Offshore Wind China Project

Mapping existing technology solutions to barriers identified in China's Offshore Wind industry

Executive Summary (1)

Background: This report lays out the key challenges that the Chinese Offshore Wind industry faces and a critical deliverable of the project that the Carbon Trust has undertaken for the British Embassy in Beijing. The aim of the project was to identify technical and other barriers to offshore wind development in China by leveraging technical and operational expertise in Europe.

China Offshore Wind Plans and Challenges: China has ambitious plans to scale up offshore wind power to 30 GW by 2020. If achieved, this unprecedented level of growth would make China the world leader in offshore wind. While comparisons may be drawn with the rapid deployment achieved in the onshore industry over the past decade, replicating this in harsh offshore environments presents significant additional challenges. These challenges are identified by the Carbon Trust in the first deliverable of this project, "Detailed appraisal of the offshore wind industry in China". Having identified the key challenges facing the industry, this deliverable maps these challenges against existing solutions from the European market.

Relevance of European Experience: Europe has taken the lead in developing offshore wind technology over the past 15-20 years, acquiring significant knowledge and expertise in the process. However, all solutions used in Europe are not necessarily applicable to China. Chinese coastal conditions are different to UK Round 3 sites, where R&D is focussing on solutions for >30m water depth. In contrast, water depth in China is unlikely to surpass 20m in most cases, while the soft seabed conditions may present different challenges. Nevertheless, there is still considerable overlap regarding the technologies employed and best practice for constructing and operating offshore wind farms, particularly given that many European projects installed to date have been in 10-20m water depth.

Report Recommendations: The report identifies challenges and possible solutions across the key parts of the offshore wind supply chain. In each of these areas, the report breaks down in to more specific challenges, what the existing local solution are to address them and what European developers have deployed. The report then offers example of deep dives into European solutions[1].

Developers:

- A critical need is to undertake wind resource assessment to help developers identify the most promising sites. Use of Lidar technologies could help to significantly reduce costs.
- Better coordination between central government, provincial authorities and the State Oceanic Administration would help speed up the consenting process.
- A key local need is to gain deeper experience of operating wind farms: partnering with European companies could be a way to achieve this.

Note 1: The detailed version of the deep dives can be discussed with the Carbon Trust

Executive Summary (2)

Turbines**:**

- Achieving 95% availability is critical to help the economics of wind farms and so ensuring gearbox and electronics reliability is critical.
- Given the unique weather conditions in China, turbines also need to be resistant to typhoons and impacts of corrosion.

Foundations

- China's existing offshore infrastructure is largely near shore. So developing expertise in foundation structures in deeper waters and at reduced. costs, such as novel suction buckets, could help deliver great impact.
- Given China's typhoon zones, finding effective corrosion resistance, such as by use of impressed current cathodic protection, will be important.

Connectivity

- The challenges of connecting farms long distances away from demand is not an issue for offshore, as it has been for onshore. But there are areas that need addressing, such as access to cables and cable installation vessels.
- As future farms are required to be at a distance of at least 10km from shore, development of offshore sub-station expertise will ne needed.

Installation

- Monopiles are the key foundations currently deployed, and limiting noise by using novel piling techniques could reduce environmental impact.
- A lack of appropriate installation vessels capable of installing multiple turbines at a time is another key need; companies such as Gaoh Offshore have developed jack-up solutions that can carry up to 16 turbines and can operate in all year conditions.

O&M

- A valuable way that wind farm operators in Europe have started to assess the ongoing performance of their farms is through the use of condition monitoring software tools. Such software could help Chinese operators better manage their infrastructure.
- The anonymous sharing of performance data by developers, such as through the National Renewables Energy Laboratory in the UK, can help the industry judge where gaps exist and make the needed R&D to help improve.
- China does not yet have a wide range of access vessels and transfer systems to enable more effective and year-round O&M to be carried out.

Challenge Areas

- Developers
- Turbines
- Foundations
- Connectivity
- Installation
- O&M

Wind resource assessments

Challenge	• Lack of accurate wind resource data to identify the best locations for offshore wind development. Accurate site-scale wind resource assessments need to be conducted. • Met masts are more expensive and slower to install than alternative solutions.
Existing local solution	• Industry standards set by NEA in 2011 require two met masts to be installed to collect wind data for at least 1 year and one of them must be at least 100m tall. • In some cases, the developer pays for and installs a met mast before the site is opened up for bidding. Whoever pays for the met masts will sit in an advantageous position in the following bidding round, and will be reimbursed by the bid winner if itself is not.
UK/European solution	1. Create a wind atlas for China. 2. Government could pay to install several met masts - like Germany has done with FINO1-3. 3. Use LIDAR devices on existing on and offshore infrastructure. 4. Use of novel Floating LIDAR.

