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China's Offshore Wind Industry 2014

An overview of current status and development

Marius Korsnes

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China's Offshore Wind Industry 2014

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Foreword

This report has been produced as part of a two-month research stay at DNV GL Renewables in Shanghai, where I was sharing offices and collaborating with the employees working with renewable energy. The work has been extensively supported by people in DNV GL, and the report would not exist without their help and useful feedback. The information in the report is also based on a one-year field stay in Shanghai, as part of my PhD dissertation on the emergence of China's offshore wind industry, at the Joint Research Centre on Sustainable Energy of the Norwegian University of Science and Technology and the Shanghai Jiaotong University. During the year I conducted 43 interviews with various stakeholders in the industry, government and research communities, and I participated in several conferences, industry exhibitions and offshore wind workshops. Any potential errors or misunderstandings belong to me.

Marius Korsnes, May 2014

1. Introduction

The 12th 5-year Plan for Renewable Energy (2012) states that the Chinese **Government's goal for 2015 is 5 GW installed offshore wind power, which will increase to 30 GW by 2020**. Some of the challenges that have inspired the Chinese Government to set this ambitious target are the facts that China has a growing population and a rapidly growing economy in demand for electricity need. China's electricity supply is heavily coal-based, and China's large cities are actively combating the presence of toxic smog. Offshore wind power may thus be a promising solution to increase the energy supply on the densely populated east coast without increasing the environmental problems.

This report presents China's policy and regulatory regime for offshore wind (section 2), then looks into the industry and the supply chain taking part in developing and deploying offshore wind in China, and finally discusses the barriers hindering this development. The remainder of this introduction provides a brief overview of the potential and situation for offshore wind in China to date.

"The major driver behind offshore wind is the energy need in China. We have a limited amount of clean energy, and the country has issues with pollution and CO_2 so we need the wind."

Government official

Offshore wind power has a clear attraction in China, given the proximity of the resource with key demand centres on the east coast, and China's increasing electricity demand. In 2010 the Chinese government initiated the first concession round for offshore wind farms, where four projects totalling 1 GW were approved in Jiangsu province – for which all developers and turbine manufacturers were Chinese domestic actors (Zhang et al. 2011). Shortly after, however, these projects underwent new environmental assessments and cable routing; it was decided that the project sites had to be changed, resulting in considerable delays and much higher costs (Li et al. 2012). Jiangsu province is the province with the highest ambitions, but most of the provinces along the coast have plans to develop offshore wind farms (Ling and Cai 2012).

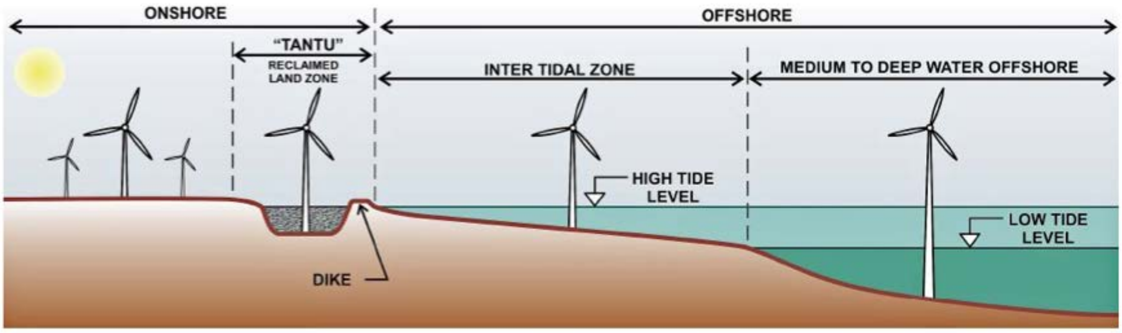
1.1 Definition

As indicated in Figure 1, China's National Energy Bureau and the State Oceanic Administration define the following projects as 'offshore wind':

- Intertidal: the zone between low- and high-tide marks along the shoreline and with water depths below 10m. This is a unique designation used only in China so far, and these areas are mainly located in Jiangsu province[1]

- Near shore: maximum 10 km from the shoreline and with water depths between 10 and 50m; and
- Deep sea: greater than 10km from the shoreline and water depths greater than 50m (MAKE 2013a, p. 5).

Figure 1 China´s definition of offshore wind. Source: World Bank & NEA (2010)



1.2 Potential

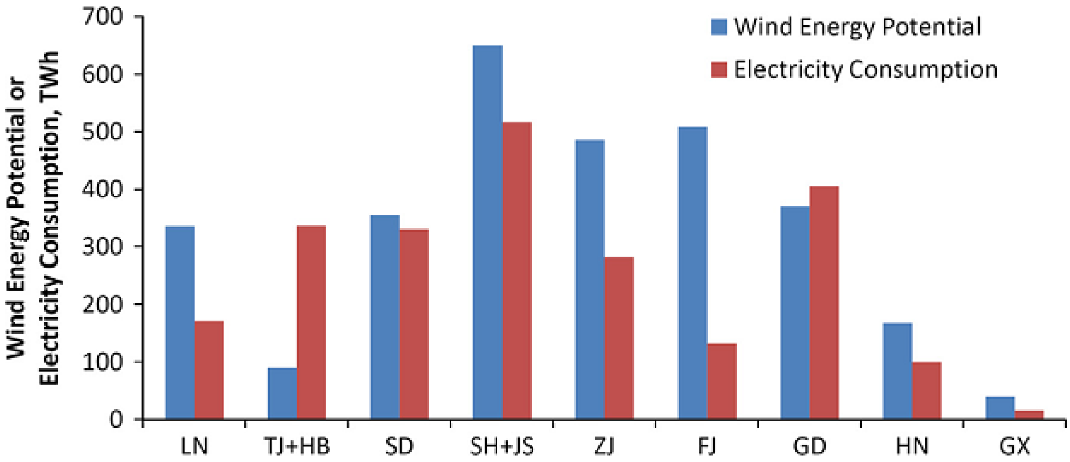
There are various estimates for China's offshore wind resource. According to the China Wind Energy Outlook 2012, the offshore wind power development potential is approximately 200GW at 5-25m water depths and 50m height, and 500GW at 5-50m water depth and 70m hub height (Li et al., 2012). Measured in terms of space distribution BTM (2012) assesses that the area from the shoreline out to water depths of 20m could accommodate a capacity of 100-200GW assuming that 10-20% of the area is available, and that every square kilometre uses a 5MW turbine.

The strongest winds are in the Taiwan Strait off the coast of Fujian, followed by Zhejiang, and the west coast of Hainan. Guangdong also shows significant potential. The adverse effects typhoons have on a wind farm still is a technical challenge that needs to be overcome in order to fully develop typhoon-prone provinces in China. WWF (2010) states that in the last 50 years 'Guangdong has had the highest occurrence of typhoons with approximately 160 typhoons coming on land'. The occurrence of typhoons makes Shandong and Jiangsu provinces more attractive for development at the present stage.

