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## Offshore wind zoning in China: Method and experience

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## ABSTRACT

Over the past decade, the increasing demand for renewable energy has driven the rapid development of China's offshore wind industry. However, it is not clear to developers and management departments which types of sea areas can be used for offshore wind projects. According to the provincial marine functional zoning (MFZ), China's coastal provinces have put offshore wind zoning (OWZ) into practice. This paper clarifies the method of OWZ, collects the results from offshore wind zones (OWZs) of 10 coastal provinces, and assesses the characteristics of OWZs by area, functional attribute and distance from the coastline. The results show that most of the areas available for offshore wind are co-existence zones where offshore wind can be sited in an agricultural and fisheries zone, an industrial and urban construction zone, a special-use zone, etc. Currently, 47% of existing offshore wind projects have been located in the OWZs in the East China Sea. Moreover, parts of the coastline distance of OWZs do not meet the "double-ten principle" in China or global siting trends. Generally, the existing areas for OWZ would allow China to meet its national target by 2020, but measures still need to be taken to meet the demands of conservation and sea-use management.

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## 1. Introduction

Renewable energy utilization is an important way to reduce global warming. The fastest growing sector of marine renewable energy (MRE) is offshore wind (Abdel-Maksoud, 2016), and as an indispensable component of renewable energy, offshore wind has been developed by many coastal countries. As of 2016, new capacity for offshore wind installations reached nearly 2219 MW, which brought the total offshore wind installed capacity to over 14,384 MW around the world. In total, 88% of capacity is located in the offshore areas of eleven European countries. The UK accounts for over 36% of global installed capacity, followed by Germany, which accounts for 29%; China, 11%; Denmark, 8.8%; Belgium, 5%; the Netherlands, 7.8%; and Sweden, 1.4%. Other markets, including Finland, Ireland, Spain Japan, South Korea, the USA and Norway, make up the balance of the market (GWEC, 2017).

China attaches great importance to offshore wind development,

and in the past decade, the pace of offshore wind development in China has been accelerated. In 2016, added capacity for offshore wind was 592 MW, which brought the cumulative offshore wind installed capacity to almost 1627 MW (Table 1); this was mostly located in Jiangsu, Fujian and Guangdong provinces. In addition, the Wind Power Development 13th Five-Year Plan has set a target of 5000 MW by 2020.

## 1.1. MSP of offshore wind around the world

As a new approach to sea use, offshore wind power may occupy a large scope of sea area as the industry gradually expands its scale of development. However, compatibility with environmental impacts or with other sea-use activities is unknown; therefore, real or potential risks of sea-use conflicts exist. Marine spatial planning (MSP) can aid in the process of wind farm site selection and conflict management. In the EU, the industry has evolved in a haphazard fashion at a pan-European level, and until recently, this trend was further exacerbated by the absence of common EU rules on maritime spatial planning aimed at mitigating the cross-boundary impacts of wind farm development on other legitimate uses of the marine environment (Long, 2014). MSP has been recognized as a way to meet multiple ecological, economic and social objectives within an increasingly crowded ocean (UNESCO, 2014). These

Abbreviations: OWZ, offshore wind zoning; OWZs, offshore wind zones; MSP, marine spatial planning; MFZ, marine functional zoning; MRE, marine renewable energy; OWE, offshore wind energy.

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**Table 1**  
Offshore wind installed capacity in China (2007–2015).

Year	Annual (MW)	Cumulative (MW)
2007	1.5	–
2009	14.0	15.5
2010	135.5	151
2011	109.58	260.58
2012	127.0	387.58
2013	39.0	426.58
2014	227.6	654.18
2015	360.5	1014.68
2016	592	1627

Data source: Global wind report-annual market update 2016 (GWEC, 2017).

objectives mainly include conserving or protecting marine resources, conserving ecological structure, protecting ecologically valuable areas, restoring degraded areas, ensuring the sustainability of economic uses of marine space, promoting appropriate uses of marine space, reducing and resolving conflicts among current and future human activities, reducing and resolving conflicts between current and future human activities and the environment, and ensuring economic returns to the public from the use of ocean space (UNESCO, 2009).