Wind resource assessments

Solution 4: Floating LIDAR

Challenge:

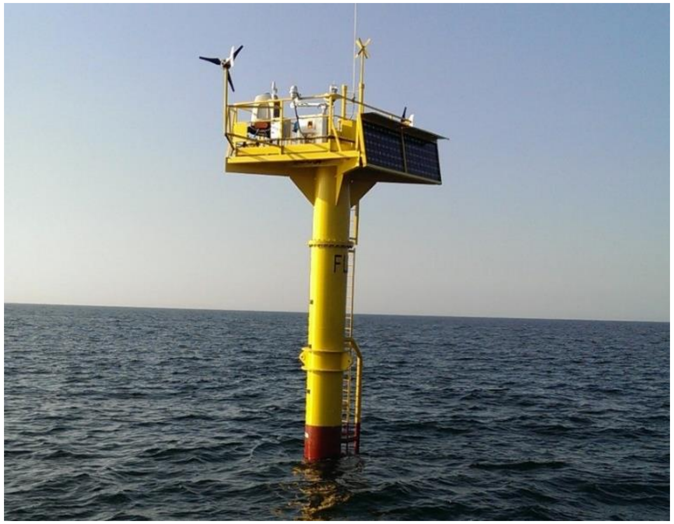
- 100m tall fixed met masts typically cost several million pounds to fabricate and install, and can take as long as a year to get into the water.

Solution:

- Floating LIDAR technology has the potential to replace meteorological met masts for the measurement of primary wind resource data – wind speed and wind direction – for a fraction of the cost.
- The Carbon Trust has supported two promising FLIDAR technologies

Babcock Zephir

- Floating spar buoy
- Installed at Gwynt-Y-Mor offshore wind farm



FLiDAR WindCube

- Buoy platform
- Installed at Gwynt-Y-Mor offshore wind farm

Source: Carbon Trust (2013); www.3e.eu

Wake Effects

Challenge	• Wake effect not well understood and very little modelling is being conducted. • Very few offshore wind farms to collect real data.
Existing local solution	Wake effects poorly understood and often not investigated. Some developers have used WASP software.
UK/European solution	1. Adopt the best wake effects tools from Europe and work with European companies to share wake effect data.

Wake Effects

Solution 1 Example: Carbon Trust project
Validating models with real data from wind farms in Europe

Carbon Trust research project launched in May 2013

- Models need to be validated against real data.
- LIDARS placed on a number of turbine nacelles at different locations across the wind farm
- LIDAR measures wind passing through the wind farm at that point
- Data will help improve software, by comparing real data with model simulations

2 Avent's Wind Iris nacelle LIDAR installed at Rødsan 2 windfarm, Denmark

Challenge for China:

- While Chinese developers understand the importance of wake effects and has began using models to understand the impact, there are very few offshore wind farms from which they can collect data to benchmark against models.

Solution:

- Collaborate with European companies to share data on wake effects.

Source: Carbon Trust (2013)

Consenting Process

Challenge	Slow consenting time (typically takes ~2 years): • Lack of coordination between government departments amid competing interests for marine activity. • Local authorities are unable to properly assess applications, due to a lack of guidance.
Existing local solution	• “Interim Guidance” document jointly issued by NEA and SOA to more clearly define the role of each in the consenting process. • In 2013, central government extended consenting rights to provincial authorities.
UK/European solution	1. Have one central body to coordinate government decisions for offshore wind (licensing, consenting, incentives, R&D, grid connections). 2. Involve the SOA and CMA early in project planning phase. 3. Spatial planning – Adopt a Geographical Information System (GIS) like The Crown Estate "MaRS" system to manage competing uses of the sea bed. 4. Allow developers to vary their consents once awarded to allow technology changes, e.g. using different turbines or foundations without putting the existing consent at risk. 5. Provide thorough guidance and training to enable local authorities to assess applications, and increase the resource (staff) of consenting authorities to cope with increasing applications.