[1] Note that other areas of the world have similar conditions, such as Gujarat in India (World Bank & NEA 2010). Experience with these conditions may therefore be useful in other markets.

Lu et al. (2013) consider the total potential generation of offshore wind electricity for China's coastal provinces, compared to these provinces' total electricity consumption in 2010 as seen in Figure 2 below. The figure shows that most of the provinces, apart from Tianjin and Beijing, can provide a substantial or surplus amount of offshore wind electricity to their inhabitants. The total estimated wind energy potential for the entire coastline is estimated to 3000 TWh, whilst the total electricity consumption in 2010 was 2288 TWh (ibid.). Figure 2 is important since the coastal provinces represent the most populous region of China.

Figure 2 Offshore wind energy potential for Chinese coastal provinces/municipalities compared with 2010 electricity demand. Source: Lu et al. (2013)



The total technical potential for each province is shown in Table 1 below, as calculated by the Sun Yat Sen University in 2010. The technical potential is the amount of energy that could be generated if wind farms were evenly spaced all along the coast, and as a measure it is not realistic in terms of actual generation capacity of offshore wind power (the total technical potential is three times higher than Lu et al.'s (2013) estimate). It is nevertheless useful in understanding the wind resource at hand.

Table 1 China's Technical Offshore Wind Potential per Province with 100km from Shore, in TWh. Source: WWF (2010)

Water Depth	0-10m	10-30m	30-50m	50-70m	>70m	Total (incl. Islands)
Shandong	167 TWh	823 TWh	301 TWh	203 TWh	23 TWh	**1,536** TWh
Jiangsu	322 TWh	481 TWh	24 TWh	0	0	**837** TWh
Zhejiang	267 TWh	372 TWh	304 TWh	280 TWh	61 TWh	**1,330** TWh
Fujian	152 TWh	512 TWh	557 TWh	652 TWh	116 TWh	**2,031** TWh
Guangdong	219 TWh	649 TWh	715 TWh	278 TWh	155 TWh	**2,049** TWh
Hainan	63 TWh	213 TWh	264 TWh	404 TWh	1000 TWh	**1,954** TWh
Total	**1,190** TWh	**3,041** TWh	**2,166** TWh	**1,816** TWh	**1,354** TWh	**9,735** TWh

1.3 Projects to date

China's first major offshore wind farm was the Donghai Bridge 102MW project outside of Shanghai, which was completed in 2010. Since then development has been slow, and only one new larger offshore wind project has finished, namely Phase 1 and 2 of the Rudong Intertidal wind farm, now totalling 232MW, since the first turbine test in 2009. Remaining projects are mostly single one-off installed turbines for demonstration purposes. In 2013 39MW of new offshore wind capacity was installed, making a total of 428.6MW of installed capacity year-end 2013 (Liu 2014).

Discussions with people working with offshore wind at DNV GL Shanghai have led to an identification of only six projects that are assessed to start construction in 2014, totalling 1GW. These projects are: Binhai Offshore Concession Project (300MW), Jiangsu Dongtai Intertidal Wind Farm Concession Project (201.6 MW)), Donghai Bridge Offshore Wind Farm Phase II (102.2 MW), Zhuhai Guishan Offshore Wind Demonstration Project (198 MW), Rudong Zhong Guang He offshore demonstration project (150 MW), Putian Pinghai bay offshore demonstration project phase 1 (50 MW). The rest of the projects are in planning stages, or their status is unclear. For more details, see Section 3.1.

2. Policy environment

China has an extraordinary capability to enforce new policies that sustain industrial growth and likewise restrain in times of overcapacity. This has been the case for China's onshore wind industry, and will likely be the case offshore as well. Due to the prominent state-owned enterprises within the sector, there is a strong direct link between policymakers and industry in China, with energy issues being recognised as of strategic importance to policymakers.

2.1 Existing policy regime – onshore wind

Several policies in China apply to the onshore wind industry and renewable energy in general, and therefore are relevant for offshore wind. These regulations are briefly outlined here. It is useful to divide the regulatory regime into:

1. Regulations that **promote industry development**; and
2. Regulations that **promote renewable electricity generation**.

2.1.1 Industry development

At least three important factors have directly promoted the development of China's wind industry:

- **Local content has spurred supply chain development:** The domestic content requirement on wind turbine manufacturing in China has led to the development of supply chain markets preventing bottlenecks in component supply (See Section 3).
- **Speedy approvals have accelerated projects:** Until 2011 speedy approvals for onshore wind power projects at a provincial level resulted in a huge number of additions each year.
- **Ready availability of finance:** China's banking system has managed to mobilise enough money to accommodate the massive investments in wind power. The government uses the China Development Bank, Agriculture Development Bank, and Industrial and Commercial Bank to offer low interest rate loans in support of renewable energy. Financing for up to 80% of a wind power project costs can be provided, with the balance of financing coming as equity investments from the loan beneficiaries (GlobalData, 2013). Many loans are issued as non-recourse based on a developer's project pipeline, as opposed to project-specific lending (Innovation Norway, 2013).

In 2002, the Chinese government decided to stimulate the development of wind energy through a **national wind concession programme**, allocating selected sites for wind farm construction to the company bidding the lowest electricity tariff (Recknagel, 2010, p. 20). Some prerequisites were made in order for projects to be accepted, such as restrictions on turbine size and local content. In effect, the price of electricity not only decided who won the bid, but also the extent to which the turbines were manufactured locally (Wang, 2010, p. 705).

As the Chinese government did not want to depend on expensive imported turbines, they decided that a **domestic content requirement** of onshore wind turbines was needed to facilitate domestic manufacturing of turbines and turbine parts (Howell et al., 2010). During the first concession round, which started in 2003, the local content requirement of turbines was set at 50%—a requirement that increased to 70% in 2004 and was finally revoked in 2009 (Wang, 2010). In addition to content requirements, import tariffs on preassembled wind turbines were at 17% in 2007, whilst tariffs on their components were set to only 3% (Martinot & Li, 2007, p. 20). This policy, together with the removal of local content requirements in 2009, have allowed domestic manufacturers to more easily access wind components

"The main driver is the local development imperative, which is city and provincial governments on the coast who would like to keep economic development within their premises"

Wind Energy Consultant

from foreign suppliers as they build the prototypes for their larger turbines (BNEF, 2010). In addition several favourable conditions exist on provincial level to attract manufacturing industries, such as income tax for wind projects, lowered from 33% to 15% and VAT for wind equipment lowered from 17% to 8.5% in 2008.

Since 2009 China has had a national **Feed-in Tariff for onshore wind**, divided into four categories based on the average wind resource in a region, and geographical conditions, as indicated in Table 2 below.

