinese universities also receive substantial funding from both government (e.g. MOST) and state-owned organisations to allow lower TRL academic research into offshore wind-related technologies. However, the Chinese government recognises that their existing research structures lack applied re-search (e.g. mid-TRL) coverage; as a result research in the universities has not been successfully transferred into the industry. The Chinese government is encouraging incubation services throughout the entire country, to ensure industry can access innovation developed within the country. More details are described in the section on enablers below.

8.3. Corporate research institutes

Some of the most influential R&D organisations in China are funded and run as a subsidiary of large state-owned companies. Key centres for the development of energy technology are run by the two state grid companies, China State Grid and China Southern Power.

These organisations carry out R&D across the full range of technology readiness levels and also deliver testing, development of standards and design and development services. These centres deliver both internal to their operating companies but also carry out R&D for national and provincial government organisations and academia.

8.4. Energy Research Institute

The Energy Research Institute (ERI) is administered by the Academy of Macro-economic Research (AMR), part of the National Development and Reform Commis-sion (NDRC). It is a national research organisation carrying out R&D focusing on China’s energy challenges. The institute is also one of seven research institutes administrated by the Academy of Macro-economic Research (AMR) of the NDRC.

The scope of research carried out by ERI includes energy production, distribution, and consumption and there is a strong focus on energy economic research, energy and the environment, and renewable energy. It is therefore highly relevant for OSW research.

8.5. China Academy Of Sciences (CAS)

CAS is China’s largest single producer of research. It comprises a network of over 100 CAS research institutes, two universities and 11 supporting organisations across the country.

CAS receives a core funding allocation directly from the Ministry of Finance and augments this income by competing for research grants.

CAS also funds basic research including collaborative projects between the UK and Chinese Research Institutes.

8.6. Universities

In the UK research has driven step-changes in the development, understanding and knowledge capital in relation to ocean energy. For example, The SuperGen UK Centre for Marine Energy Research (UKCMER), formed in 2003 established a strong foundation in marine renewable energy lead by the University of Edinburgh. The restructure of SuperGen groups in 2018 generated the ORE Supergen Centre that has fostered a strong network of universities, including the University of Plymouth, the University of Hull, the University of Edinburgh, the University of Exeter, the University of Manchester, the University of Oxford, the University of Southampton, the University of Warwick, the University of Aberdeen and the University of Strathclyde. In parallel the joint UK-China Joint Offshore Renewable Energy Centre has been established chaired by the University of Exeter that works closely with the ORE Supergen Hub.

They demonstrate strong and internationally recognised capability in areas such as resource assessment, design engineering, energy yield modelling, structural analysis and network integration. Developing device prototypes, their testing and their commercialisation often bring together industry, the supply chain and academia, capitalising on the UK's renowned research expertise in these fields.

The UK's strong university research base has also led to the formation of a number of innovative spin-out companies, such as Aquatera, a marine consultancy in Orkney specialising in marine renewables, and Nautricity, a tidal developer emerging from the University of Strathclyde.

A key role in the research and development is provided by the ORE Catapult, enabling strategic innovation developments between Universities and industry.

In China over the past ten years, significant government investment has been made into wind power research in Chinese universities, and there is a good base of capabilities within this academic community in wind turbine technologies and onshore wind. The mission had minimal contact with universities during the visit, so it was not possible to determine the level of research being carried out into OSW. Key universities known to be working on wind energy include:

1	Zhejiang University	http://www.zju.edu.cn
2	Chongqing University	https://www.cqu.edu.cn
3	Tsinghua University	https://www.tsinghua.edu.cn
4	Huazhong University of Science and Technology	https://www.hust.edu.cn
5	Harbin Institute of Technology	http://www.hit.edu.cn
6	South China University of Technology	https://www.scut.edu.cn
7	Shanghai Jiaotong University	https://www.sjtu.edu.cn

8	North China Electric University	https://www.ncepu.edu.cn
9	Tianjin University	http://www.tju.edu.cn

Recently, Chinese government launched some of funding to support the research in the field of ocean energy, such as 863 high-tech project. Some major universities in China known to be working on ocean energy, mostly current energy and wave energy, include:

1	Zhejiang University	http://www.zju.edu.cn
2	Harbin Institute of Technology	http://www.hit.edu.cn
3	Dalian University of Technology	https://www.dlut.edu.cn
4	Ocean University of China	http://www.ouc.edu.cn
5	Sun Yat-sen University	http://www.sysu.edu.cn

References

1. Innovate UK, 2018. China Offshore Wind Expert Mission 2018. https://admin.ktn-uk.co.uk/app/uploads/2019/06/2018-China-OSW-Expert-Mission-Report-public.pdf.

9 INVESTMENT POLICIES

9.1. Support mechanisms

Technology-specific demonstration projects will be required, as learnings from a given pilot farm or plant cannot be transferred from one ocean energy technology to another. For these early projects, risks cannot be insured and are too high for a single player, calling for public backing.

Before the ocean energy sector can reach bankability and commercial viability necessary for industrial roll-out, the first ocean energy pilot projects must reach financial close. Demonstration and pre-commercial farms and plants require a specific financing solution, as high levels of uncertainty and risk make them unsuitable for commercial debt or pure revenue-based finance.

• Creation of an Investment Support Fund for ocean energy farms: EU and National Authorities should create a Fund providing flexible capital, and enabling further private capital to be leveraged.

• Creation of an EU Insurance and Guarantee Fund to underwrite various project risks: This would be targeted at the first ocean energy projects to cover risks such as availability, performance, unforeseen events, failures, etc. A common reserve fund available to multiple projects in the initial farm or plant roll-out, to spread the risk and reduce the cost of providing guarantees.

In the demonstration and pre-commercial phases, considerable uncertainty about both revenue from power production and maintenance costs means financial risk remains high and transition to a pure revenue support dominated mechanism is premature. Upfront capital to support investments therefore, remains essential.

This upfront capital no longer needs to be grant-only. It can take the form of public equity, public debt, repayable loans or even access to low cost finance (e.g. zero or low interest loans) provided lending criteria are suitable for high-risk projects.

Revenue-based support schemes can and should commence to give long-term visibility and confidence to investors and reduce the cost of capital. Short-term or short-lived support schemes do not give market players the visibility required for long-term energy investments.