Consenting – Environmental Impact Assessments

Challenge	Environmental Impact Assessments have a big impact on consenting – they are time consuming and are a barrier to offshore wind farm development. Key issues are: • Visual impact • Piling noise • Bird collisions
Existing local solution	None
UK/European solution	Speed up Environmental Impact Assessment: 1. Create joint industry projects to speed-up environmental impact assessments (EIAs) 2. Run competitions to develop technologies which reduce piling noise

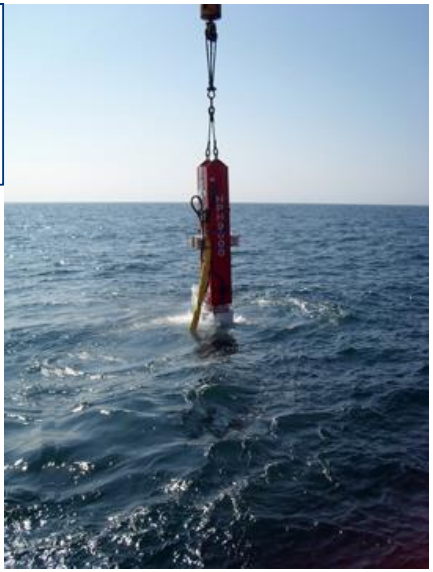
Environmental Impact Assessment

Solution 1 & 2: Offshore Renewables Joint Industry Programme (ORJIP)

Bird Collision Avoidance:
Study to collect data on and understand bird avoidance behaviour in wind farms.

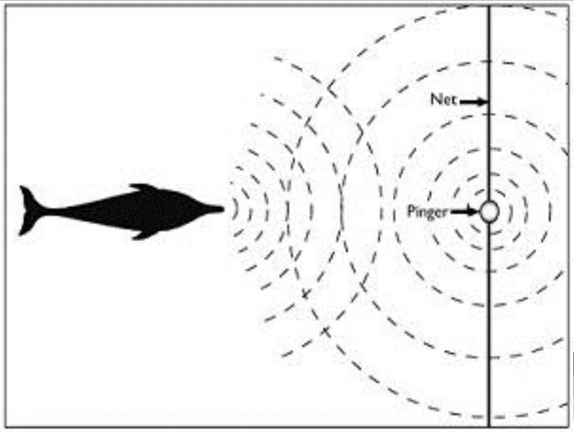
ORJIP

Noise Mitigation for Piled Hammers:
Project to identify best technology solutions for reducing the noise generated from hammer piling.



Acoustic Disturbance:
Study to better understand impact of hammer piling noise on marine mammals.

Acoustic Deterrent Devices:
Project to develop acoustic deterrent devices to deter marine mammals from the wind farm during construction.



Source: Carbon Trust (2013)

Project Development Timeline

Challenge	Risk of developing projects quickly, and not conducting rigorous FEED assessments
Existing local solution	None
UK/European solution	1. Spend more time up-front on FEED assessments linked to engineering and stakeholder management

Project Development Timeline

Challenge Examples: China and Europe

- **Jiangsu Rudong Intertidal (China):**
- Generators had to be replaced after just one year due to rusting in the nacelle.

- **Alpha Ventus (Germany):**
- Gearbox had to be replaced in 12 turbines after just a few months of operation.

- **Greater Gabbard (UK):**
- Problems with the monopile and transition piece:
  - Poor quality steel
  - Poor transition piece design
- Resulted in significant delays and an expensive lawsuit.

Alpha Ventus: Repairs on Areva Multibird M5000 turbine

Lack of Project Development Experience

Challenge	Chines developers lack experience constructing and managing offshore wind projects – only one commercial offshore project in China.
Existing local solution	None
UK/European solution	1. Joint Ventures with European players.

Challenge Areas

- Developers
- Turbines
- Foundations
- Connectivity
- Installation
- O&M

Reliability

Challenge	Reliability claimed to be ~95% in existing projects; however, given the importance of availability on project economics, this is a key area. **Gearbox:** • Chinese OEMs have limited experience of producing turbines for the offshore market. • Limited design experience of medium speed WTG (no bespoke medium speed WTG in China) • Challenge to develop high reliability and light gearbox. **Power electronics:** • Electrical components are prone to failures.
Existing local solution	In-house OEM R&D.
UK/European solution	**1. Gearbox:** Partner with European turbine designers and gearbox suppliers to develop capability in producing direct-drive and medium-speed geared turbines. **2. Power electronics:** Partner with European turbine designers and component suppliers **3. Testing facilities:** Collaborate with European companies to share test facilities.