Table 2 China's Feed-in Tariff Policy

Resource category	FiT	Notes
Category 1 (High resource)	CNY0.052/kWh	The FiT prices were established based on lessons from earlier concession rounds. Support is provided over a 20-year period, or a total load time of 30,000 hours, depending on the resource. 30,000 hours typically amount to 15 years.
Category 2 (Mid resource)	CNY0.055/kWh,	
Category 3 (Mid resource)	CNY0.059/kWh	
Category 4 (Low resource)	CNY0.061/kWh	

The FiT system is structured as follows. The two grid companies State Grid and Southern Grid are mandated to buy all renewable electricity supplied to the grid. The Ministry of Finance collects a price surcharge for all electricity consumption in China, in mid-2013 raised from RMB 0.008/kWh to RMB 0.015/kWh for industrial customers, and RMB 0.008/kWh for residential and agriculture customers (Davidson 2013), which is allocated to the grid companies. Grid companies use this money to cover the price difference between market price and the feed-in tariff paid to the onshore wind power developers.

For the offshore wind industry the government plan was that the **first concession round of 2010** would provide guidance in terms of prices for a feed-in tariff. The first round consented four projects in Jiangsu province; however, final approval was only given to three of these projects end-2013, and one is still yet to be approved.[2] Moreover, the winning bid prices for the four projects were very low, ranging between RMB 0.6235/kWh (Dongtai Intertidal) to 0.737/kWh (Binhai Offshore). The NEA regulation stipulated that winning bids were the ones that were priced closest to 10% lower than the average price offered by all participants (Qi 2012). The FiT for the operational projects in China have

[2] More on the concession projects in Section 4.2.

been RMB 0.8/kWh for the Rudong Intertidal project, and RMB 0.978/kWh for the Shanghai Donghai Bridge Project for the first 60,000 equivalent full load hours (approximately 22 years) (BTM 2012).

Interview information suggests that the government intends to establish a FiT for offshore wind, distinguished from onshore wind, although no concrete proposal has been made to date. The government still needs more experience with demonstration and concession projects before a price can be set. In conversations with government and the industry most seem to agree that a price range between RMB 0.8-1/kWh is reasonable. In addition, after the failure of the first concession round, there appears to be a consensus amongst stakeholders that prices should be decided on a project by project basis through tenders, since each project has different cost characteristics. Most interviewees agree that the single most important barrier to developing the offshore wind industry in China is the lack of an established pricing mechanism for projects.

2.1.2 Electricity generation

Measures aimed at increasing the proportion of renewable electricity production in China are covered in the **Renewable Energy Law (ReLaw) enacted in 2005**, with amendments effective from April 2010. The Central Committee enacted the law with overwhelming support, suggesting that Chinese legislators almost unanimously recognised the need for renewable energy (Wang, 2007). This support for renewable energy also applies to offshore wind energy, especially because of the resource's proximity to load-centres and the industrial opportunities for local governments, but with some modifications that can be seen in Section 4.2 Political Barriers.

ReLaw measures include government installation goals, mandatory market shares for power producers, a tariff system, a power purchasing agreement for grid companies and a cost-sharing principle with a price surcharge of electricity. Apart from the tariff system, these principles are also valid for offshore wind projects. Nevertheless, they face competition with other renewable energy technologies.

All utilities with a capacity of more than 5 GW of thermal power electricity generation were **mandated by the government**, through the 11th Five-Year Plan for Renewable Energy, **to install at least 3% *non-hydro* renewable power as a portion of their total capacity by 2010, and 8% by 2020** (Li et al., 2010). These mandated market shares undoubtedly led to an increase in onshore wind power investments, and are an important incentive for power producers to develop offshore wind farms. However, the policy also made large power utilities focus less on *electricity generation* (MWh), which demand more resources for operation and maintenance, and more on *installed capacity* (MW). Also, in accordance with the ReLaw, electric utilities are obligated to purchase all wind power produced, and, with the 2009 amendment of the ReLaw, this obligation applies even when there is insufficient power demand on the grid (Martinot & Li, 2010).

2.1.3 Policy loopholes

Two major challenges associated with the renewable energy law are: The absence of functioning enforcement mechanisms; and a lack of clear formulation of responsibilities

These two problems together reduce the commitment of grid companies to acquire wind generated electricity. For instance, the law requires grid companies to acquire all electricity produced from renewable energy, but the wording 'guaranteed acquisition' is not adequately defined. This leaves room for interpretation, and grid companies end up curtailing wind power without any repercussions (Li et al. 2012). Furthermore, wind power producers are also required to assist grid companies in ensuring power supply safety, which gives grid companies more arguments to curtail wind power when there is oversupply. These problems are serious for the wind industry in total, but will likely not be as significant for the offshore wind industry as the grid is more developed along the large load centres.

2.2 Offshore wind policies

For the development of China's offshore wind industry the two relevant government agencies - the National Energy Administration (NEA) and the State Oceanic Administration (SOA) –have published a series of regulations and interim measures. The first was the 2010 'Interim Measures for the Administration of Offshore Wind Power Development and Construction' covering offshore wind farm development plans, an offshore project authority, the examination and endorsement of applications to use sea areas, ocean conservation, the project approval process, final construction acceptance and operational management (BTM 2012).

After problems occurred with the concession round projects in 2010 the NEA and the SOA released the 'Implementation Rules on Interim Measures for the Administration of Offshore Wind Power Development and Construction' in July 2011, where they introduced a more standardised process of site selection, project application, approval, construction and operation. Moreover, this regulation announced that **only wholly- or majority-owned (51%) Chinese companies are allowed to bid**. This is similar to China´s policies for the offshore oil and gas sector, and it indicates that the development of China's coastline is a highly strategic and sensitive topic for the Chinese government, as mentioned in section

4.2. The regulation specifies several criteria for winning bids, amongst them the cost of the power grid development, the technical competence and previous performance of the bidder. Nevertheless, price per kWh remains the most important factor. The regulation also specifies that projects must start construction, defined as installation of the first wind turbine foundation, within two years of receiving project approval. If not, the NEA and the SOA can withdraw the right of project development and the licence for seabed usage (BTM 2012).

