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Global Expert Mission China Offshore Wind Expert Mission 2018

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Contents

1. Welcome

This report provides an overview of the findings from the Innovate UK Global Expert Mission to China on offshore wind (OSW). During the mission, a delegation consisting of government representatives and industry experts travelled to Yangjiang, Guangzhou and Beijing to meet key stakeholders from the Chinese OSW market.

The findings from the mission are presented in three sections:

- Chinese OSW market landscape
- Chinese OSW R&D landscape
- Potential for collaboration between China and the UK on OSW innovation.

DATE: 15-19 October 2018	LOCATIONS: Yangjiang, Guangzhou, Beijing
UK MISSION DELEGATES: • CS Wind • EDPRenewables • Innovate UK • James Fisher Marine Services • Knowledge Transfer Networks (KTN) • Offshore Renewable Energy (ORE) Catapult • UK Research and Innovation China • University of Strathclyde – Representing the SUPERGEN Programme	KEY CHINESE STAKEHOLDERS: Governmental stakeholders • Guangdong Provincial Department of Science and Technology (GDST) • Ministry for Science and Technology (MOST) • Energy Research Institute, National Development and Reform Commission (NDRC) Industrial stakeholders • CECEP – OSW developer • CSIC Haizhuang Windpower Co Ltd – Wind turbine manufacturer and developer • China Resource Power Holdings Co Ltd – OSW owner • China Southern Power Grid – State Grid operator and OSW developer • Goldwind Science and Technology Co Ltd – Wind turbine manufacturer and developer • Minyang Smart Energy – Wind turbine manufacturer and developer • Shanghai Electric Wind Power Group Co Ltd – Wind turbine manufacturer and developer • Sinovel – Wind turbine manufacturer and developer • TUS Wind – Part of TUS Holdings. A large company focused on new technology commercialisation

The objectives of the mission were as follows:

- Gather market insight and build foresight on the Chinese OSW sector.
- Identify benefits and synergies between the UK and China to create commercial opportunities and support the growth of the UK OSW sectors.
- Identify technology and business priorities which could be built upon and supported to make the UK "Partner of Choice" in partnerships with the Chinese on OSW.
- Identify collaboration models with Chinese stakeholders in OSW.
- Set groundwork for early dialogue between Chinese OSW stakeholders and UK stakeholders and business community to catalyse future internationalisation opportunities.
- Align innovation policy direction and unlock barriers for future international partnerships.

2. Chinese Market Landscape

2.1 Market Size

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.

There is potential for over 15 GW of turbines to be in the water by 2025. This means China has the potential to be the world's largest offshore market by 2025.

2.1.1 National targets

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.

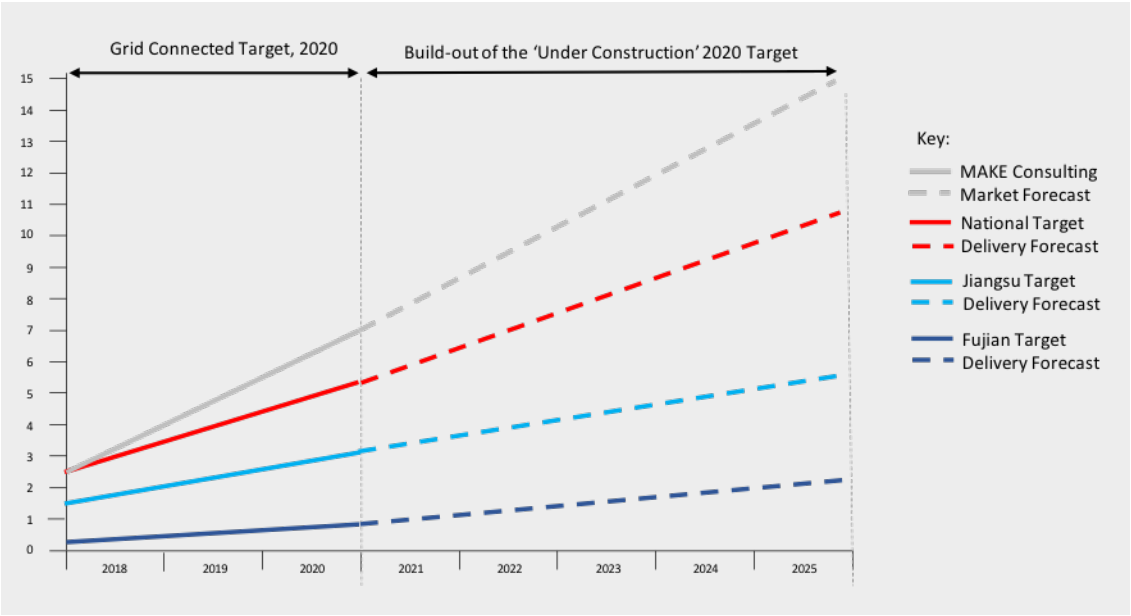
This is considerably reduced from ambitious targets set out in China's 12th Five Year Plan for Energy, which set a goal of 5 GW capacity by 2015 and 30 GW by 2020. However, this failure to meet targets appears to be more due to "teething issues" in establishing the OSW industry at scale, rather than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

2.1.2 Market expectation

As of March 2018, there was an estimated 2,790 MW of OSW capacity installed off the Chinese coast[1]. 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.