Supply & Performance of Control Systems

Challenge	• China lacks capability to produce downstream products such as control systems and power converters - currently import from foreign suppliers. • Fault rate of power electronics is high. • Larger turbines require improved control systems to reduce loads. • Control during typhoon conditions.
Existing local solution	None
UK/European solution	1. Work with engineering consultancies to adopt leading control systems and build capability in-house. 2. Advanced control based on LIDAR wind measurement for Independent pitch control.

Improving control system performance

Solution 2: Use of Lidar Data

Challenge:

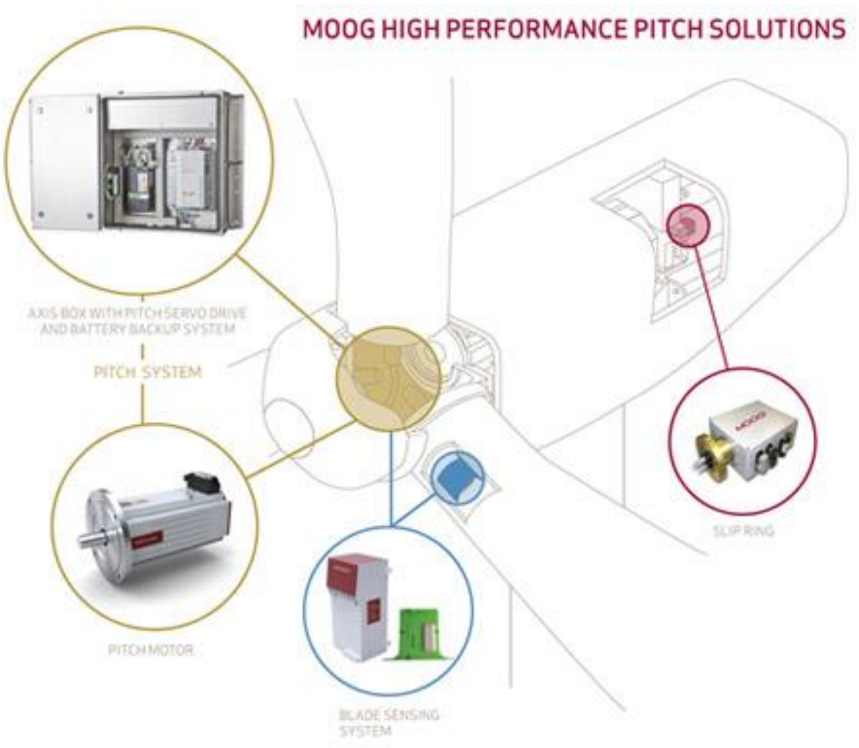
- Larger capacity turbines have larger blades, which contribute to larger unbalances loads for the rotor, require improved control systems, particularly during typhoon conditions.

Solution:

- Advanced control based on LIDAR wind measurement: LIDAR sensors can be installed to precisely measure the incoming wind as it approaches the turbine, allowing control systems to adjust accordingly to reduce loads and maximise yield.
- Independent pitch control: Advanced blade pitch control systems can be used to maximise energy production from turbines.

Example:

- Moog, a US company which provides of blade pitch control, slip ring and rotor monitoring solutions for wind turbines, recently launched its new AC Moog Wind Turbine Pitch System in China and integrated it in Envision Energy's 4 MW offshore wind turbine in Rudong Intertidal zone.



Source: www.nawindpower.com; Moog

Load Analysis

Challenge	Chinese companies lack the ability to model integrated load analysis on turbines.
Existing local solution	Some experience of using Bladed software.
UK/European solution	1. Master the leading European load analysis tools, such as Bladed.