2.2.1 Consenting regime for offshore wind

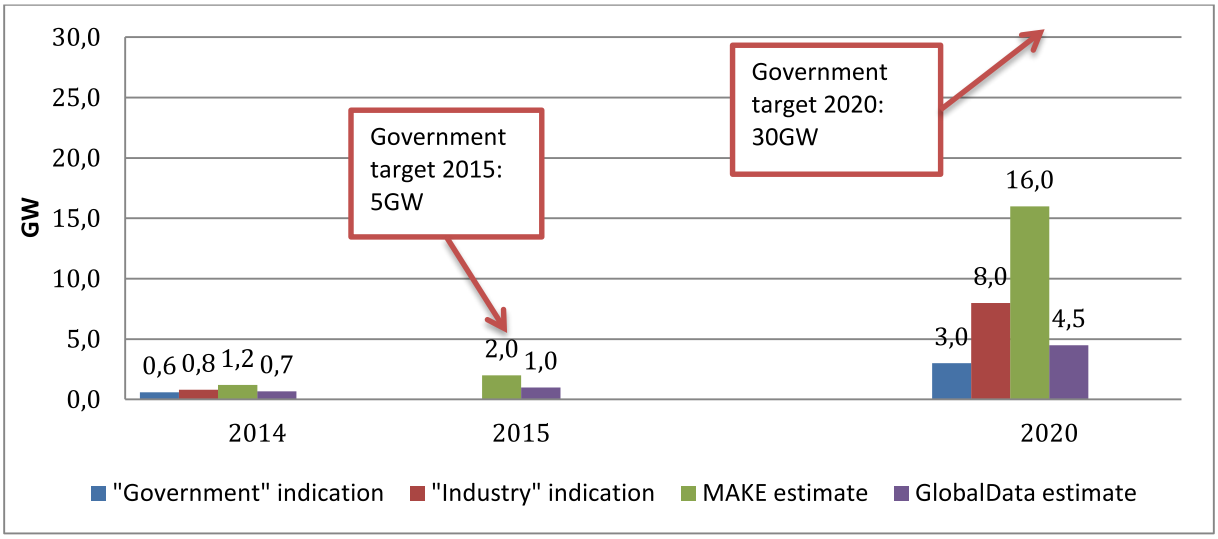
The National Energy Administration (NEA) and the State Oceanic Administration (SOA) are the two key approval authorities for offshore wind projects in China, according to the 2011 'Implementation Rules on Interim Measures for the Administration of Offshore Wind Power Development and Construction'. In addition to approval from the NEA, projects also need to apply for a license from the SOA. Interviews with policymakers informed that the decision of approving offshore wind projects again recently has been delegated to provincial governments, easing the workload of the NEA. Nevertheless, because the application for a license from the SOA still exists, the central government has the final word in the approval process.

2.3 Policy and development prospects

Conversations with government agencies and policymakers indicate that the **commitment from the central government to reach the 2015 and 2020 targets appears to be low**. Several interviewees from the government pointed out that the outlook for 2015 is quite low, and that the government goals will not be reached, or outright changed. One policy advisor noted that **the 2015 development target has been changed from being 5GW of 'installed' capacity, to 5GW of projects 'under construction'**, reflecting a central government acknowledgement that the goals may not be reached. The new wording gives a much broader timespan for actual completion of projects, as the definition for "under construction" is not defined (it could potentially mean an installed met mast).

The same advisor pointed out that the new and renewable energy department of the National Energy Administration within the NDRC has only 20 employees, and they are all mainly focussing on other renewable energy industries, leaving **limited resource to address offshore wind.**

Figure 3 Projections of cumulative installed capacity until 2020, government and various estimates, in GW



Source: GlobalData (2013) and MAKE consulting (2013b, p. 23)

Figure 3 displays some estimates on the development of China's offshore wind industry. The **"government" indication** is given based on feedback from various government employees working with renewable energy policy-making. Some high level government officials expressed low expectations for the development of offshore wind the next five to ten years, emphasising that they believed demonstration projects with a total size of 3GW would be optimal in that time span. This implies that also the 2020 goal of 30GW installed offshore wind power capacity would be well out of reach.

Another issue is the risk that central government faces in terms of finance. Most financing for projects comes from centrally state-owned banks, whilst development of projects is pushed through on a provincial basis. Because of this, provincial governments do not face the same commitment to make investments profitable, since the risk is on a central government level. This makes central government more reluctant than provincial governments to develop projects quickly.

The "industry" indication is based on conversations with offshore wind turbine and component manufacturers. These estimates are more ambitious, and there are high expectations of developing the industry closer to the set government targets. This enthusiasm stems from support from local and provincial governments that are positive towards developing offshore wind farms. Local and provincial governments may be able to push through more projects, but ultimate approval must come from the central government through the State Oceanic Administration, as explained above.

"In the next five years the development will be slow, and after 5 to 10 years it will be faster. Similar to the onshore industry I would say"

Developer

Most estimates indicate that the 2020 target of 30GW offshore wind power in China will not be met; although experience from China's onshore wind development suggests that it is not impossible. It seems a large amount of stakeholders agree, however, that the offshore wind industry should not develop at the same break-neck speed as the onshore wind industry, and that quality, security and profitability are more important factors than quantity. This may lead to more opportunities for foreign companies with substantial offshore wind experience.

3. Industry development

This section gives a brief overview of all the relevant stakeholders in the emerging offshore wind turbine supply chain and balance of plant supply of China's offshore wind industry today. There are not many actors to date, since offshore wind turbines and projects not yet are constructed in a larger scale.

3.1 Overview

China's offshore wind industry is still in its early development, and there are not many industry players. The first turbine was installed in 2007, and by the end of 2013 the installed capacity of offshore wind power was 428.6 MW (Liu 2014). These projects are mainly demonstration and test sites, and apart from the Donghai Bridge project (102MW), most turbines are installed in the intertidal zone.

In order to see how the projects advance in China, we need to look at the details of the projects that have already been completed, and that are currently under construction. An overview of the projects that have been commissioned to date is provided in tables 4 to 7 in the appendix. There is not much of a supply chain to talk about, and most players see offshore wind as a means of diversification from their primary business, which are typically offshore oil and gas, maritime industries, as well as electric power generation.

Overall these tables show that there are already some preferred companies for certain segments. For cable's provision, for instance, Jiangsu Zhongtian Technology is by far the most experienced company. Sinovel and Goldwind are the two Chinese turbine providers with the most experience. The project in Donghai and the ones in Rudong have used different foundation providers; CCCC 3rd Harbor Engineering, Nantong Ocean Water Conservancy Engineering and Jiangsu Longyuan Zhenhua Marine Engineering Co signalling that this is a segment with high levels of interest and potential for competition. Moreover, the tables show that the foundation suppliers typically also install the foundations in each project. Unfortunately the tables are incomplete due to a lack of access to information especially in the extension of the Rudong intertidal windfarm. Note also that offshore substations have yet to be used in offshore wind projects in China.

In addition, the companies listed in table 8 in the appendix have installed several **turbine models for demonstration** purposes, including the ones in the Rudong trial wind farm in operation since 2010, **totalling 60 MW by the end of 2012**. The performance of these turbines will give strong indicators to what turbine models will be chosen for future offshore wind projects in China.