Growth scenarios for the Chinese offshore wind market 2018-2025
Source: MAKE Consulting

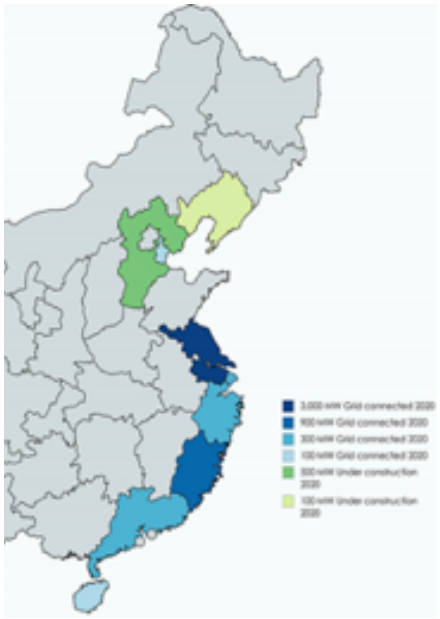
[1] Source: Jiangsu Province Renewable Energy Association

Engagement with MOST and provincial governments during the mission suggests there will be ongoing governmental support for OSW. However, there is a focus on bringing down costs to build a sustainable industry.

2.2 Where is Development of OSW?

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.



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

China 2020 offshore wind development targets

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.

2.2.1 Key provinces

A summary of activity in the three provinces leading in the development of OSW in China is provided overleaf.

JIANGSU	• Current estimated capacity: 1.4 GW (early 2018) • National target: 3 GW grid connected, 4.5 GW under construction by 2020

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.

FUJIAN	• Current estimated capacity: 0.1 GW operational, 0.4 GW under construction (April 2018) • National target by 2020: 900 MW grid connected and 1.1 GW under construction.

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.

GUANGDONG	• Current estimated capacity: 1.2 GW (early 2018) • National target: 300 MW installed and 1,000 MW under construction by 2020 • Provincial target: 2 GW operational and 12 GW installed, by 2020, 30 GW by 2030

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.

CAN THE CHINESE OSW MARKET MEET ITS AMBITIOUS TARGETS?

Yes, and probably surpass these targets…

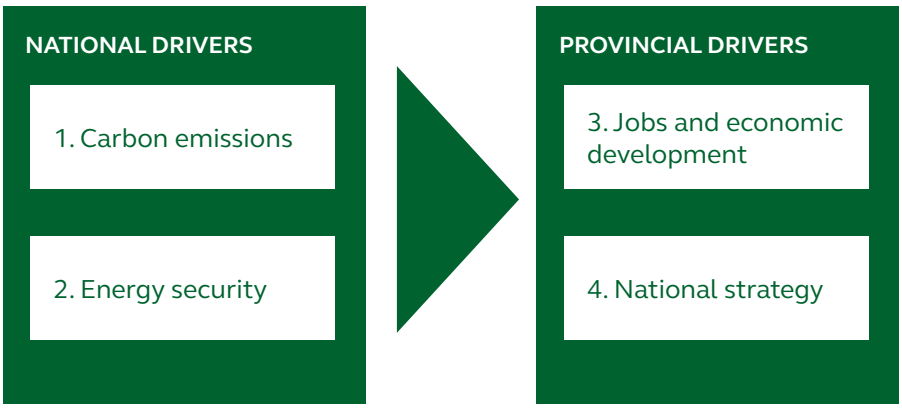
There have been technical and regulatory challenges caused by the lack of coherent support mechanism, challenging wind regimes and seabed conditions but the industry is moving and moving fast. Evidence suggests that the 5 GW target by 2020 will be easily broken as the level of ambition in the provinces and by the developers massively outreaches this target.

For this initial market rush to be sustainable in the long term, the government is looking for significant cost reductions, and they are looking to Europe to see how this has been achieved within European markets.