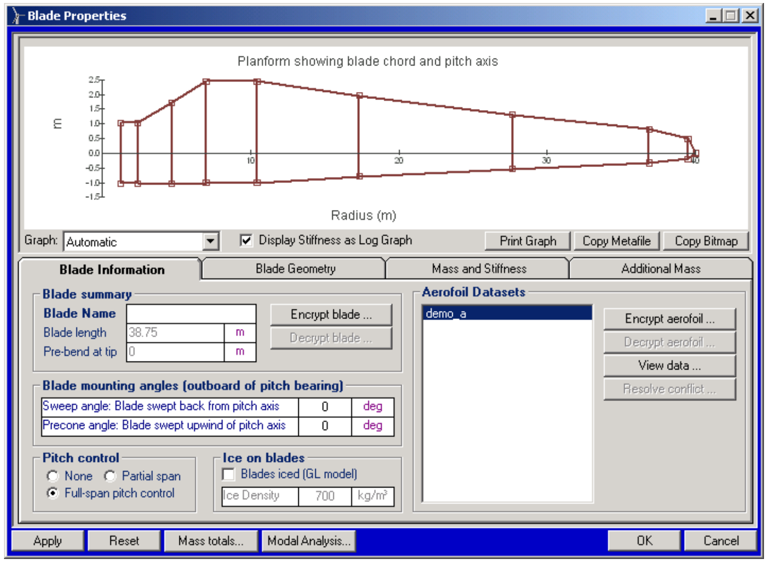
Load Analysis

Solution 1: Leverage European load analysis software and tools

- Engage with GL Garrad Hassan to develop capability using Bladed software

Example: Bladed (Garrad Hassan):

- Bladed is the industry standard integrated software package for the design and certification of offshore turbines.
- The design tool has been extensively validated against measured data from a wide range of turbines.
- Supports calculations of combined wind and wave loading, with full aeroelastic and hydroelastic modelling.
- Various modules available:
  - Steady state analysis
  - Dynamic load simulations
  - Analysis of loads and energy capture
  - Batch processing and automated report generation
  - Interaction with the electrical network
  - Model linearisation for control design



Source: GL Garrad Hassan

Corrosion & Over-heating

Challenge	Over-heating and rusting poses risk to component reliability.
Existing local solution	Local OEMs have designed control systems for typhoon conditions.
UK/European solution	1. Develop sealed nacelles with heat and moisture control. 2. Seek additional engineering support from European companies working in this space e.g. Hydac and Goaland Watertech.

Blade performance

Challenge	• Larger turbines require longer and lighter blades. Most use glass fibre; likely to move to carbon fibre in future. • Blade manufacturers in China are able to conduct static tests, but few are able to do dynamic load tests.
Existing local solution	In-house OEM R&D – developing modular blades (built in sub-sections).
UK/European solution	1. Work with turbine OEMs and blade suppliers (e.g. LM, Blade Dynamics). 2. Form partnerships with European blade testing facilities.

Cold climates – Ice & snow impact

Challenge	Ice forms on blades in northern China in winter, especially in OW farms in Shandong.
Existing local solution	No existing solution.
UK/European solution	1. Adopt leading European ice detection technologies. 2. Adopt leading European de-icing technologies. 3. Construct blades/rotor from icephobic surfaces.

Resistance to typhoons

CARBON TRUST

Challenge	Typhoons pose potentially major threat to offshore turbines: • Blade strength - batch of onshore turbines suffered blade damage from recent typhoon. • Control systems are required to adjust the pitch and yaw of blades during a typhoon.
Existing local solution	• Local OEMs have blade testing facilities, but only few can do dynamic load testing. • OEMs also have designed control systems for typhoon conditions.
UK/European solution	1. Work with leading technical consultancies and blade suppliers (e.g. LM; Blade Dynamics) to better understand the loads of a tsunami on the turbine blades and tower 2. Ensure rigorous testing of blade strength in the design and manufacturing process 3. Develop control systems to adjust the pitch and yaw of turbines in typhoon conditions 4. Ensure consistency in the lifetime of components 5. Develop a set of industry standards for typhoon resistance

Resistance to typhoons

Challenge:

- Typhoons pose a major threat to Chinese wind farms
  - E.g. In September 2013 Typhoon Usagi damaged 26 turbines at Honghaiwan onshore wind farm in coastal Shanwei City, Guangdong.
  - Resulted in CNY 100 million loss of revenue.

Solutions:

1. Work with leading technical consultancies (GL Garrad Hassan; Ricardo) and blade suppliers (e.g. LM; Blade Dynamics) to better understand the loads of a typhoon on the turbine blades and tower
2. Ensure rigorous testing of blade strength in the design and manufacturing process
3. Develop control systems to adjust the pitch and yaw of turbines in typhoon conditions
4. Ensure consistency in the lifetime of components
   - i.e. Develop turbines capable of withstanding once-in-50-year typhoons
5. Develop a set of industry standards for typhoon resistance
   - E.g. J-Class Wind Turbine Guidelines in Japan