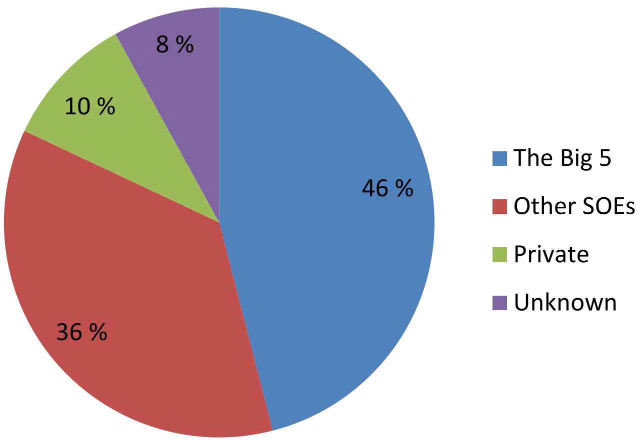
3.2 Developers

The most important developers with already commissioned projects are Longyuan and Shanghai Donghai Wind Power Generation Company, a Joint Venture between Datang and China Guangdong Nuclear. The developers of China's offshore wind farms are mainly state-owned enterprises (SOEs) including provincial and regional developers backed by their respective authorities. **The largest developers of Chinese onshore wind farms are state-owned power generation companies** especially the 'Big Five' Guodian, Huaneng, Datang, Huadian and China Power Investment Group (CPI). These will likely continue to be important developers of offshore wind projects, but other developers also have shown interest. By 2020, Longyuan, China National Offshore Oil Company, Huadian, Datang, Shenhua Group and China Three Gorges are likely to be the top developers in terms of installed capacity, each developer already being consented to develop between 300 and 600 MW (ibid.). SOEs generally have a steady availability of funds and receive loans from central government banks, such as the China Development Bank (Quartz+Co, 2013).

Table 3 Large Offshore Wind Developers' Investment Plans and Funding. Gathered from Quartz+Co (2013)

Developer	Investment plans	Investment / Funding
Longyuan	1 GW by 2015	1.6 billion EUR estimated investment
China Three Gorges	695 MW, four project pipeline	
Huadian		Planned investment of 738 million EUR in Jiangsu
Datang	1.2 GW	Planned investment of 7.4 billion EUR (not confirmed)
China National Off-shore Oil Company (CNOOC)	1 GW in Bohai Bay	Received 1.7 billion EUR funding from govern-ment

Figure 4 Offshore wind developers project pipeline, by developer category, end 2012. Source: Innovation Norway (2013)



Longyuan is the largest and most experienced developer of offshore wind projects in China. It is the largest wind power operator in China, and the second largest in the world (BTM 2012). The offshore wind business unit, Jiangsu Longyuan Offshore Wind Power was established in Nantong in 2007 (ibid.). Longyuan has a 50-50 joint venture with Shanghai Zhenhua Heavy Industry named Longyuan Zhenhua Marine Engineering. This company has supplied foundations and towers to the 150MW Rudong Intertidal demonstration project. The company also owns two vessels for installation in the intertidal zone, as well as vessels for offshore cable installation. Longyuan has a strategic cooperation with the two turbine manufacturers Sinovel and Goldwind, choosing 17 and 20 turbines respectively from the two companies, to the Rudong Intertidal demonstration project phase 1. Also, together with Goldwind it won a bid to develop the Dafeng intertidal concession project, planning to use 40 2.5MW Goldwind turbines. Moreover, the company used 21 Siemens SWT-2.3-101 turbines in the Rudong project, marking Siemens first order of offshore wind turbines outside of Europe.

A trend amongst Chinese offshore wind developers is to cooperate with local turbine manufacturers. One important company in that respect is the South Offshore Wind Joint Development Corporation, a company established through the cooperation between eight companies, amongst them China Southern Power Grid, International Power, Guangzhou Development Renewable, CTC New Energy and the turbine manufacturer Mingyang.

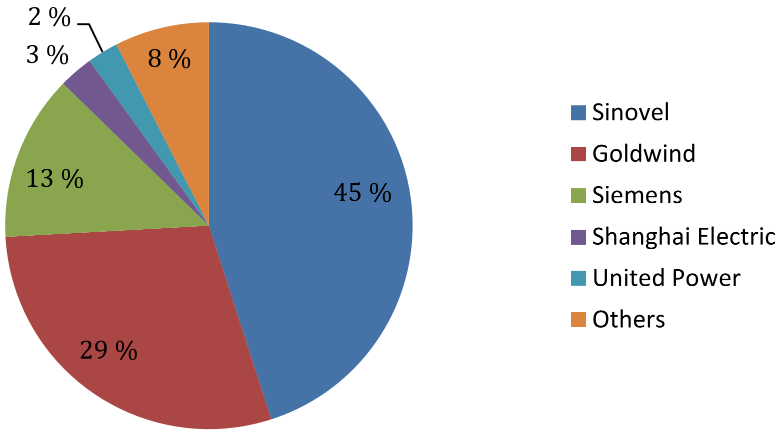
3.3 Wind Turbine Generators (WTGs)

Chinese manufacturers' experience with onshore turbines has benefitted their entry into offshore turbine manufacturing. The most important manufacturers for offshore wind turbines are Goldwind, Guodian United Power, Mingyang, XEMC-Darwind, CSIC Haizhuang, Shanghai Electric, Sanyi, Sinovel and Envision, all of which have at least one installed turbine. According to a report from Li et al. (2012) manufacturers still have a long way to go before they can commercialise their offshore turbines due to a lack of experience with offshore wind farms. As seen from the tables in the appendix, the largest companies are already testing their largest offshore turbines of up to 6 MW. The company with the most offshore experience is Sinovel who together with the US-firm Windtec co-designed the 3 MW turbine used in the 102 MW Donghai Bridge offshore wind farm outside of Shanghai (Zhang et al., 2011). Together with the Shanghai Jiaotong University, Sinovel has started a research centre on offshore wind turbines called 'National Energy Offshore Wind Power Technical Equipment R&D Center', where they are developing a 5 MW offshore turbine (Li et al. 2012). Conversations with the research community at Shanghai Jiaotong University reveal that this research cooperation now is dormant due to Sinovel's downturn during the past year. There are not many other research centres focussing on offshore wind, but XEMC Windpower supports a research centre called 'State Key Laboratory of Offshore Wind Power Generation Technologies and Inspection' (Li et al. 2012). Both Sinovel and United Power completed their 6 MW turbine designs in 2011 (ibid.), but Sinovel's future contribution is unclear due to internal management as well as technology reliability problems during the past two years, leading to a drop in sales.

In 2007 Goldwind was the first Chinese company to research into and demonstrate an offshore wind turbine in a pilot project, when a 1.5 MW PMDD turbine was installed at an oil field in Bohai Bay (Lewis, 2013; Zhang et al., 2011). Today Goldwind is still pursuing expertise in offshore wind turbine design. According to Lewis (2013: 124), Goldwind is planning to purchase a majority stake in Golden Concord Wind Power of Jiangsu, where the stated goal is to develop a 6 MW offshore wind turbine.