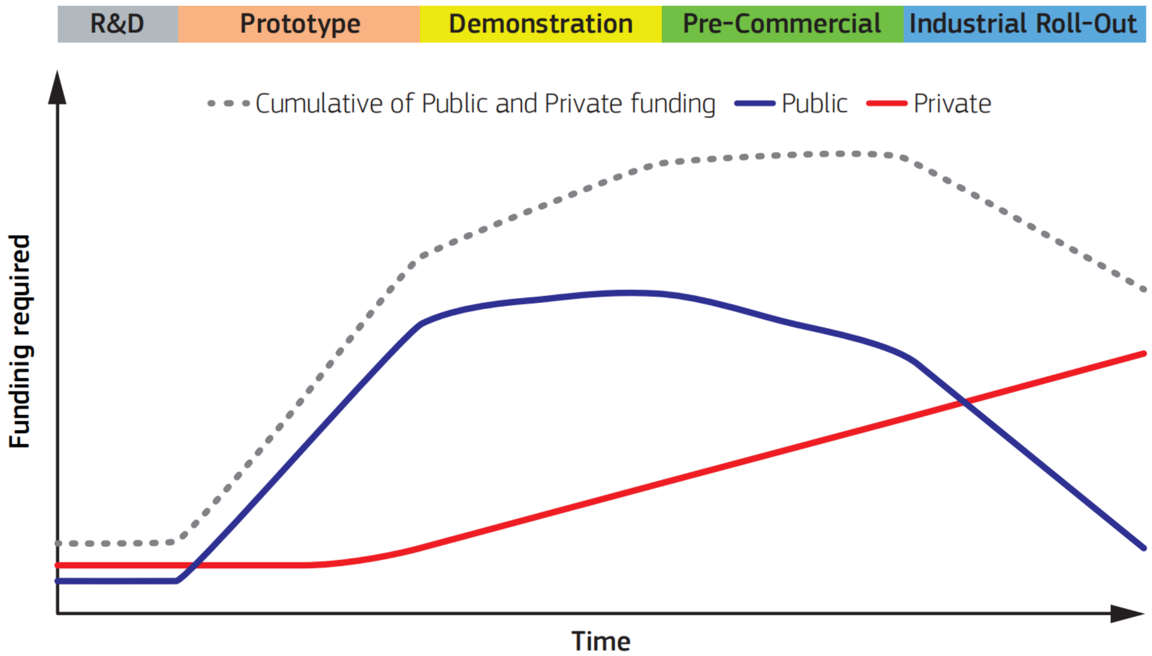


Figure 14. Indicative share of private and public funding for an ocean energy concept per development phase (Source: Ocean Energy Strategy Roadmap)

A combination of both private and public funding can be considered, provided it ensures both the upfront capital requirements of early stage projects and the medium-term visibility to entice investors to consider a new and promising technology and market.

Figure 14 outlines the share of private and public capital in total costs of bringing an ocean energy device from early R&D to industrial deployment in a farm or full-scale power plant.

• Investment support must remain an essential part of support schemes for each specific technology until the industrial roll-out phase is reached. If withdrawn too early in favour of revenue-support mechanisms, the technology might not have reached the required maturity to make use of the scheme.

• Investment support can come in the form of equity, debt, grants or repayable grants, or capital guarantees.

Innovative projects are by nature subject to planning uncertainties. Financial mechanisms put forward by both EU and governments need to keep pace with advances in the ocean energy sector and respond quickly to new developments, delays, or small changes in project parameters. Several ocean energy projects did not proceed or risked failure (such as Skerries or some NER300-funded projects) due to the inability of support schemes to adapt to delays.

• While some framework and reporting is required to ensure good use of public funding, innovations schemes should aim at being least bureaucratic, most flexible and most responsive as possible, to match the fluid nature of innovative technology development.

9.2. State aid rules

EU State aid rules should allow Member States to adequately support new technologies as they emerge and move through demonstration and pre-commercial stages to reach industrial roll-out. An explicit distinction needs to be made between support for mature technologies and support for emerging technologies.

Emerging technologies such as ocean energy require investment- or project-specific support rather than pure revenue support. Even with the more restrictive Guidelines on regional State aid for 2014- 2020 it is still possible for national governments to set up adequate revenue support schemes to incentivise ocean energy production. However, for investment and project-specific (individual) support, EU State aid guidelines remain burdensome and restrictive.

This could be achieved, for example, by increasing the notification thresholds for individual and investment aid for emerging technologies to €30m. Eligible costs caps (percentages) should also be increased for emerging technologies, using the same logic as that applied to projects developed in European regions with low per capital GDP.

• State aid rules should be more flexible for emerging technologies and provide increased thresholds for eligible costs and notification.

• National authorities should offer guidance on combining diverse sources of funding into a successful investment support for projects.

9.3. Public investment banks

Commercial debt will not be available in the short-term for ocean energy projects given their current risk profile. Some technologies will require more time than others to reduce risks to a bankable level. Consequently, the European Investment Bank’s (EIB) current low-risk investment stance is inadequate both for the ocean energy sector and for Europe’s industrial development in general.

The new InnovFin Energy Demo Projects (EDP) scheme, with an initial envelope of €100m for all renewables, is an important step towards more risk-taking, though budgets are clearly misaligned with the financial needs of the demonstration and pre-commercial phase: ocean energy projects in those phases are likely to cost each in the range of €40m to €100m. The European Fund for Strategic Investments (EFSI) should also become relevant for ocean energy as budgets are at more appropriate levels.

• National investment banks, the EIB and European Investment Fund should support the industry's progress to the next phase of development by unlocking risk capital.

9.4. National Natural Science Foundation of China (NSFC)

NSFC administers and steers the National Natural Science Fund provided by the central government and directly under jurisdiction of the State Council. It supports basic research and develops international cooperation. NSFC's budget is substantial. In 2012 it amounted to RMB 17 billion per annum, and it provided over 38,000 awards per year. It has memoranda of understanding with over 35 countries and regions, including the UK.

UK-China Research and Innovation Partnership Fund

The UK-China Research and Innovation Partnership Fund is a collaborative funding programme coordinated by the Newton Fund that supports collaboration between Chinese and British R&D organisations. In addition to ongoing support to academia-industry partners between the two countries. A call was announced in late 2016 explicitly focused on Offshore Renewable Energy Systems; it was supported by EPSRC, NERC and NSFC. Up to £4 million was made available to support UK researchers, matched with NSFC funding of up to RMB 3 million per project. Topics of interest included:

1. Array infrastructure and network resilience
2. Integrated offshore natural resource systems
3. High-efficiency ORE-to-wire design with scaled modelling
4. Building resilience against extreme events into ORE systems
5. Natural resource characterisation to support the development of large ORE arrays.