Source: www.windpowermonthly.com

Challenge Areas

- Developers
- Turbines
- Foundations
- Connectivity
- Installation
- O&M

Foundation design

Challenge	• Stability: Soft soils along east coast pose a challenge for foundations. • Cost: Current high cost of foundations that use more steel than needed Potential to reduce cost through using less steel and less complex designs which are less labour intensive. • Ease of installation: Current installation techniques are costly. Potential to reduce cost and improve efficiency by adopting foundations which can be installed.
Existing local solution	Monopile, gravity base and high-rise pile cap foundations currently installed.
UK/European solution	Optimise design of monopile and gravity base foundations and adopt leading novel designs of alternative foundation concepts from Europe: 1. Monopile (Ramboll; Ballast Nedam Concrete Drilled Monopile) 2. Gravity base (COWI; Gravitas) 3. Suction bucket (Universal Foundation) 4. Jacket Foundations

Foundation designs

Solution 3: Suction Bucket

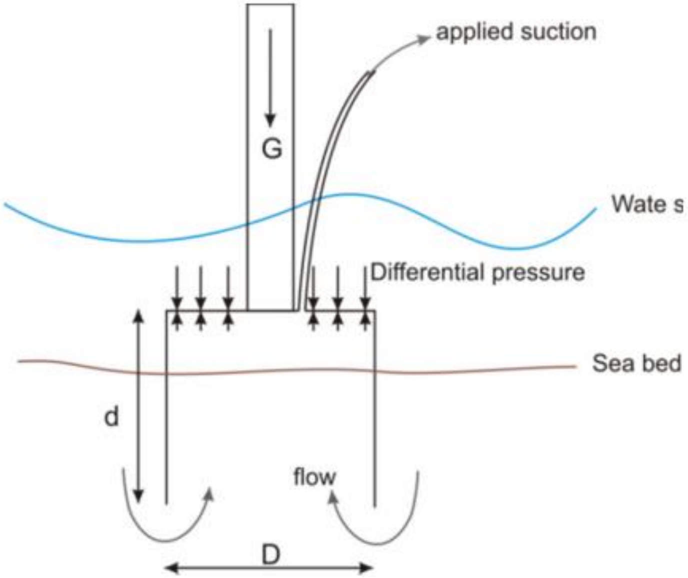
Universal Foundation (Carbon Trust Foundation Competition)

Manufacture:

- Reduced steel
- Simple geometric welded steel structure suitable for mass production
- Reduced need for scour protection

Installation:

- No seabed preparation
- The structure is upended by ballast water or by crane
- Crane is hooked on to stabilize touch down
- After initial penetration, suction is applied using snap-on pump unit aboard the installation vessel



Source: Carbon Trust (2013); Fred Olsen (2013) Universal Foundation Suction Bucket