2.3 Key Drivers for OSW Development in China

China recognises that it is in a period of industrial transition and the key focus is on energy and particular on electricity. It has a target of 27% of electricity generation from renewable sources by 2020. The national strategy very heavily drives the regional strategy. More specific policy mechanisms are outlined in section 2.5 of this report.

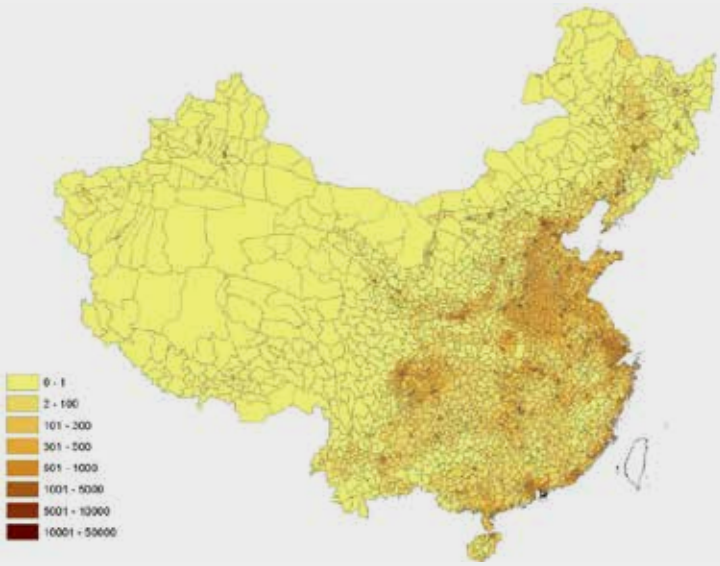
The drivers for development of most renewables, and in particular OSW, in China are broadly similar to those of most OSW markets globally. At a national level, the OSW market appears to be driven by the need to provide additional energy to meet growing demand in coastal regions and decarbonisation commitments.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



COASTAL ENERGY USE IN CHINA

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.



Source: https://www.researchgate.net/figure/Figure-A1-Map-of-county-population-density-in-China-n-2869_fig3_281058456 based on last census in 2010

2.4 Key Policies Supporting OSW in China

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.

2.4.1 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.

2.4.2 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.

2.4.3 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.

2.4.4 Made in China 2025

This is the policy that supports the growth of a manufacturing base for OSW in China and promotes innovation within key industrial sectors including OSW.

2.4.5 Revolutionary Innovation Action Plan for Energy Technologies (2016-2030)

This is the national roadmap and action plan for development and implementation of new energy technologies including next generation (larger) OSW turbines.

2.4.6 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.

2.5 Mechanisms for Supporting OSW in China

The national and provincial level policies specify mechanisms to support the growth of the Chinese OSW industry. These mechanisms are, at present, essential both for the commercial viability of windfarms and to ensure the focus of key public and private stakeholders on OSW in China.

Overleaf are a few examples of mechanisms which help to increase the economic attractiveness of OSW projects and support the local supply chain.

MECHANISM	EXAMPLE
Clear commitment to OSW by Chinese government	• Ambitious targets set out within the REL provided certainty to the market about China's mid-term 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.
Providing access to development sites	• The release of public tenders for concessions within the provinces allows developers to access sites.
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 non-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 OSW development commercial support is a Feed-in Tariff (FIT). 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. • Preferential Tax Policy – 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. • 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 OSW regions. • Observed provincial level support mechanism for supply chain stimulation includes: o Development of dedicated OSW industrial zone including key facilities o Active inward investment incentives to build local competency o Direct funding to companies in the province for development activities and infrastructure development o Development of dedicated port facilities.
Innovation support	See section 3.2

2.6 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.

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>
<tr><td rowspan="6">State level agencies</td><td>National Development and Reform Commission (NDRC)</td><td>National Energy Administration (NEA)</td></tr>
<tr><td>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.</td><td>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.</td></tr>
<tr><td>State Oceanic Adminstration (SOA)</td><td>Chinese National Renewable Energy Centre</td></tr>
<tr><td>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.</td><td>CNREC is the national institution that supports China's energy authorities on policy research, and industrial management and coordination of renewable energy.</td></tr>
<tr><td colspan="2">Design and engineering institutes</td></tr>
<tr><td colspan="2">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.</td></tr>
<tr><td rowspan="2">Regional and local agencies</td><td>Provincial-level agencies</td><td>City-level agencies</td></tr>
<tr><td>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.</td><td>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.</td></tr>
</table>

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.

[2] Carbon Trust: Detailed Appraisal of the Offshore Wind Industry in China (2014)

Case study:

Goldwind's technology is based on a design from the German wind turbine company, Vensys. Since 2008, Goldwind has developed this technology and become the world's largest wind turbine supplier.