9.5. Provincial and city-level funding

Funding for R&D is also available for companies and organisations at both provincial and city level. Provincial and city governments appear to work closely together to ensure strategic alignment for investment. Funding is provided for offshore renewable R&D via a number of channels, such as Provincial Departments for Science and Technology, Department of Water Resources, Administration of Ocean and Fisheries, Provincial Academic of Sciences, Department of Commerce etc or various regional economic development agencies. Funding from these departments is highly dependent on the research topics, economic impact, development strategy alignment, and budget availability. Many of the large state-owned organisation will have dedicated R&D funding from the provincial government to support economic and technological growth; part of these will be managed and distributed by the state-owned organisation through innovation challenge schemes.

Funding is provided to both industry, research institutes and regional academic organisations by the provincial governments. From discussions on the mission, the primary mechanisms for funding appear to be support for infrastructure development, research project support and skills training, but exact mechanisms were not discussed in detail.

During the mission's engagement with Yangjiang city, the preferred support mechanism appears to be provisions of land and facilities within their industrial development zones dedicated to OSW and tax incentives for locating within these zones.

9.6. Industrial funding

A significant amount of OSW R&D in China is funded directly by industry. This is either through internal R&D programmes, funding to corporate or state research institutes or incubator/accelerator type organisations.

(1) Internal R&D Programmes

With the exception of basic component manufacturers, all of the large corporations met during the mission have extensive internal R&D departments delivering research, development and demonstration of new technologies. These are primarily funded through internal balance sheets.

(2) Industry to corporate and state research institutes

In addition to internal R&D-funded programmes, the large corporations also support R&D programmes within their subsidiary research institutes or through national research institutes and academic organisations.

(3) Incubator/accelerator organisations

Incubators designed to support, and fund innovative start-up companies are booming in China. In 2017, there were over 7,500 incubators in China, making it a world leader. The 13th Five-Year Plan aims to increase this number and sets a target of over 10,000 incubators by 20207. Therefore, investment from incubator organisations must be considered a substantial source of funding for innovation in China.

During the mission, the delegates met TUS Holdings, a science park and incubator company with origins in Tsinghua University. More details of this are provided in the case study overleaf.

10 POLICY & STRATEGIC PLANNING

The development and deployment of demonstration and pre-commercial devices, arrays and plants will provide a key opportunity to validate predicted environmental impacts. A data gap analysis will be required to identify priority issues, enabling a strategic research agenda to be established to cover emerging gaps in knowledge. A research agenda should focus on addressing key consenting issues and risks whilst gathering information and data to help inform the planning and consenting of larger scale projects. Existing strategic research programmes such as the UK's Offshore Renewables Joint Industry Programme for Ocean Energy (ORJIP) could play a key role in the development of an EU strategic research agenda for ocean energy.

A strategic broadscale monitoring programme on highly mobile species such as birds and mammals would greatly assist decision makers in ensuring obligations under environmental Directives are met. From the developer's perspective, a common structure for project monitoring should be established focusing on likely environmental impacts and seeks to progress projects through a risk-based approach. This will provide guidance for determining project baseline characterisation requirements and developing project environmental management plans that are proportionate to the level of risk posed by any specific proposed ocean energy project. A review of the environmental impacts associated with new and emerging technologies on an ongoing basis will ensure that the best and most up-to-date information and data regarding the potential impacts of ocean energy projects are available to decision makers, developers and stakeholders. Sharing data from monitoring programmes will both facilitate future project consenting and reduce duplication of effort. Existing platforms and programmes for data sharing could play a key role in data sharing and dissemination including the International Energy Agency (IEA) Ocean Energy Systems' Annex IV programme (along with its Tethys database) and the Crown Estate's Wave and Tidal Knowledge Network.

10.1. Capacity & Targets

It was evident from the mission that it is challenging to get an accurate and consistent picture of the exact scale of the current and mid-term Chinese OSW market. However, there is no doubt that this is a rapidly developing market and it is going to be one of the – if not the – biggest OSW markets in the world over the next few decades, driven both by national strategy and provincial economic development objectives.

In December 2016, the China 13th Wind Energy Development Plan (2016-2020) was issued by the National Energy Agency. It set a target 5 GW of OSW being grid connected by 2020, with another 5.05 GW to be under construction in this timeframe.

This is considerably reduced from ambitious targets set out in China's 12th Five Year Plan for Energy, which set a goal of 5 GW capacity by 2015 and 30 GW by 2020. However, this failure to meet targets appears to be more due to "teething issues" in establishing the OSW industry at scale, rather than long-term barriers or a reduction in ambition.

It is also worth noting that the total targets set by three key provinces alone – Jiangsu, Guangdong and Fujian – total nearly 6 GW by 2020, more than the national target

10.2. Benefits

10.2.1. Socio-economic benefits

From the perspective of promoting social and economic development, we need to adapt measures to local conditions and formulate corresponding plans according to specific environmental conditions. For design and installation of the balance of plant civil engineering, the experience of European developers, design houses and installers has limited relevance as the seabed conditions are significantly different. China has some of the best civil and geotech capabilities so is likely to develop its own capabilities very fast. We also need to promote the development of science and technology. By developing technologies, we can reduce costs in the development and installation of farms. In addition, development of policy and supporting mechanisms is important to stimulate the ORE market. Only with good policy support can the rapid development of maritime energy be achieved.

10.2.2. Environmental benefits

Enhancing knowledge of the marine environment is crucial to better inform plans and more efficient licensing for all marine related activities. This should be informed by the strategic and project environmental assessment under the Strategic Environmental Assessment (SEA), EIA, Natura 2000 and MSF Directives. Ongoing review of environmental impacts associated with new and emerging technologies will ensure that the best and most up-to-date information is available to decisionmakers, developers and stakeholders. A key component will be the establishment of a strategic environmental research programme to address key consenting issues and emerging gaps in knowledge. The UK's ORJIP for Ocean Energy has shown how industry, regulators and researchers can collaborate to identify and address the priority challenges.

A framework for strategic broadscale monitoring which is focused on likely environmental impact and seeking to progress projects through a risk-based approach will provide guidance for determining project baseline characterisation requirements and developing project environmental management plans that are proportionate to the level of risk posed by a project.

- Investigate the possibility and best means of expanding the remit of ORJIP Ocean Energy to inform the development of strategic research plans for the EU and Member States.

- Explore the ORJIP model and consider how it could be expanded to cover all Member States.

- Establish a working group to develop a common framework for project monitoring and environmental management.

10.3. Regulations/Lease/Approvals/Permits

Development of OSW in China is highly dependent on regulations and policies from central government. The following supporting policies were identified during the mission. This is not an exhaustive list.