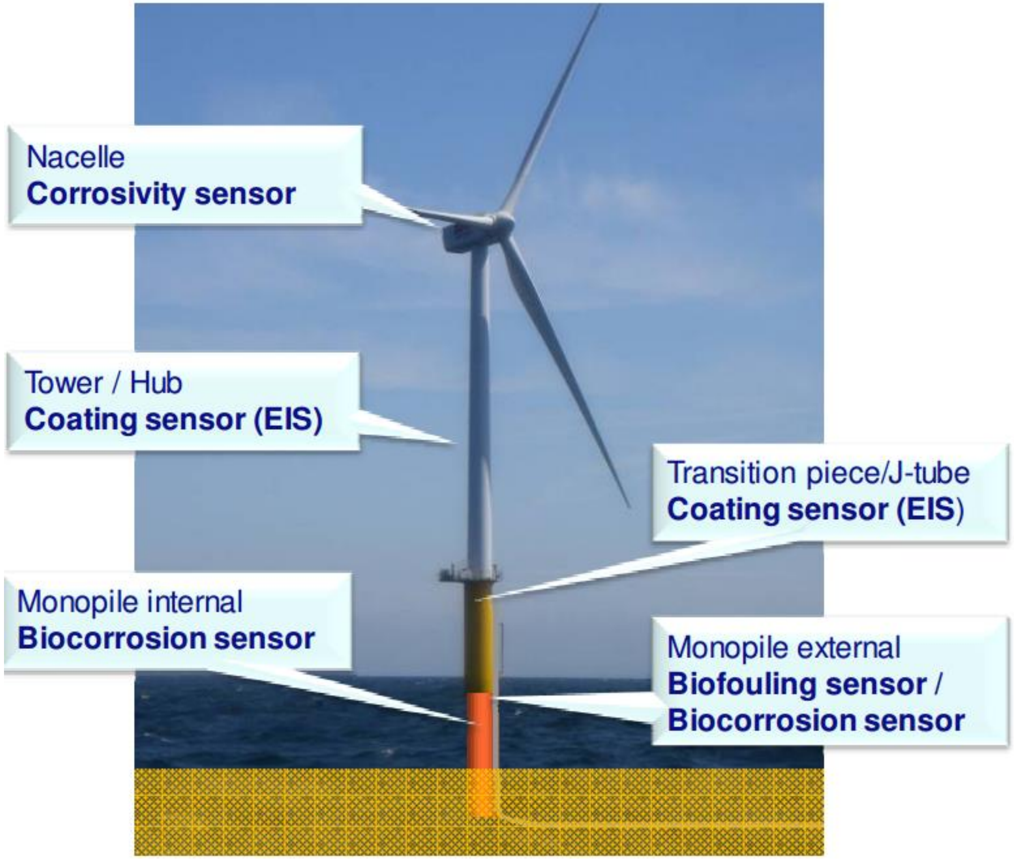
Corrosion

Challenge	Corrosion can negatively impact on the asset integrity of the foundation.
Existing local solution	Various coating institutes and commercial products in China.
UK/European solution	1. Adopt conventional anti-corrosion protection 2. Use Impressed Current Cathodic Protection 3. Use remote monitoring to detect corrosion 4. Form joint industry project to tackle corrosion 5. Partner with European companies: • Hempel (Denmark) • Cathelco (UK) • FORCE Technology (Denmark) • The Welding Institute (TWI) (UK) • TNO (Netherlands) • Local shipping industry

Corrosion

Solution 3: Remote monitoring and diagnostics

- Remote monitoring and diagnostics sensors placed on the turbines can be used to identify corrosion early, so that they can be treated before the structural integrity or of the structure is compromised
- Sensors can be installed in critical parts of the structure where corrosion is most anticipated



* EIS = Electrochemical Impedance Spectroscopy

Source: TNO (2012)

Fatigue

Challenge	The welded joints of foundations are susceptible to fatigue.
Existing local solution	None
UK/European solution	1. Reduce the number of welded connections. 2. Introduce industry standards and certification for foundation quality. 3. Use modelling tools to improve structure design. 4. Engage with The Welding Institute (TWI) in UK.

Transition piece connection

Challenge	Early projects experienced problems with TP slipping over monopile.
Existing local solution	None
UK/European solution	1. Conical design in grouted section of monopile and transition piece 2. Use foundations without TPs e.g. Universal Foundation 3. Use latest DNV standards 4. Use bolted connections