Shanghai Electric, China's fourth largest turbine manufacturer, recently engaged in a Joint Venture (JV) with Siemens, focussing uniquely on developing offshore wind turbines. An informant from Siemens explained that the nature of this JV is more of a "technology for market" cooperation, where Siemens benefits from Shanghai Electric's experience and influence in the Chinese market in return for technology learning opportunities.

Figure 5 Offshore Wind Turbine Generators, Market Share by Cumulative Installed Capacity (%), 2012. Source: 4coffshore (2013)



3.4 Offshore turbine supply chain

Suppliers of offshore wind turbine components in China typically also supply components for onshore turbines. China's component supply for onshore turbines has a shared supply-base of components allowing for industrialisation and quick manufacturing, and economies of scale that reduce prices (Lema et al., 2012). In contrast to Europe, where many turbine manufacturers produce the majority of components in-house, the Chinese onshore wind turbine supply chain has a large amount of manufacturers and a highly competitive environment. This drives down prices, and makes relationships short-term (ibid.). There are currently more than 50 blade manufacturers, 100 tower manufacturers and more than one thousand manufacturers producing other components and parts for the industry (Innovation Norway 2013). In the offshore turbine supply chain in China many companies increasingly choose to source their components from abroad. For instance, Goldwind has decided to increase international component sourcing to approximately 50% of its needs (Quartz+Co 2013).

According to BTM (2012) calculations; towers, blades and gearboxes are considered the most important components of a turbine in terms of cost, and make up approximately 56% of the capital cost of an offshore turbine.

There is a general concern amongst turbine manufacturers that components have inadequate quality, and it is the opinion of the author that, in order to ensure the longevity of the industry, these concerns are taken seriously. This has become more apparent after Sinovel faced great costs due to component replacement of rusted parts in a pilot intertidal turbine (Quart+Co 2013).

3.5 Cables

There are two kinds of cables used for offshore wind farms: inter array cables and export cables.

- **Inter-array cables** typically have a voltage up to 35 kV and are used to link individual turbines as well as connecting turbines to a transformer station.
- **Export cables** typically have a much higher voltage, up to 600 kV, and connect the substation with the electricity grid.

The availability of these high voltage export cables is a concern for the European offshore wind market at the moment, but is not as pressing in China due to the close proximity to the shore. Therefore, no offshore substations have been used yet for Chinese offshore wind projects.

Zhongtian Technologies Submarine Optic Fiber Cable has supplied cables to both the Rudong and the Shanghai Donghai Bridge projects in China and is therefore the leading cable supplier. Starting as an optical cable company it has now moved into 110kV cables. Its product was approved by the China Electricity Council in Oct. 2009 (Azure International, 2010). In addition, four other companies are involved with cable supply in China: the two Chinese companies Qingdao Hanhe Cables and Ningbo Orient Wires and Cables, and Nexans, a French company, and Fujikura Shanghai Cable. Nexans formed a joint venture with Yanggu Cables Group in 2011 purchasing 75% of the shares in the company (Quartz+Co 2013). The joint venture has plans to increase its production capability of offshore cables, and to capture a larger share of the growing high-voltage cable market (ibid.). Ningbo Orient Wires and Cables is a subsidiary company of the Orient Group, and started manufacturing 110KV submarine cable in 2007 (Azure International, 2010). Its cable has been used in grid connection in Zhanjiang and Shantou (ibid.). Fujikura Shanghai Cable is a JV formed in 2005 between the Japanese Fujikura group, and Shanghai Cable Works. The JV manufactures ultra-high voltage submarine cables.

According to a MAKE (2013b) outlook report on offshore wind, most Chinese projects situated in intertidal zones 'will lead to HVAC technology dominating export cable supply in the region. The local cable manufacturers supplying other industries have sufficient HVAC and MVAC cable capacities, hence oversupply exists in the market during 2013-2017'.

3.6 Foundations

China's capability of manufacturing foundations for offshore wind turbines is based on its previous experience with offshore oil and gas structures. Thus far, most installed turbines have used a multi-pile concrete cap solution due to difficult seabed conditions and installation equipment size restrictions. Various types of foundations are currently being tested in demonstration projects. Chinese design institutes typically design the foundations themselves, and often with support from foreign companies such as DNV GL.

There are five players that dominate the foundation manufacturing industry for offshore wind turbine use in China.

1. **Jiangsu Longyuan Zhenhua Marine Co**. is a JV between Longyuan and ZPMC, a ship construction company. The JV has as a goal to provide overall offshore wind farm construction equipment and services (Quartz+Co 2013).[3]
2. **China Offshore Oil Engineering Corporation (COOEC)** uses its experience from offshore oil and gas, and delivered the jacket for China's first offshore wind turbine installed in 2007.
3. **Nantong Ocean Water Conservancy Engineering** has provided and installed a large share of the turbines used at the Rudong Intertidal project.
4. **Jiangsu Daoda Heavy Marine Industry** has provided and installed a suction bucket foundation prototype installed in September 2010 at their shipyard in Qidong, with an XEMC 2.5 MW direct drive turbine on top. The design was introduced in response to challenges concerning the soft seabed that does not support well heavy loads (BTM 2012).
5. **CCCC 3rd Harbor Engineering Co.** made the gravity base foundations for the Shanghai Donghai Bridge. Eight steel piles with a diameter of 1.7m, providing foundation support due to unstable soil conditions, support the foundation (BTM 2012).

Two of the above foundation suppliers are also active in the North Sea. Shanghai Zhenhua Heavy Industry (ZPMC) supplied 140 monopiles and transition pieces for the UK offshore wind farm Greater Gabbard in 2009. The foundations were designed by Rambøll. The experience was useful to ZPMC, but there were reports of quality problems with 52 of the transition pieces delivered, and 35 of the monopiles, compromising the potential for future deliverances to Europe (Reina 2012). The quality problems related to poor welds that needed repair, incurring additional costs on the project.

[3] BTM (2012) reports that Longyuan Zhenhua has experience with installing offshore wind turbines directly on the top of monopiles without using a transition piece.

3.7 Installation and logistics

This section covers installation ports, installation of foundations and turbines, and cable installation.

Ports

Several ports have emerged along China's east coast since the first commercial offshore wind parks were installed in 2010. The Nantong Port 120 km north of Shanghai is currently the most important offshore wind port in China (BTM 2012), and it is conveniently placed in Jiangsu province, where the most ambitious plans have been made for offshore wind development. It has a total storage area of 340 km^2, warehouse space for 27 km^2 and 24 quays with depths between 4m to 10.8m. The two leading Chinese offshore wind contractors Nantong Ocean Water Conservancy Engineering and Longyuan Zhenhua Marine Engineering have made Nantong their main operating base (BTM 2012), and several other shipyards, such as Daoda Heavy Industry, are placed in Qidong 80 km to the west from Nantong. Shanghai Lingang and Jiangsu Dafeng will likely become important offshore wind bases in the future, where infrastructure is currently under construction. The Shanghai Lingang port is located some 75km south of Shanghai city centre, and covers an area of 36 km^2. The port and logistic centre are still under construction (BTM 2012).