Goldwind's market remains the supply of predominantly onshore turbines, both in China and globally[3], but, in recent years, it has become the third largest OSW turbine supplier globally, based entirely on sales to the Chinese OSW market. This global position is likely to grow in line with the expansion of the Chinese OSW market. It has also stated its intention to try and enter the European OSW market. While the European market appears theoretically prepared to accept turbines from leading Chinese manufactures, Goldwind's largest turbine is currently only 6.7 MW so will not be competitive in the European market.

The majority of Goldwind's facilities are based in China, but they have manufacturing in the US and R&D facilities in Denmark. Over the last ten years, Goldwind has made a notable transition from a turbine manufacturer, heavily reliant on importing European technology to one that has the capability to develop technology that can be exported globally and compete with established European suppliers onshore and, in the near future, offshore.

[3] Bloomberg New Energy Finance (2017)

2.7 Chinese OSW Market Site Conditions and Technology

2.7.1 Site conditions

The Chinese OSW market can be divided into regions north and south of the Yangtze river. The conditions and challenges differ significantly between the two regions. In the short-term, the market is concentrated in the southern region (Fujian, Guangdong, Zhejiang), with development in the northern region expected to follow soon.

Site conditions in both differ significantly from those experienced in the UK.

		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

FLOATING WIND IN CHINA

An initial review of the Chinese market would suggest that there should be limited interest in floating wind as there are large numbers of undeveloped shallow water sites which offer a more economical opportunity for development. However, stakeholders in China, including developers and MOST expressed significant interest in floating wind.

A potential reason suggested for this is the buoyancy of the Chinese OSW market. While a large number of near-shore, shallow-water sites are not yet developed, many of the viable sites have been allocated. Developers who have not been successful in the first allocation rounds are now looking at the viability of deeper water sites that may require or benefit from floating wind technology.

2.7.2 Technology and O&M strategies

The combination of the immaturity and unique conditions presented by the Chinese market means that there is little consensus on best practice, and therefore a wide range of approaches to deployment and operation are still evident and under development. The current status of technology and best practice is outlined in the table below. An indication is also provided as to how this compares to UK technology and best practice.

	Sub-section		Similarity between installed UK projects and planned Chinese projects
TECHNOLOGY	Foundations	Chinese seabed conditions are significantly different from European conditions; therefore many of the foundation solutions developed in Europe have limited use in China. Optimal solutions for the Chinese market are still under development, and there is a lot of variation in technology. While monopiles were initially used, the emerging trend seems to be for jackets and multiple piles. Floating solutions are also under development but not widely deployed to date.	LOW
	Turbines	Like the Chinese onshore wind market, turbines in the Chinese OSW market are almost exclusively three-bladed horizontal axis, similar to the European market, except for Mingyang turbines, which have two blades. However, at present turbines installed in China are smaller than in Europe. The larger Chinese manufacturers are demonstrating 6-7 MW compared with 9-10 MW in the UK. There was variation of opinion about if, and how fast, China should follow Europe. Efficiency from the use of larger turbine has been a key driver in reducing the cost of offshore wind development in Europe, and China is keen to benefit from the same cost reductions. However, the local supply chain at present is better suited to the delivery and installation of smaller turbines. It is arguably inevitable that eventually, the Chinese market will adopt larger turbines, particularly if Chinese turbine manufacturers have ambitions in the wider global market, but potentially smaller turbine will continue to be used in the planned rounds of development.	MEDIUM
	Electrical BOP	As most planned Chinese sites are near-shore, even intertidal, it is expected that they will be connected at AC. The further offshore sites will require offshore sub-stations. Very near-shore may export direct to shore without an offshore sub-station. This is similar to Electrical BOP in the UK. There is research ongoing on HVDC, but this is unlikely to be needed for any of the current round of development.	HIGH
INSTALLATION & OPERATION STRATEGIES	Installation	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” ap-proach, as typically used in Europe.	LOW (AT PRESENT)
	O&M	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.	MEDIUM

So how does Chinese technology and best practice compare with Europe?

- All Chinese sites to date have been near-shore and therefore have not faced the technical challenges for far-offshore development that have been addressed in Europe. As such, the UK is significantly ahead of China in technology and best practice for turbine installation and O&M.
- In addition, China is only beginning to consider cost reduction mechanisms for offshore wind, which has been a decade-long journey in the UK.
- In terms of turbine technology, Chinese manufacturers are still behind the European manufacturers, but only just and they are catching up fast. However, Chinese manufacturers are still looking to Europe for innovation around turbine technology and next-generation products.
- 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.

2.8 Key Barriers to Delivery of OSW in China

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.