10.3.1. Renewable Energy Law

In 2006, China brought into force the Renewable Energy Law (REL). This was revised in 2009 and sets out the foundations for planning and development, economic incentives, grid connection policies and technical standards for OSW.

10.3.2. 13th Five-Year Plan for China's National Economy and Social Development

"China's construction of clean, low carbon, safe and efficient modern energy has become a national development strategy." Within this plan, the Chinese government has made a commitment that the proportion of non-fossil fuel energy will account for 15% of primary energy by 2020 and 20% by 2030. This is driving an adjustment of the national energy structure.

The strategy plan promotes the development of wind and photovoltaic (PV) power. As a result, the NDRC and State Energy Bureau have developed a number of energy-related five-year plans, including the 13th Five-Year Plan on Energy Development and the 13th Five-Year Plan on Renewable Energy Development.

10.3.3. 13th Five-Year Plan for Wind Power Development

In December 2014, the State Energy Bureau issued A Notice on the Development and Construction of the National Offshore Wind Power Development (2014-2016) and approved a target of 10.5 GW. This was followed in 2016 by the 13th Five-Year Plan for Energy Development, which focused heavily on offshore wind. This was further detailed in the 13th Five Year Plan for Wind Power Development, which set a 2020 offshore wind grid installed capacity of 5 GW with another 10 GW under construction.

10.3.4. Provincial/regional OSW development plans

The key provinces for OSW development have OSW development plans, for example, Guangdong has developed the Guangdong Sea Wind Development Plan (2017-2030), which sets targets for OSW development. Other plans vary by province. There are also regional development incentives and plans, notably for this mission, around the Hong Kong Macao area, which would cover Guangdong.

10.4. Supply chain localisation

China, as with all countries building an ORE market, is keen to ensure as much domestic supply as possible. Many Chinese tier 1 suppliers have relationships with other European manufacturers, which can offer more comprehensive packages. OSW, for example, there is already a substantial tier 1 and 2 supply chain in China for onshore wind which is making the transition to supplying OSW. In addition, China has a large marine industrial base in shipping, building, oil and gas which has the potential to fulfil specific OSW market requirements such as foundation manufacturing and O&M provision.

Many Chinese turbine manufacturers and suppliers have stated their ambition to break into other global ORE markets. In addition to accessing the Chinese market, if foreign companies can integrate into the key Chinese ORE supply chains, there is an opportunity for foreign suppliers to access other global markets, through these relationships.

10.5. China/Global markets (electricity)

As of March 2018, there was an estimated 2,790 MW of OSW capacity installed off the Chinese coast1. As outlined above, the national target is set at 5 GW by 2020. This is considered by market analysts and Chinese stakeholders to be conservative, and it is expected that total installed capacity by 2020 will exceed this amount, given the level of ambition within the provinces and amongst developers in the country.

MAKE consulting expect Chinese installation to reach 7 GW by 2020, exceeding the 5 GW target. The market is expected to rapidly pick up the pace. MAKE predict the size of the national market to be between 10-15 GW by 2025. This would make it the largest offshore market in the world at that point in time. Forecast market growth is summarised in the graph below.

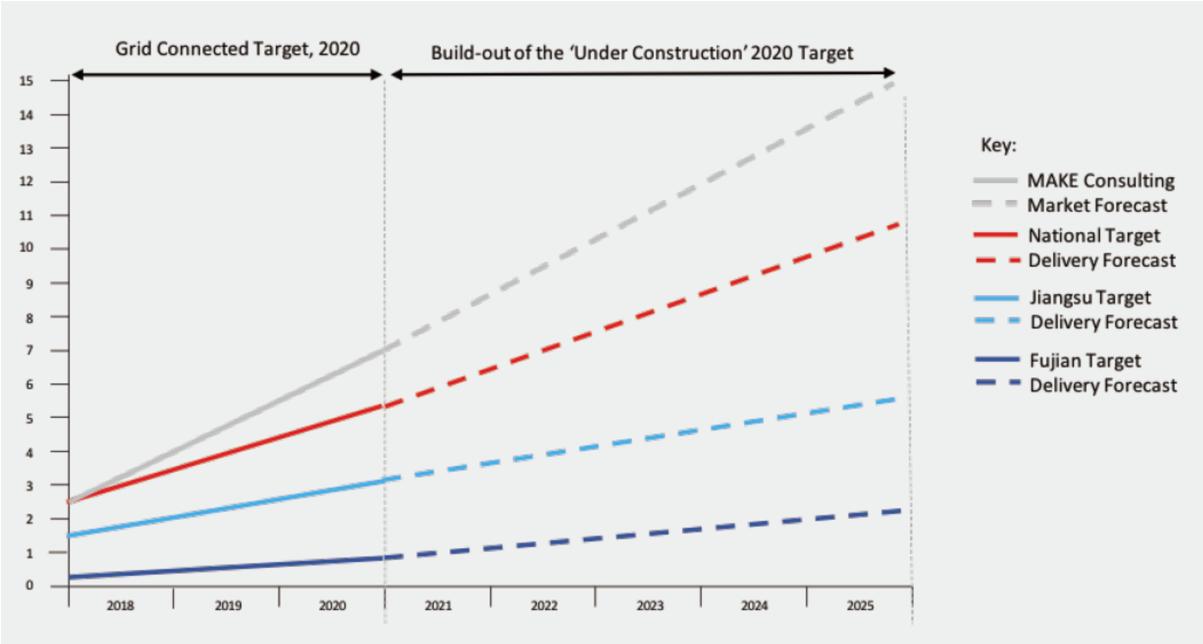


Figure 15. Growth scenarios for the Chinese offshore wind market 2018-2025; Source: MAKE Consulting

The question is often asked: why does China need OSW when it has vast areas of land with a decent onshore wind resource that could be at a significantly lower cost than developing a new coastal OSW sector? The answer to this relates to the distribution of both the population and industrial bases in China.

In China, 94% of the population live on 46% of the land, clustered in the east of the country. Around a third of these people live on the coast. Therefore, despite the size of the country, the majority of energy consumption is within highly-populated coastal areas. OSW offers relatively local generation source to the population centres, avoiding the transmission costs and losses associated with bringing onshore wind energy from the less populated west of the country.