"Jiangsu Province has a well-developed construction industry, so all the related manufacturing industries support the development of offshore wind here."

Industry Association

Installation of foundations and turbines

Because of the soft seabed conditions in the intertidal zones jack-up vessels are not always suitable for installation. Therefore, China has thus far mainly used floating heavy lift vessels. There are more than ten such heavy lift vessels that are capable of installing offshore turbines and foundations, and seven of these have actual experience with offshore wind (BTM 2012). Several of these cranes were primarily designed for use in offshore oil and gas installations. Since 2010 Longyuan Zhenhua Marine Engineering and Wuhan Bridge Heavy Industries Group have both built vessels that are specialised for offshore wind turbine installation (BTM 2012).

ZPMC and COSCO Nantong Shipyard have manufactured several installation vessels for both Asian and European customers. Foreign companies typically deliver the designs, and the Chinese shipyards manufacture the vessels. COSCO Nantong has developed a concept categorized as an ultra-large offshore wind installation platform project. The project was included in the 2012 National Key New Project Plan, originally initiated by the Ministry of Science & Technology to encourage independent innovation and to promote the development of new products. Other shipyards that have built offshore wind vessels are Yantai Raffles and Jiangsu Jiaolong Heavy Industry (JHI) (Innovation Norway, 2013).

Cable installation

China has four cable laying ships used in the instalment of offshore turbines. However, the cable laying vessels are not uniquely used for offshore wind cable installation: they are shared with the telecommunication and oil and gas industries. Two of the four vessels are operated by S. B. Submarine Systems Co., Ltd.(SBSS), China's leading provider of submarine cable installation. One vessel is operated by Hong Kong Marine Contractors, and one by Nantong Ocean Water Conservancy Engineering Co. The latter was used to lay the cables for the Rudong Intertidal Demonstration Project (BTM 2012). Quartz & Co (2013) assess that there will not be enough cable laying vessels to cover long-term demand. This will especially be evident as cable sizes increase and larger custom built vessels are needed.

4. Potential barriers to China's offshore wind industry development

Potential barriers that are specific to China's development of offshore wind industry can be divided into technical and political. Technical barriers are here defined as barriers that need a certain amount of engineering hours to solve, and in China the most pressing are seabed conditions, typhoons, earth quakes and low wind speeds. Political barriers include all barriers that can be solved by means of negotiation between governing politicians and between the government and the industry. In China these barriers are particularly present when coordinating and planning an offshore wind project, selecting appropriate sites, and deciding upon a financial support mechanism to make an offshore wind farm profitable.

4.1 Technical barriers

The most pressing technical challenges in China are related to seabed conditions. The reason for this is twofold:

- Much of the current installations happen in the intertidal zones with shallow sea, making it difficult to install turbines and foundations using conventional jack-up vessels;
- The Seabed consists of a soft mud-wedge in the North, and an unconsolidated upper layer lacking lateral strength in the South.

Picture 1: Vestas Turbines after a Typhoon

Source: Guohua

Wind speeds are slower in the North, and higher in the South. However, areas where wind conditions are better are exposed to extreme weather conditions such as typhoons, potentially causing huge damage, as can be seen in picture 1. The technical barriers that exist are manageable in short and mid-term, and are currently not regarded as a major factor inhibiting industry development.

4.2 Political barriers

Political barriers are more urgent for the present stage of development, since politics will dictate the speed of China's offshore wind development. Several political conditions inhibit government support, especially the following two:

- **Security concerns** along the coastline makes offshore wind a sensitive topic, causing complicated approval processes. This is one of the reasons the government is sceptical to participation from foreign companies;
- **High cost of offshore wind** makes it less attractive in competition with other energy technologies, incentivising project approval delay.

After the first concession round for offshore wind was established in 2010 it seemed as if the offshore wind industry was ready to take off in China. However, the State Oceanic Administration (SOA) had not been involved in project planning and siting, when the NEA designated the 2010 concession project

"The Jiangsu Dafeng project did not start construction yet, and is not approved because of a conflict with the military, so it has been postponed to 2017"

Industry Association

sites. Moreover, the State Oceanic Administration is responsible for administering China's coastline usage, but in 2002 when it created its 'marine functional zones' the SOA failed to consider offshore wind power development (Pengfei 2013). This led to a stalemate in 2010, and all sites had to change their location or their size. The new project sites had to go through new assessments and the developers had to repeat all the project approval formalities at the new sites. For instance, the Binhai Offshore Concession project had to reduce its size from 70 km^2 to 50 km^2 (4coffshore 2013). The 200MW Dongtai Intertidal Concession project had to be moved ten km further away from shore because the site assigned by NEA is a nature reserve, and the 300MW Sheyang Offshore Concession project conflicts with navigation channels (Qi 2012). This latter project is the only one of the four concession round projects that did not receive final approval from the Jiangsu Development and Reform Commission in the end of 2013 (Pengfei 2013).

As mentioned in section 2.2.1 provincial governments are able to approve projects independently, but all projects still need approval from the SOA, leading to long approval processes. These issues arise due to low coordination and planning between the different stakeholders in the government, e.g. between different ministries on a central and regional level. China's coastline is highly strategic for the Government, and usage and information about the coastline is therefore very sensitive. The NEA has stated that the regulation stipulating that only wholly- or majority-owned (51%) Chinese companies are allowed to bid in official tenders was created to prevent disclosure of sensitive data, such as ocean currents (BTM 2012).

"The main barriers for the offshore wind industry here in China today are two things: price and the approval process is not quick enough"

Wind Turbine Manufacturer

Since offshore wind still is a relatively expensive technology compared to coal power in China, it is dependent on government support to achieve levelised cost of energy. The industry is therefore relying on the government to set tariff prices that will make it profitable for companies to invest. The prices decided through the bidding in the first concession round were too low to be profitable for developers, and after the project sites were changed developers fear that costs and risks will be even higher. It seems therefore that offshore wind project developers are waiting patiently for the government to implement a suitable tariff price before they move on with their projects.

5. Conclusions

China's offshore wind industry is emerging and this report has pinpointed some major factors that contribute to or inhibit this development. Section 2 described the current policy regime, Section 3 provided a supply chain overview, and Section 4 sketched the main barriers for the industry at the moment.

The major barrier to offshore wind development in China today is the high cost of developing offshore wind projects. In order for projects to obtain an acceptable rate of return, the government needs to set policy incentives that encourage large SOEs to invest in offshore wind farms. The supply chain in itself seems to be able to support a long-term market of sufficient scale. The concern is therefore not whether there will be supply chain bottlenecks, but rather if the government will support project approvals and establish policies on electricity feed in pricing for offshore wind within a relatively short time span. The cost of offshore wind electricity is high compared to other forms of electricity generation, and an established pricing mechanism is the single most effective measure that would kick-start the industry.