Lack of coordination on consenting and leasing	Failure to meet initial national OSW targets was partially caused by lack of coordination between SOA, which wanted OSW to be as far offshore as possible to avoid conflict with other maritime users, and the NEA, which wanted close in-shore OSW to reduce costs[4]. However this has been resolved and joint guidelines were published in 2010 and should not be a significant barrier moving forward.
Lack of clarity of financial incentives	Another initial barrier to OSW development has been a lack of clarity on the value of FIT incentives. During initial development rounds, this level of FIT was deemed to be too low. However, this has been resolved, which has provided security to developers to progress with projects.
Cost	China is still at the start of the cost-optimising curve for OSW. Costs are relatively high and need to be reduced in order to deliver a sustainable long-term industry.
Environmental conditions	China has extremely challenging environmental conditions. Wind speeds in the north are relatively low compared with European development and, whilst wind speeds are higher in the south, sites are subjected to regular typhoons. The combination of muddy seabed and earthquakes in the region further compound the challenge.
Wildlife impact	While China has not historically had a strong reputation in wildlife protection, developers are reporting significant delays caused because of marine mammals and other marine wildlife.

CONCLUSION ON CHINESE MARKET

The Chinese market is developing fast and it is going to be one of the, if not the, biggest OSW markets in the world in the next decade. Accessing the Chinese market does not just offer access to one market but presents an opportunity for global expansion of the supply as Chinese developers and suppliers look to enter other global markets with their partners.

China has the capabilities to build a comprehensive domestic supply chain but it is likely that specialist niches, for specialist knowledge or cutting edge technology will remain. Despite being niche, these still represent a significant opportunity for UK companies if they can negotiate the complexities of the Chinese OSW market and cultural challenges of working in China.

An effort to integrate UK companies into the Chinese supply needs to happen fast. The UK has a limited window of time to access this market before the Chinese supply chain becomes fully-established and other European countries are the development partner of choice.

[4] Carbon Trust: Appraisal of the Offshore Wind Industry in China 2014

2.9 Barriers to UK Companies Entering the Chinese Supply Chain for OSW

Whilst there are significant opportunities for UK companies to enter the Chinese OSW markets, there are also significant challenges. These are outlined below.

Existing and potential Chinese supply chains	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. China, as with all countries building an OSW market, is keen to ensure as much domestic supply as possible so UK companies looking to enter the market will need to bring a product not already available in China. Many Chinese tier 1 suppliers have relationships with other European manufacturers, which can offer more comprehensive packages.
Complexity of the market	The Chinese OSW market is very large, complex and opaque. It is challenging to get an accurate and coherent picture of the market from the UK without investing significant resources, and ideally having an agent or staff in China. This is a barrier to SMEs in the UK who can find it difficult to assess the viability of the market and find an entry point.
Cultural challenges	The business culture in China is noticeably changing towards a more relaxed western style. However, there is still a significant cultural difference between the UK and China. Likewise, although the use of English is becoming widespread, it is by no means ubiquitous. While this is not an insurmountable barrier, it is intimidating for UK companies and can impair the relationship building needed to form a successful partnership in China. The importance of relationships in China for companies looking to enter the market should not be underestimated.
Long-term sustainability of revenue streams	It was evident from the mission that Chinese stakeholders are very keen to learn from European organisations. Historically, China has been good at taking lessons learnt from Europe, and replicating or developing them further domestically. For example, most of the larger Chinese turbine manufacturer bought their initial designs from European design houses or turbine manufacturers and then developed on these platforms within their own R&D capabilities. This is still ongoing. During a recent discussion with a UK-based design house, they expressed concern about how their operations were progressing in China. They had success selling design services into the Chinese market, but after the initial work, the Chinese customer clearly stated that they would replicate the work for their other sites. They, therefore, did not need to engage the consultancy further, as would be expected in Europe. Chinese project developers are also buying into European projects with an intent to transfer knowledge from Europe into Asia. While IP protection in China is, supposedly changing, there is still a higher risk of IP leakage in China than in Europe. This risk can be managed, but it is perceived as a barrier by many UK companies. There is an immediate opportunity for the supply of specialist equipment and services into the Chinese OSW market but companies entering must have a longer-term strategy. This might either be to focus on short-term gains, for example, the sale or licencing of IP, or to have a strong strategy for staying ahead of Chinese suppliers and customers, for example, not selling cutting-edge products into China.

3. R&D Landscape

3.1 Overview

China's R&D spend has been increasing rapidly both in the public and private sectors. This reflects China's ambition to become a global leader in technology by 2035, as set out at the 19th National Congress of the Communist Party of China in October 2018.