10.6. Capacity Building

10.6.1. Components testing facilities

The larger turbine manufacturers all have in-house testing facilities for key components. No evidence was presented to the mission for very large testing facilities (e.g. 12 MW+) such as are available in the UK and Europe but Goldwind, one of the more advanced wind turbine companies, has the ability to test nacelles up to at least 6 MW. Standard testing of the wind turbine and sub-components in China, in general, are compliant to international standards or guidelines. The Chinese government is very proactive ensuring international standards are met and has adopted a leading role in the international standard committees (e.g. IEC, ISO). However, in addition to testing for certification, wind industry players in the UK and Europe are heavily engaging in research for new testing methodologies and using the full-scale (e.g. 15 MW) test facilities to conduct detailed validation to ensure their product's reliability from both design and development aspect. This places the UK and Europe in a more advanced stage compared to their Chinese counterpart.

The mission was not made aware of any publicly-accessibly large/full-scale OSW turbine system/component testing facilities in China. MOST indicated that they were investigating the potential for a public centre, but no firm plans were in place, as far as the mission could establish. Conversations with Sinovel and Goldwind, in separate meetings, indicated they both have plans to develop 10 MW+ powertrain/nacelle test facilities in China.

Smaller blade and nacelle testing facilities that are suitable for China wind turbine components are available both within the key turbine manufacturers and through testing and certification companies such as SGS.

Extensive grid integration testing facilities are available within CEPRI and CSPEPRI, both in voltage level and power capacity.

10.6.2. Demonstration sites

A number of first rounds of the commercially-developed OSW projects in China have been named as demonstration projects. These include the Xiangshui Development Project (202 MW), Zhuhai Guishan Hai Demonstration Project (102 MW) and Pearl Estuary. More demonstration sites are planned. Further demonstration site are planned supporting floating offshore wind; examples are support through Shandong province.

10.6.3. ORE contribution towards energy mix

The drivers for development of most renewables, and in particular OSW, in China are broadly similar to those of most OSW markets globally. At a national level, the OSW market appears to be driven by the need to provide additional energy to meet growing demand in coastal regions and decarbonisation commitments. At a provincial level, the key drivers are national strategy and economic development.

11 ECONOMICS & COMMERCIALISATION

11.1. LCOE of technologies

Wave, Tidal Stream and Ocean Thermal Energy Conversion (OTEC) technologies have been the subject of much research both nationally and internationally. While much development has taken place, the technologies have not yet realised commercial array scale deployment. Energy system modelling to incorporate future technological advances is based around a series of assumptions which attempt to present potential pathways for new energy technologies to emerge and become established as a part of the wider energy mix. In order to enhance existing energy system modelling, a thorough investigation of the Levelised Cost of Energy (LCOE) for wave, tidal and OTEC technologies has been undertaken. This assessment draws upon industry's state of the art knowledge around the costs to

deploy and operate each technology in its current state, and the cost reductions that are foreseen on the route to product commercialisation.

Each technology under consideration in different stage of development will presents its own unique challenges. In addition, the likely scale of technology varies between wave,tidal and

OTEC, with the latter more likely to be deployed as a large-scale multi-MW power plant (similar to conventional thermal power generation) in comparison to the modular design of wave and tidal stream technologies. Wave and tidal technologies are modular in design, and therefore large power plant capacities will be achieved by the utilisation of multiple modular energy converters.

The assessment of the Levelised Cost of Energy (LCOE) for ocean energy devices represents a critical element of understanding in the development of ocean energy projects. While the cost of existing prototype devices is high, there is scope for significant reductions of the cost of energy. LCOE projections are a cornerstone of the deployment strategy for all device and project developers. The final goal for all wave, tidal and OTEC technology developers is to generate power at a cost that is competitive with alternative forms of generation. Cost competitive marine energy devices could then foster ocean energy technologies as realistic alternatives of conventional electricity generation, and as complementary technology to other sources of renewable energy.

Currently, there is not an international and standardised approach to draw LCOE estimates, and the lack of rules and guidance regarding the boundaries and assumptions often makes LCOE results incomparable and non-transparent. By defining sets of parameters such as capital expenditures (CAPEX), operational and maintenance expenditures (OPEX) and input resource data, each project can deliver a clear and unbiased model to calculate the LCOE of different ocean technologies.

Furthermore, the work aims to provide an authoritative view on what cost reductions are feasible at a global level has been made, taking into account the experience from other technologies. By undertaking a bottom up assessment of the cost components of leading wave, tidal and OTEC systems, this work investigates the development and fabrication of leading devices or systems, and their integration into commercial arrays and large-scale power plants. The assessment includes project development, operation and maintenance costs. The work is informed by a series of in-depth interviews with technology developers, and is built upon work carried out by different international projects (e.g. SI Ocean, DTOcean, Equimar, the Danish LCOE Calculation Tool, Carbon Trust, and US Department of Energy).

11.2. Supporting mechanism/incentives

Clear commitment to OSW by Chinese government: Ambitious targets set out within the REL provided certainty to the market about China's midterm commitment to OSW. These targets indicate a strong commitment to OSW by the government. This enables a range of support mechanisms to be implemented at national and provincial levels and ensures focus by public sector enablers and public corporations on the sector. The release of public tenders for concessions within the provinces allows developers to access sites. Strategic set-up of demonstration sites in support mostly through region support.

Enforced obligation on developers: On 23 March 2018, the NEA announced a draft version of Renewable Electricity Quota and Assessment Method. This is expected to introduce obligatory province-level quotas for none hydro-power renewable generation through a Renewable Energy Electricity System, similar to the UK Renewables Obligation scheme. Grid companies, retail electricity companies and large energy users which directly purchase electricity will be obliged to purchase a set percentage of their electricity from renewable sources.

Financial incentive mechanisms: The primary mechanism for ORE development commercial support is a Feed-in Tariff (FIT). For example, REL established a FIT for OSW based on the region and project specifications. The initial lack of clarity on FITs for OSW has been cited as one of the key reasons for a slow start to the Chinese OSW sector. There are two sets of rates, one for projects that started construction before 2017 and one for those that started after. On top of this, the Preferential Tax Policy is built that investments in OSW benefit from reduced value added tax (VAT) and enterprise income tax (EIT).

Grid connection policy: Grid operators are obliged to source a proportion of their electricity from renewable sources. In addition, developers need grid connection approval to begin construction.

Supply chain development support: A range of provincial and city level industrial strategies have been implemented in key ORE regions. Take OSW as an example, observed provincial level support mechanism for supply chain stimulation includes:

- Development of dedicated OSW industrial zone including key facilities
- Active inward investment incentives to build local competency
- Direct funding to companies in the province for development activities and
- infrastructure development
- Development of dedicated port facilities.

The policy was sustained until 2019, when the new auction schemes were introduced.