By the end of 2014, at least six countries, Belgium, the Netherlands, German, Norway, Australia and China, and three American states had implemented MSP. The countries that employ related work for offshore wind zoning include the United Kingdom, Portugal, Sweden, Norway, China, Canada, and the United States (Ocean Energy System, 2016). The Marine Policy Statement in the UK states that marine plans should take account of and identify areas of potential for the deployment of different renewable energy technologies. Renewable energy has been categorized as offshore wind, wave, and tidal energy for the purpose of marine planning (Her Majesty's Government, 2011). In Portugal, within the preliminary marine spatial mapping exercise, renewable energy is included as one of the “prospective visions” for ocean use, which covers both offshore wind and wave energy (Santos et al., 2015). In Sweden, 27 offshore wind areas were designed by the Sweden Energy Agency in 2013 over an approximate total sea area of 4000 km<sup>2</sup>. In Norway, there were 15 proposed area impact assessments connected with offshore wind power in 2010; five areas were recommended as a priority, four of which are in the North Sea (Ocean Energy System, 2016). In Canada, the Pacific North Coast Integrated Management Area Plan (2013) covers waters from the north Canadian border with Alaska to Vancouver Island, and includes offshore wind resources (DFO, 2013). In the United States, the “Smart from the Start” program of the Bureau of Ocean Energy Management (BOEM) identifies “wind energy areas” (WEAs) of the Atlantic Outer Continental Shelf; which are places where the agency could make a “finding of no significant impacts” for wind development and where BOEM could then offer leases (Tierney, 2013). Moreover, the Pacific Northwest National Laboratory (PNNL) and Parametrix conducted a spatial analysis for the state of Washington's MRE, and offshore wind was included (PNNL, 2013).

Most of the methodologies used for planning purposes are based on geographic information systems (GIS) due to their powerful capabilities in managing, formatting and modeling the large amounts of geo-referenced data usually involved in planning procedures (Costa et al., 2016). GIS and multicriteria evaluation techniques can be combined to evaluate MSP scenarios, such as co-location of offshore wind farms and aquaculture (Gimple et al., 2015). In addition, spatial distribution models of marine birds from aerial surveys can be used for OWE MSP (Kristopher et al., 2014). During the process of MSP, the scenarios of MSP would be set. To identify spaces suitable for offshore wind generation in the

central and southern North Sea in Europe, four scenarios (‘Little Will, Little Wind’, ‘Going Solo’, ‘In the Deep’ and ‘Grand Design’) were developed based on differences in spatial prioritization and technological development. The ‘Grand Design’ possibilities for offshore wind are optimal. At the same time, consequences for non-wind sea-use functions were evaluated for the different scenario outcomes. Possibilities for co-use and options to minimize negative impacts were also identified (Van der Wal et al., 2011). In Spain, 3 different scenarios for MSP have been established. Using the calculations of ArcGIS, the marine windfarm layer distinguished among suitable zones, suitable zones with conditions, and exclusion zones (Rodríguez-Rodríguez et al., 2016).

## 1.2. MFZ of offshore wind in China

In China, marine function zoning (MFZ) is a kind of MSP for sea-use activities that divides marine space into different functional zones by following the criteria of MFZ. MFZ not only provides the legal basis for marine management but also guides the distribution of industries in marine space. MFZ is a fundamental tool for regulating the use of sea areas, protecting the marine environment, and promoting the rational and sustainable use of the territorial sea and exclusive economic zone of China (Fang et al., 2012).

When China first began employing MFZ in 1979, the Chinese government deployed the “National Coastal Areas and Tidal Flat Resources Integrated Survey”. Subsequently, the first generation of MFZ (1989–1993) began. MFZ is a continuing and iterative process. After implementing, monitoring and evaluating the first generation, the second generation of MFZ (2002–2010) began. From 1979 to 2010, China's MFZ has gradually matured; at different governmental authority levels, national, provincial and municipal levels of MFZ have been established. On the regulation side, an integrated system of assembling compiling, approving, registering, monitoring, evaluation and revision has been established. An official MFZ guidance document, the *Technical Requirements on the Compilation of Provincial Marine Functional Zoning* (MFZ guide), was published in 2010 to establish methods and technologies. From 2009 to 2012, the third generation of MFZ (2011–2020) was planned according to the MFZ guide, which covered the national, provincial and municipal levels. With the existing MFZ regulations and technology systems in place, China has completed 11 provincial-level plans covering its entire sea area under national jurisdiction, and these include the use of offshore wind. The offshore wind zones (OWZs) provide the legal basis for offshore wind management.

The sea-use function classification system in the MFZ guide includes 8 classes and 22 subclasses. OWZs would have been zoned together with these sea uses but were not included in the classification system. The MFZ guide clarifies that “*The offshore wind resource is widely distributed but has not been fully investigated yet. The offshore wind farm is partially compatible with some sea-use activities. Currently, proper sea areas can be selected for offshore wind farms according to scientific assessment on the basic condition of not destroying the basic marine functions, so that the basic marine functional zones are not specifically set for offshore wind zones*”. In this paper, the OWZs mainly include 2 types of zone; one is the MRE zone, whose dominant function is set as offshore wind (the MRE zone is a subclass of mineral and energy areas and refers to the sea areas used for developing and utilizing tidal energy, wave energy and other renewable energies), and the second includes the zones that are compatible with offshore wind, such as the agricultural and fishery zones.

For offshore wind zoning (OWZ), provincial OWZs have unique characteristics due to differences in resources, the ecological, social and economic parameters, and environmental protection targets, as well as local development strategies. In addition, offshore wind

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