3.1.1 Offshore Wind R&D

The OSW R&D sector is also developing fast, in line with growing market requirements and is supported at both national and provincial level, within relevant coastal provinces.

China's capability is built on 15 years of onshore wind R&D in the country. During this period, the sector has evolved, from one that was heavily reliant on importing design and expertise from Europe, to a substantial domestic base of wind R&D capabilities and resources.

> "China is projected to spend $658 billion on R&D in 2018 and is predicted to overtake the US as the world's largest R&D investment nation by 2022. The country is home to 25% of the world's R&D workforce, and in the past 15 years, the number of foreign-run R&D centres in China has increased from 200 to over 1,500."
> **UKTI**

Much of the expertise and experience sits within private and state-owned companies, and in particular within the domestic turbine manufacturers, such as Goldwind, Mingyang and Shanghai Electric, who have large R&D capabilities both in China and in Europe. In addition, R&D is also being carried out by the two large state grid companies. During the mission, little evidence was observed of SME engagement in the OSW R&D sector.

OSW project developers and operators appear to have a strong focus on implementing demonstration projects in order to gain experience and insight into project development and installation. Little evidence was presented of significant activity in R&D for the operational phase, but it is expected that this will become more of a focus as operational challenges become evident and solutions are required.

Whilst industrial R&D dominates the Chinese OSW R&D landscape, there is also a substantial base of wind energy research being carried out within universities and research institutes. Very little visibility of this was achieved during the visit.

3.2 Key Stakeholders

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.

3.2.1 Key R&D delivery organisations

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.

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.	
China Electric Power Research Institute (CEPRI)[5]	CEPRI is operated by China State Grid. It runs a range of National State Labs, mostly focused on grid integration and power systems, including the National Large-Scale Wind Power R&D (Test) Centre (NWIC). It also operated the Renewable Energy Research Centre (RERC).
China Southern Electric Power Research Institute (CSPEPRI)[6]	CSPEPRI is operated by China Southern Power. It operates a number of facilities for test and development of energy technologies, including the National Enterprise Technology Centre, National Power Grid Energy Technology Entre and an Ultra-High Voltage lab.

[5] http://www.epri.sgcc.com.cn/html/eprien/index.html
[6] http://eng.csg.cn/Branches_Subsidiaries/201512/t20151209_109557.html

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.

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.

Universities

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:

- Zhejiang University
- Chongqing University
- Tsinghua University
- Huazhong University of Science and Technology
- Harbin Institute of Technology
- South China University of Technology.

3.2.2 Key enablers and funders

The following organisations are known to fund or support OSW R&D activities in China.

National level funding coordination and R&D policy development

Ministry Of Science And Technology (MOST)

MOST steers national-level science and technology policy and coordinates national-level R&D programmes. It is responsible for supervising and distributing the majority of China's civil R&D budget. It also works with provincial governments and other government departments to develop and fund regional and specialised R&D programmes. MOST receives finance directly from the Ministry of Finance and distributes through R&D programmes or directly for R&D activities within institutes or industry.

MOST is the counterparty on the Flagship Challenge Programme funding and considered to be a key future partner for UKRI. It is a key enabler for UK-China cooperation in OSW.

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.

Other funding source and enabling organisations

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.

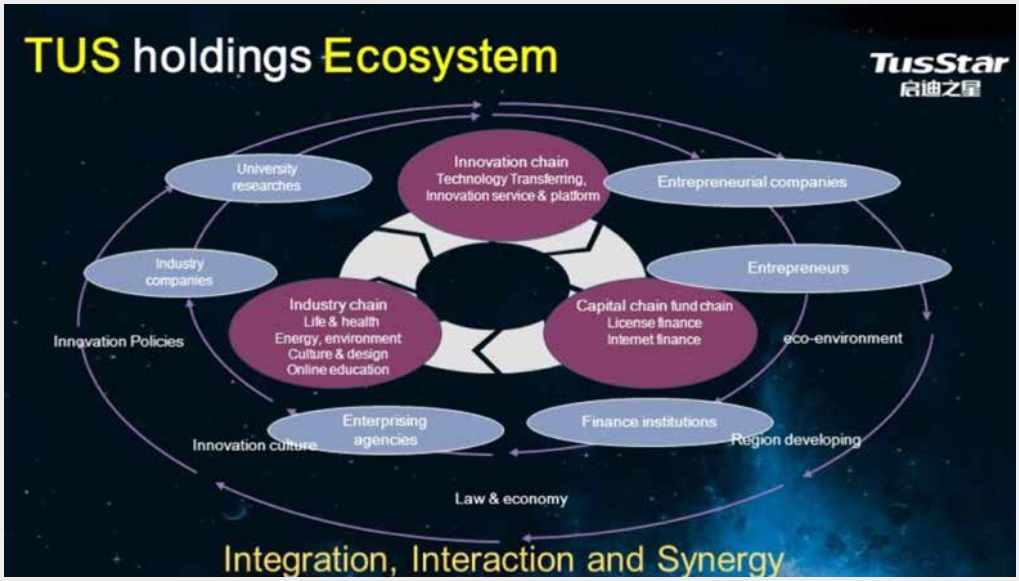
Industrial funding	
A significant amount of OSW R&D in China is funded directly by industry. This is either through internal R&D programmes, funding to corporate or state research institutes or incubator/accelerator type organisations.	
Internal R&D Programmes	With the exception of basic component manufacturers, 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.
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.
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 2020[7]. 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.