11.3. Circular economy

Circular economy is presented as a system of resources utilization where reduction, reuse and recycling of elements prevails: minimize production to a bare minimum, and when it's necessary to use the product, go for the reuse of the elements that can not return to the environment. Renewable energy production obviously fit in the classical circular economy as the raw material could be recycled and reuse (Fig. 16). ORE indeed is included in blue econmy as an emerging blue technology sector, which could provide value as an enabling function to advance the goals of low-carbon and circular economy. Although ORE technologies are at an early stage of development, there are encouraging signs that the investment cost of technologies and the levelized cost of electricity generated will decline from their present non-competitive levels as R&D and demonstrations proceed, and as deployment occurs. Whether these cost reductions are sufficient to enable broad-scale deployment of ocean energy is the most critical uncertainty in assessing the future role of ocean energy in circular economy.

In the light of eco-civilization construction in China, circular economy will be increasingly important in the reform of national economic systems, and ORE development could play a key role in blue economy. The idea of integration of multi types of ORE, supporting for the local community’s electricity, freshwater as well as for the mariculture, could archive the goals of self-sustained for coastal communities (Fig.19). It indeed is currently testing in Zhairuoshan Island by Zhejiang University, in Zhejiang Province. This model could be further modified and applied to promote the ORE development in circular economy system.

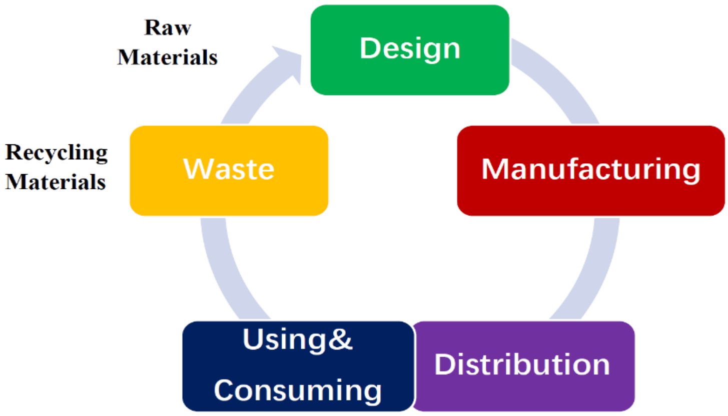


Figure 16. Circular economy (Hao S, 2020)

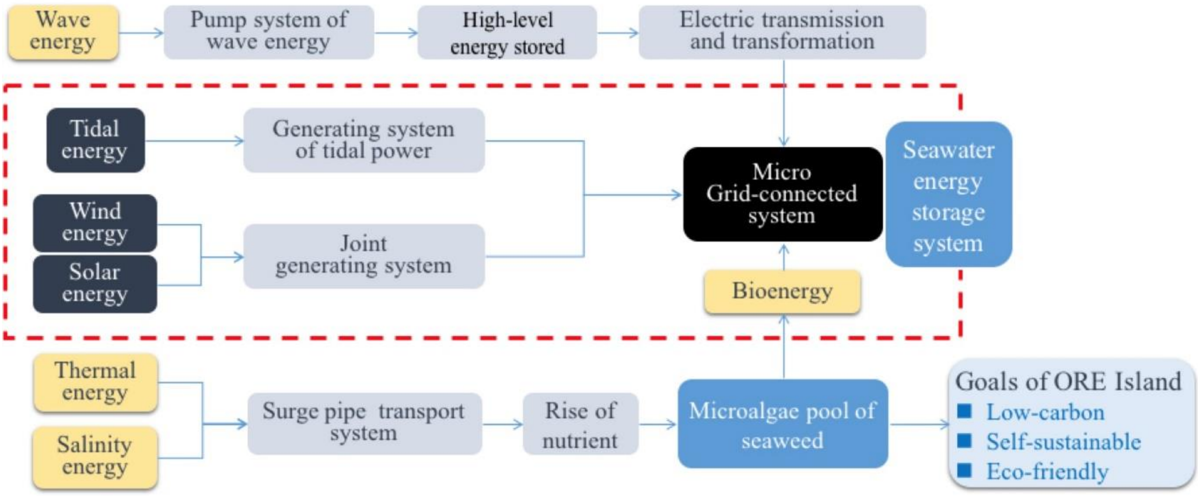


Figure 17. Circular economy (Steve Harris, 2018)

11.4. Industrial roll-out

Industrial roll-out enables a shift from investment support to revenue support via instruments such as feed-in tariffs or renewable energy certificates. It is essential that this transition is tailored to the specific needs of the given technology as not all ocean energy technologies will reach this phase at the same time even with the same energy source strand. Attempting to shift the policy environment too soon is likely to result in a collapse of demand, slowing of deployment, even a potential halt. This would delay the growth of the technology and the learning opportunities, and may mean the collapse of even leading companies resulting in a loss of knowledge and opportunities.

When designed properly, revenue-based schemes have been shown to drive innovation, deployment and cost reduction in renewable energy technologies, such as in Denmark for onshore wind in the 1990s. Revenue-based schemes should be suitably targeted, predictable and stable. Revenue support can also be gradually and predictably reduced in time to adapt to cost reductions and avoid over-compensations, possibly linked to the total volume of technology that comes online or its estimated cost.

Regulatory uncertainty in revenue support, such as during the Electricity Market Reform (EMR) debate in the UK, greatly contributes to a reduction in market confidence and therefore increases the cost of capital. In the worst cases such as retro-active changes to renewable support in Spain, it may lead to market slowdown and reduction of industrial development.

• Stable, long-term revenue support schemes will ensure the predictability of income, thus reducing risk and reducing the cost of accessing capital, taking account of the size and quality of the resource, with objective and defined criteria.

• Governments should strive to achieve cross-party support for policy initiatives relevant to ocean energy. This could reduce the potential for de-stabilizing the policy environment following changes in administration and act to reduce political risk to the support schemes, hence lowering the cost of capital.

11.5. Insurance

Insurance for ocean energy projects is currently expensive, with high deductibles and limited cover. The insurance sector's experience with ocean energy is very limited, particularly with regard to marine operational issues.

In the ocean energy sector, operating data and credible estimates of potential claims costs are still being developed. The number of players in the sector with relevant credible experience is limited but growing. The ocean energy sector must identify and exploit opportunities to accelerate insurers' confidence in, and knowledge of, the sector, its technology and the likely costs of claims. This will allow for insurance costs to be managed.

• Set up a working group with developers (including representatives of all stages of device development), contractors, etc. and insurers/brokers, to derive a contract structure model with risk options and strategies, codes of best practice, certification standards for marine deployment, moorings, cabling, sea fastenings, vessels, studies of weather risk etc., and use it to engage with the insurance industry.

• Develop mechanisms for co-operation between the ocean energy sector and the insurance sector with a view to enabling protected access to data.