Cost reductions that accompany maturing technologies, such as supply chain scale effects or more project planning experience are also important. Cooperation with experienced foreign companies can significantly reduce the risk of projects experiencing unexpected costs. The lessons learned in Europe can provide safety and standards that are currently not yet in place in China. China does not require project certification as in Europe, and uncoordinated projects and fragmentation of responsibility may also increase the cost of future projects. One area of concern for the industry as a total is the lack of mechanisms that ensure the quality and long-term performance of offshore wind technologies. Government development targets focus on the total amount of installed wind capacity, and large state-owned electricity generation companies, such as Longyuan (Guodian) or Huaneng, are mandated to install 8% renewable energy of their total capacity by 2020. These targets do not incentivise companies to ensure the long-term performance of their projects. Nevertheless, the fact that China's offshore wind industry is developing slower than expected indicates that quality-issues are taken seriously, for instance in terms of selecting appropriate sites.

China is so far the first country to gain experience of installing offshore wind turbines in intertidal zones, and companies here have faced challenges not encountered elsewhere. These companies have proved creative in developing solutions, and their quick learning indicates that Chinese companies are adapting rapidly to this new industry. The supply chain is still immature since experience with offshore wind is limited, but the eagerness of some companies to enter this industry and get first-mover advantages suggests that the industry will take off as soon as government support mechanisms are in place.

Appendix

List of major commissioned projects

Table 4 Donghai Bridge - Shanghai

Background				
Commissioned	2010			
Size	102 MW			
Developer	Shanghai Donghai Wind Power Generation Company Ltd (Consortium of China Datang, Shanghai Green Energy Engineering, Guangdong Nuclear Power, China Power International Co., Ltd)			
CapEx, Mill RMB	2360			
Project Design	Shanghai Investigation, Design & Research Institute (SIDRI)			
Contracting Structure				
Tier 1 contractors	**Turbines**	**Foundations**	**Cabling**	**Substation**
Design	AMSC and Sinovel	Shanghai Investigation, Design & Research Institute (SIDRI)	Zhongtian Technologies Submarine Optic Fiber Cable Co. Ltd and Qingdao Hanhe Cable	
Supply	Sinovel (SL 3000)	CCCC 3rd Harbor Engineering	Zhongtian Technologies Submarine Optic Fiber Cable Co. Ltd and Qingdao Hanhe Cable	
Install	CCCC 3rd Harbor Engineering	CCCC 3rd Harbor Engineering		
Details				
Ownership	China Datang Corporation	28%		
	Shanghai Green Energy Co., Ltd,	24%		
	China Guangdong Nuclear Power Group	24%		
	China Power International New Energy Holding Ltd.	24%		
Foundation type	Combination of gravity based structures and high-rise piles with a concrete cap			
Cabling	Array cabling was provided by Qingdao Hanhe Cable Co.,LTD			

Source: 4coffshore (November 2013)

Table 5 Rudong Intertidal Phase 1 - Jiangsu Province

Background				
Commissioned	2011			
Size	100 MW			
Developer	Jiangsu Longyuan, subsidiary of Longyuan, developed the site; 100% stake			
CapEx, Mill RMB	2500			
Project Design				
Contracting Structure				
Tier 1 contrac-tors	**Turbines**	**Foundations**	**Cabling**	**Substation**
Design	Siemens / Sinovel & AMSC		Jiangsu Zhongtian Technology Co.,Ltd. (ZTT)	
Supply	21x Siemens 2.3MW & 17x Sinovel 3MW	Nantong Ocean Water Conserv-ancy Engineering	Jiangsu Zhongtian Technology Co.,Ltd. (ZTT)	
Install	Jiangsu Electric Power Construction Corpora-tion	Nantong Ocean Water Conserv-ancy Engineering		
Details				
Ownership	Longyuan			
Foundation type	21 multi-pile founda-tion (Siemens) 17 monopile founda-tion (Sinovel)			

Source: 4coffshore (November 2013)

Table 6 Rudong Intertidal Phase 2 - Jiangsu Province

Background				
Commissioned	2012			
Size	55 MW			
Developer	Jiangsu Longyuan, subsidiary of Longyuan, will develop the site, 100% stake			
CapEx, Mill RMB	790			
Project Design				
Contracting Structure				
Tier 1 contrac-tors	**Turbines**	**Foundations**	**Cabling**	**Substation**
Design	Goldwind / CSIC Haizhuang		Jiangsu Zhongtian Technology Co.,Ltd. (ZTT)	
Supply	Goldwind 20x 2.5MW & CSIC Haizhuang 1x 5MW	Jiangsu Longyuan Zhenhua Marine Engineering Co., Ltd	Jiangsu Zhongtian Technology Co.,Ltd. (ZTT)	
Install	Jiangsu Longyuan Zhenhua Marine Engi-neering Co., Ltd	Jiangsu Longyuan Zhenhua Marine Engineering Co., Ltd		
Details				
Ownership	Longyuan			
Foundation type	Monopiles for the Goldwind turbines, and a high-rise pile cap for CSIC Haizhuang			

Source: 4coffshore (November 2013)

Table 7 Rudong Intertidal Extension – Jiangsu Province

Background				
Commissioned	2012			
Size	50 MW			
Developer	Jiangsu Longyuan, subsidiary of Longyuan, developed the site; 100% stake			
CapEx, Mill RMB				
Project Design				
Contracting Structure				
Tier 1 contractors	**Turbines**	**Foundations**	**Cabling**	**Substation**
Design	Goldwind			
Supply	Goldwind			
Install				
Details				
Ownership	Longyuan			
Foundation type	Monopile, No transition piece used because Longyuan have a patented method for monopile installation that does not require a transition piece.			

Source: 4coffshore (November 2013)

Table 8 Installed Demonstration Turbines including Rudong Trial Wind Farm

Company	Turbine Model	Quantity	Capacity
CSIC Haizhuang	2MW (Rudong)	1	2 MW
Envision	EN-82/1.5MW (Rudong)	2	3 MW
Goldwind	GW100/2500 GW1500 & 2500 (Rudong)	1 2	6.5 MW
Guodian United Power	UP6000-136 UP82-1500KW (Rudong)	1 2	9 MW
Mingyang	MY1.5MW (Rudong) MY 3.0MW SCD (Rudong)	2 1	6 MW
SANY	SE9320III-S3 2.0MW (Rudong)	1	2 MW
Shanghai Electric	SE 2.0/93	2	4MW
Shanghai Electric – Aerodyn	W2000/93 W2000 (Rudong)	1 2	6MW
Sinovel	SL3000/105 SL3000/113 (Rudong)	2 2	12 MW
Wuxi Baonan	BN82-2000 2 MW (Rudong)	1	2 MW
XEMC	XE93-2500	1	2.5 MW
XEMC – Darwind	XE/DD115	1	5 MW

Source: 4coffshore (November 2013)

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