[7] http://www.chinadaily.com.cn/business/2017-09/19/content_32203134.htm

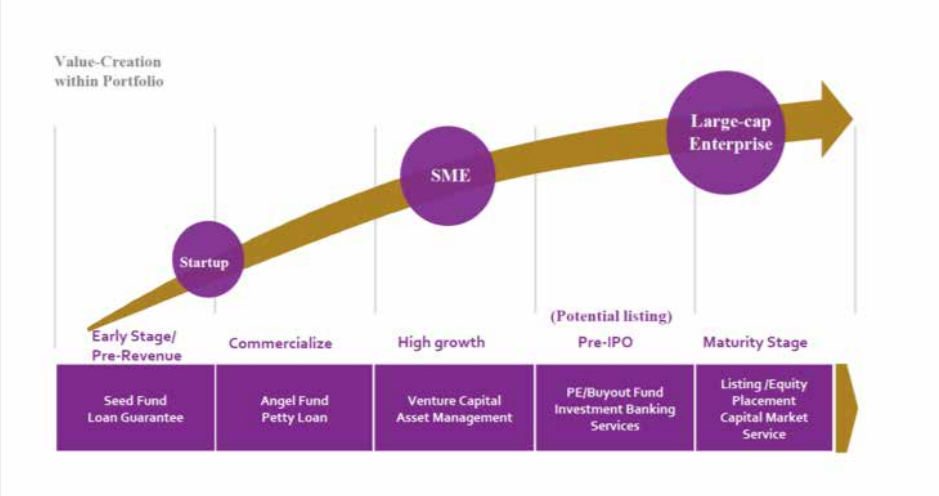
Case study: TUS Holdings

TUS Holdings is an operator of incubators and science parks across China and is a significant investor in innovative start-up companies. It was formed in 2000 by Tsinghua University and holds assets of over RMB 350 billion (approximately £40 billion), including incubators, science parks, science cities and equity in a wide range of high-tech companies.

Its remit is to promote innovation, ensure technology transfer from universities and R&D organisations into industry and integrate industry, government, academia and finance organisations.



This is achieved both through the provision of supported facilities for start-up companies, provision of finance at all stage of development (shown in the figure below), and training and support for companies.



TUS has international collaboration across Europe, Asia and North America, including with Cambridge Science Park in the UK. It also has a branch in Newcastle. TUS has a department addressing offshore wind and is currently working with ORE Catapult in establishing a collaborative R&D centre in Shandong Province (see section 4.2).

3.3 Key Facilities

3.3.1 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.

3.3.2 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.

UK-CHINA DEMONSTRATION WINDFARM

A notable new development is the proposed UK-China Demonstration Windfarm, part of the China-UK Accelerator Programme.

TUS Holdings is proposing to develop a 300-500 MW demonstrator windfarm in Shandong Province. TUS has been collaborating with the UK's Offshore Renewable Energy Catapult, to set a target of 10 - 15% of the technology content of this project to be sourced from UK companies and universities.

This should provide innovative UK companies with the opportunity to demonstrate UK technology in the Chinese market. This 10 - 15% is estimated, by ORE Catapult, to be worth around £220 million to UK organisations. It is currently undergoing final consent at provincial government level.

China is talking to other European countries regarding demonstration sites. In 2017, discussions started with Denmark to co-develop a demonstration windfarm and test centre. However, it is unclear how these plans have proceeded.

3.4 Technical Focus of Chinese OSW R&D Sector

The following areas of R&D activity were highlighted, during engagement on the mission as being of interest to Chinese OSW stakeholders.