• TP Ocean to review ways and means of providing warranties and performance guarantees for 'first-farm-ready' devices, sub-systems and components which have successfully passed through the stage-gate process outlined at 3.2.3, but which do not have the balance sheet strength required by utilities and site developers.

11.6. Loan guarantees

At the current stage of development of the ocean energy sector, the risk profile of projects means that there is limited or no availability of commercial debt, with commercial models relying on equity and grant funding. Market analysis suggests that there is limited availability of equity from venture capital sources or the public equity markets due to low project returns. The use of loan guarantees might enable public authorities to leverage more finance into the ocean energy sector than would otherwise be the case were it simply to provide direct grant support.

Loan guarantees can cover the risk of default as well as the cost of the scheme. Pricing this risk is critical and the responsible public sector bodies must have the required commercial expertise to undertake the necessary due diligence.

These instruments are more fitting for the post demonstration phase, yet work on their design needs to begin now so that they are available when needed. This will also give technology developers and funders a line of sight to future funding opportunities and so incentivise near term CapEx funding.

- Establish a working group between ocean energy industry and private and public finance institutions on loan guarantee design.

11.7. Export markets

11.7.1. Create route to market for innovation

China potentially offers a much more open market for UK development technology than Europe – particularly around wind turbine component technology – and could address one of the key barriers to market entry for innovative UK companies working in OSW.

The European OSW market has consolidated and is dominated by two large turbine manufacturers and a limited number of large OSW developers. The Chinese market still supports a large number of developers and turbine manufacturers. This naturally creates more route-to-market opportunities for new technologies.

This is particularly true for the wind turbine concept or component technologies. The dominant European manufacturers have highly-integrated component development and design teams and a valuable track record in specific technologies. This means that adoption of technology developed outside the companies is relatively low. This is a significant barrier to commercialisation of new technologies developed in the UK and turbine-focused technology developers.

Chinese manufacturers appear more open to the adoption of externally-developed technology. A number of the manufacturers expressed an interest in meeting UK-based companies with relevant technology during the mission.

11.7.2. Create route to market for supply chain

The Chinese offshore market is growing fast. By 2025 it is expected to be the largest OSW market in the world. At present, the market is immature, and supply chains are under development. This presents a significant opportunity for UK companies to find specialist niches within the supply chains of Chinese developers, turbine manufacturers and other tier 1 suppliers.

The size of the market means that even niche opportunities could be highly beneficial to any company that breaks in. R&D collaboration can be an enabler to increase the visibility of UK innovations to the Chinese and allow the development of relationships that build into supply opportunities.

Many Chinese turbine manufacturers and suppliers have stated their ambition to break into other global OSW markets. In addition to accessing the Chinese market, if UK companies can integrate into the key Chinese OSW supply chains, there is an opportunity for UK suppliers to access other global markets, through these relationships. Given the challenging IP conditions in China, ensuring how UK companies get value from this needs to be carefully considered.
Further collaboration with China on OSW can strengthen this reputation and increase the UK's visibility in the Chinese OSW sector, allowing a "softer landing" for UK companies looking to break into the Chinese OSW market.

The UK faces stiff competition in both these areas from Denmark, Germany, Norway and the Netherlands, who are actively pursuing collaboration with China on OSW. In many aspects, Denmark (and to a lesser extent Germany) is significantly ahead of the UK in terms of reputation and engagement in OSW. This is not an entrenched position, and immediate action and a demonstration of the UK's commitment to an ongoing relationship in this area should ensure the UK is regarded as a valuable partner in OSW on a par with these countries.

11.7.3. Attract investment opportunity

While the UK funding mechanisms and investment appetite are in place for TRL 1-6, raising the investment needed for prototyping and demonstration projects, which can be expensive due to the scale of devices and development project in the OSW market, can prove a significant challenge for UK companies developing the technology. Chinese investment may enable more UK companies to bring new technologies through to TRL 9 in addition to offering a clear route to market in some cases.

China has ambitious targets for OSW development. While there is already over 3 GW installed in China, the general perception of the experts on the mission is that the Chinese OSW market is 5-8 years behind the UK in terms of technology and best practice. This is broadly recognised by Chinese stakeholders. In order to deliver on the proposed targets, improvements in technology and cost reduction will be required.

As a result, both Chinese public and private sector stakeholders are keen to learn from European experience in OSW in order to bring China on a par with Europe, both in terms of cost of technology, best practice and to ensure rapid cost reduction.

Chinese stakeholders recognise that they can significantly improve domestically-developed and manufactured technology with the integration of European innovations. This will also better position them for expansion outside the Chinese market, both in terms of ensuring their technology is competitive but also by ensuring it has credibility. Partnering with UK companies allows access to this technology.

There is a strong appetite in China for financial investment in UK companies. There is interest both in investment in OSW technology companies and OSW projects. During the mission, multiple organisations conveyed the message that they were looking for European investment opportunities. Innovation collaboration with the UK gives visibility of investment opportunities in technology companies, an opportunity to assess technologies and builds the necessary relationships needed.

Specific cities, such as Yangjiang, and provinces such as Shandong and Guangdong, are investing heavily in developing the infrastructure to support inward investment in OSW. These include science parks and industrial areas as well as providing tax and funding incentive for setting up facilities in the region.

While it is anticipated that the majority of this inward investment will be from domestic companies, regional development agencies are keen to attract inward investment from European companies. These incentives aim to both stimulate job creation and also to ensure transfer of expertise and capability from European into domestic firms.

References

1. Hao S, Kuah A T H, Rudd C D, et al. A circular economy approach to green energy: Wind turbine, waste, and material recovery. Science of The Total Environment, 2020, 702: 135054.
2. Steve Harris, Louise Staffas, Tomas Rydberg, Elin Eriksson, 2018. Renewable materials in the Circular Economy. https://www.ivl.se/download/18.2aa2697816097278807e8a5/1523522038883/C296.pdf

12 GENDER

The energy sector remains one of the least gender diverse sectors and closing this gender gap will be vital as women are key drivers of innovative and inclusive solutions. A clean energy transition will require innovative solutions and business models to be adopted and greater participation from a diverse talent pool.

12.1. China current situation (statistics)

In China, women can be rarely found in the renewable energy industry on account of the heavy work, especially in the coastal areas and offshore platforms. The situation seems not to be improved in the near future if the working condition is not improved.

In research field, Chinese women are small number of scientists and engineers to study ocean renewable energy comparing the foreign research institution. According to a very optimistic estimate, 10% of ocean energy research force are women in China. We believe that more and more young women will enter ocean energy sector to do the research in the future as ocean energy becoming more important nowadays.