	Focus areas	Level of interest	Level of capability in China compared with UK
Optimising turbine and BOP design	Floating wind	M	Lower
	Fixed foundations and structures design	H	Lower
	Next generation drive train	H	Lower
	Next generation drive train manufacturing	M	Higher
	Development of turbines for low wind regimes	H	Higher
	Design for typhoon survival	H	Higher
	Large rotor design	M	Lower
	Next generation power electronics design	M	Lower
	Power electronics manufacturing	M	Higher
	Blade and drive train testing design	M	Lower
	Wind farm design optimisation	M	Lower
Policy and market	Techno-economic modelling	H	Lower
	Support mechanisms	H	Lower
Site development	Wildlife impact monitoring and assessment	M	Lower
Installation	Installation of windfarms	H	Lower
	Piling technologies	M	Lower
Operational challenges	O&M operations	M	Lower
	Wind farm typhoon and storm survival	H	Higher
	Condition monitoring and diagnostics	M	Lower
Grid	Integration of intermittent renewables onto grid	M	Lower
Other	Data science	M	Lower

In addition, a study was commissioned by ORE Catapult in early 2018[8] which identified areas where interests expressed by Chinese companies aligned well with UK's capabilities. While not observed on this mission, they should be considered. They included:

- Substation design
- Construction strategy and coordination
- Cable installation and protection
- Marine coordination and planning
- Vessel design.

[8] Final Report: UK-Jiangsu-Fujian Offshore Wind Cooperation 31/3/18

4. Potential for Collaboration between China and the UK on Offshore Wind

This section of the report examines the benefits, opportunities and mechanisms for collaboration with China on OSW R&D.

4.1 Potential Benefits of Collaboration.

Illustration of the benefits to both parties for development of collaboration activities

4.1.1 How the UK can benefit from collaboration with China

Create route to market for UK 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.

Provide access for UK companies to Chinese OSW 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.

Positioning UK as an innovative country and leader in OSW

As an early technology adopter, the UK is recognised globally as a leader in OSW. Its role in bringing significant innovation into the sector was widely acknowledged by Chinese stakeholders during the mission.

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.

Attract investment in UK technology companies

From the mission, it was evident that there was significant interest from both developers, equity investors and turbine manufacturers in investing in UK technology companies.

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.

4.1.2 Why China is keen to collaborate with the UK

Accelerate Chinese OSW industry development

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.

Gain access to UK technology for integration in China

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.

Create opportunities for investment in UK companies

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.

Attract inward investment into core OSW regions

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.

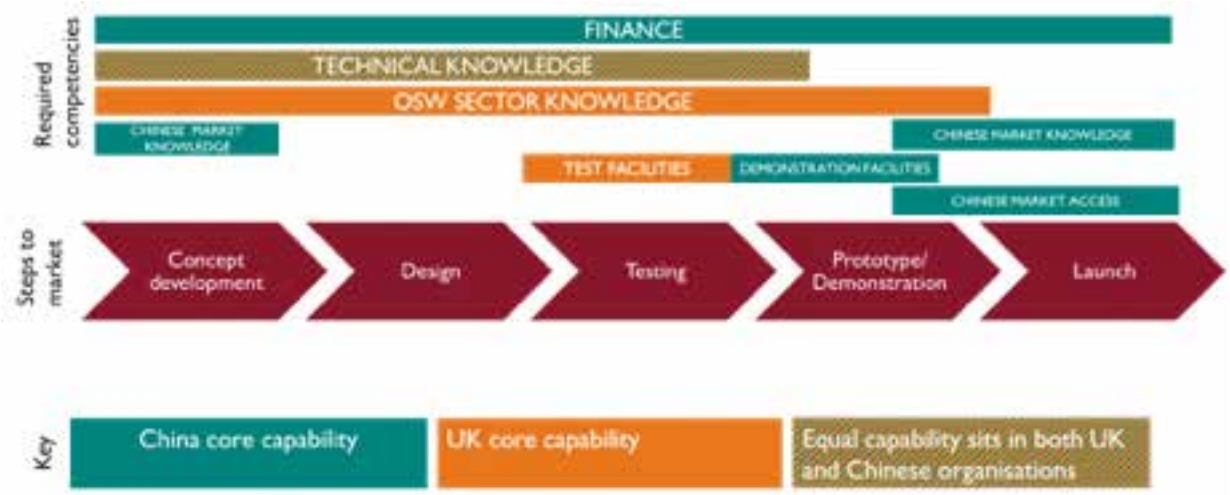
4.2 Synergies

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.



4.2.1 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.

4.2.2 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.

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.

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.

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.

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.

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.

> "After a dozen years of rapid growth, China today manufactures and installs half of all onshore wind turbines in the world. We are now at the start of such a journey in offshore wind, and there is no better place to learn than from the extensive experience and expertise of UK innovators and the Offshore Renewable Energy Catapult".
> **Yingzhuo Du, Senior Vice President of TusEnergy**

4.2.3 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.

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.
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.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