Globally, the energy sector remains one of the least gender diverse sectors. But women have been proved that are the key drivers of innovative and inclusive solutions for a clean energy transition. The 2030 Agenda for Sustainable Development adopted in 2015 introduced a dedicated goal on gender equality in SDG 5, aiming to "achieve gender equality and empower all women and girls by 2030". A survey conducted by IRENA 2019, revealed that women represent 32% of the fulltime employees of responding organisations in renewable energy sectors, much higher than the 22% average in the global oil and gas industry. Still, in renewables, women's participation is much lower in science, technology, engineering and mathematics jobs than in administrative jobs. As ORE industry is relatively new and small, the gender statistics is kind of lacking. But we believe that it would be a big issue as female practitioners could be even less than the current oil and gas industry.

In China, its sex ratio at birth is already the most imbalanced in the world, with only 87 girls born per 100 boys. But China's constitution guarantees women "equal rights with men in all spheres of life," and over the last several decades, women in China have enjoyed more benefits from health, education and economy. In 2018, female workforce participation had dropped to 68.6 percent, slightly higher than the US (66.1 percent) and roughly equal to Japan (68.7 percent). Regarding the marine and energy sectors (Table 19 and 20), the overall ratio of males to females in the marine industry is about 2.60:1, among which there are significantly fewer females in the water transport industry. The imbalance of the ratio of men to women in the energy industry was even more serious, with the overall ratio of men to women being about 3.52:1, especially the coal mining and washing industry reaching 6.12:1. As adopting a gender perspective to renewable energy development is critically important to ensure that women's contributions, China's marine and energy industry is obviously facing a huge challenge to fill the gender gaps. Yet, detailed information on the status and trends related to gender equality sector remains sparse.

Table 19 Gender distribution in marine industry of China (data from the sixth national population census of China)

China's marine industry	Fishery	Water transport industry	Water management industry	Total
Number of males	223046	57446	31243	311735
Number of females	91252	15672	13084	120008
Males to females ratio	2.44:1	3.67:1	2.39:1	2.60:1

Table 20 Gender distribution in energy industry of China (data from the sixth national population census of China)

China Energy Industry	Coal mining and washing industry	Oil and gas extraction	Petroleum processing, coking and nuclear fuel processing industries	Production and supply of electricity and heat	Gas production and supply	Total
Number of males	405874	72047	59899	272829	31497	842146
Number of females	66310	33193	23690	100942	15217	239352
Males to females ratio	6.12:1	2.17:1	2.53:1	2.70:1	2.07:1	3.52:1

12.2. Global situation (statistics)

Global employment in the renewable energy sector grew by nearly 4 million jobs in six years from 7.1 million in 2012 to 11 million in 2018 (IRENA, 2019a). IRENA's socio-economic footprint analysis estimates that employment in renewables will almost triple to 42 million in 2050 (IRENA, 2020).

In order to realise this success, and to ensure that everyone benefits from the socio-economic opportunities created by the energy transition, the sector must be accessible to women, youth, minorities, and others who are often left behind.

In 2019, IRENA examined the question of gender equity throughout the renewable energy sector. The analysis found that women make up, on average, 32% of the sector workforce. However, imbalances abound across different roles and occupations. At 28%, women's presence in jobs requiring knowledge in science, technology, engineering and mathematics (STEM) is still lower than in non-STEM positions (35%) and administrative jobs (45%).

IRENA alsoe made a survey of the wind value chain in collaboration with GWEC and GWNET. This survey found that women represent 21% of the sector workforce, according to a statistical analysis that accounts for different sizes among participating firms and other organisations in the sector.

13 RECOMMENDATION

(1) Setting up a sound policy mechanism to support the industry

By drawing on the development philosophy of offshore wind power, the potential areas for developing marine energy should be planned to lay a foundation for large-scale application and promote the introduction of on-grid tariff, cost compensation and allocation mechanism for marine energy. National policy investments and financial support from local governments and industrial funds, and tax reduction and exemption policies for enterprises should be promoted.

(2) Further expanding the use of marine energy

Innovations in core technology and independent development of equipment should be promoted for marine energy. Large-scale demonstrative application of wave energy, tidal current energy and energy mix should be carried out. 100MW-class tidal current energy power stations and MW-class wave energy power stations should be built. Industrial demonstration areas and clusters for tidal current energy and wave energy should be empowered. Demonstration projects of power supply based on marine energy for offshore islands, deep-water aquaculture and offshore equipment should be constructed to promote the development of industrial agglomerations.

(3) Strengthening top-level design and providing strong support for industrial development

We should promote the Chinese government to formulate an industrial development roadmap and relevant action plans for marine energy, continue to improve the evaluation ability of the development and utilization potential of marine energy resources, accelerate the construction of innovation centers, test sites and testing and certification platforms. In addition, China should gradually cultivate and improve the industrial chain and technical standards system, and strengthen international cooperation and exchange in technologies.

The following are the specific recommendations put forward for ocean renewable energy (ORE). First of all, they emphasize that an industrial supporting policy mechanism should be established and improved. Furthermore, the scale of ORE utilization should be promoted, whilst financial or venture capital communities as well as private capital should be encouraged by governmental policies. Finally, offshore wind should be accelerated whilst environmental and socio-economic impacts assessed; mechanisms to accelerate commercial realisation of other ORE technologies should be supported by the government.

Policy

- Industrial supporting policy mechanism should be established and improved.
- Scale of ORE utilization should be promoted.
- Enable RD&I to address challenges to reduce costs further to reach parity with other energy technologies.
- Enhance capacity to accelerate innovative and resilient technology development.
- Engage at an early stage with stakeholders include fishermen, community members, regulators, developers, scientists, and tourists.
- Integration emerging ORE technologies into wider applications such as military applications, electricity generation for remote community's, freshwater generation , hydrogen production or aquaculture applications.

Market

- Financial or venture capital communities as well as private capital should be encouraged by governmental policies.
- Strengthening the global export and market opportunities.
- Grow ORE industry, create jobs and take advantage of opportunities within its competency to global markets.

Offshore wind

- Offshore wind should be accelerated whilst environmental and socio-economic impacts assessed.
- Increase Offshore Wind deployment addressing many strategically important goals such as decarbonisation, security of supply, and new business opportunities.

Marine Energy

- Tidal current energy research and development should be encouraged by government as expected to be next type of ORE
- Mechanisms to accelerate commercial realisation of ORE technologies ORE technologies (wind, wave, current, tidal range, ocean thermal) should be supported by the government.