Challenge Areas

- Developers
- Turbines
- Foundations
- Connectivity
- Installation
- O&M

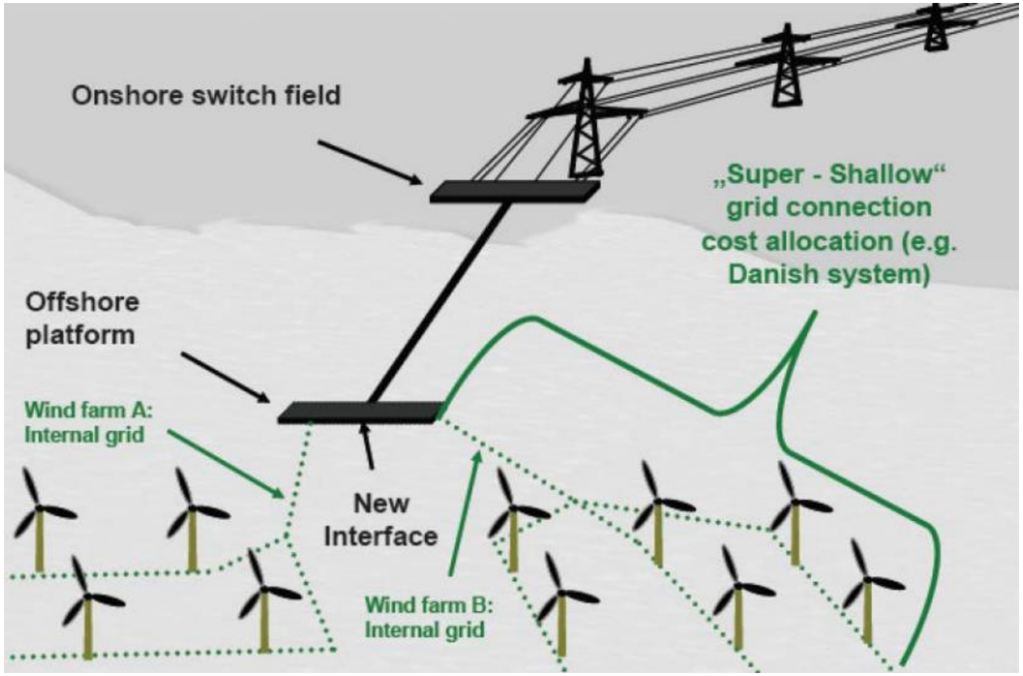
Grid Connection

Challenge	Connection from farm to shore
Existing local solution	• Common practice is the developers will build everything up to the onshore station (included). Anything beyond that is the grid company's responsibility. (shallow charges model) • Developers need to apply to the grid companies for approval to be connected
UK/European solution	1. Adopt super shallow model to encourage developers to enter the market. 2. Assign clear responsibility for connecting wind farms – either grid company or developer – to ensure that there are no delays in connecting the wind farm to the grid.

Grid Connection

Solution 1: Adopt super-shallow charging model

- Developer pays for:
  - Inter-array cables only
- Rest of the network, such as offshore platform, export cables, onshore substation and onshore reinforcement are socialised across all network users.
- E.g. Germany, Denmark
- **Pros:** Removes up-front cost for developers.
- **Cons:** Risk of delays if state grid is unable to build infrastructure in time, particularly if the state grid lacks capability and experience of building out to the wind farm.



Source: Meeus (2012)

Cost of Connection

Challenge	Connecting wind farm to grid is expensive. Innovative solutions can both reduce costs and improve efficiency.
Existing local solution	None
UK/European solution	1. AC-connections 2. Offshore bundling station 3. Future proof infrastructure so that links are scaled for future pipeline of projects to minimise total costs i.e. grid reinforcement and offshore bundling stations

Offshore Substations

Challenge	No offshore substations installed, but increasing need as projects move further from shore. China has no experience and limited capability.
Existing local solution	• Turbines currently connected directly to onshore substation. • R&D initiatives on substation design (Huadong Engineering Corp; East China Investigation & Design Institute) and construction (China Datang Corp Renewable Power Co).
UK/European solution	1. Work with European companies such as Siemens, ABB, and Alstom.

Transmission losses

Challenge	Medium voltage arrays experience transmission losses and are vulnerable to cable failures
Existing local solution	None
UK/European solution	1. Move straight to higher voltage arrays (e.g. 66kV) to minimise losses 2. Use ring, rather than radial, networks to increase redundancy and reduce downtime 3. Commercialise 66kV cables

Transmission losses

Solution 3: . High voltage arrays (66kV)
CT Cable Competition - 66kV cables

- **<u>Barrier:</u> Need to reduce costs and prove technical feasibility of 66kV cables**

- Transformers and switchgears are commercially available for 66kV
- However, 66kV cables are too expensive with traditional lead sheath to keep cables dry
- New cables are needed
- Cable manufacturers (e.g. Prysmian; Nexans) have developed innovative 66kV wet cable designs, which would provide significant performance improvements for small increase in costs

- **<u>Solution:</u> Carbon Trust competition to qualify and certify 66kV cable designs**

- Lack of qualified 66kV cables at the right price is last barrier to 66kV adoption

- Carbon Trust have recently launched a competition for suppliers to qualify 66kV cables

Connection Planning

Challenge	Inherent tendency for developers to focus FEED on foundations and turbines, and neglect cabling.
Existing local solution	None
UK/European solution	1. Conduct cable route surveys early in the planning phase. 2. Involve suppliers and contractors early in the FEED process.

Supply of export cables

Challenge	Market dominated by one supplier of 220kV cables – ZTT. Four other domestic suppliers exist, but little application to date means that they have no track record.
Existing local solution	Develop local capability as Chinese OW market grows.
UK/European solution	1. Increase local manufacturing capacity 2. Reduce the number of cables required 3. Import cables from overseas suppliers (Europe and Asia)

Supply of export cables

Solutions 3

3. Import cables from
   I. European suppliers e.g. Nexans (France); Prysmian (Italy); ABB (Sweden); NKT (Germany); NSW (Germany)

   II. Asian suppliers e.g. Viscas; J-Power; Nexans/Viscas JV; Exsym (all Japan)

Cable installation vessel availability

Challenge	• Shortage of cable installation vessels - only 2 available, and lack of players with plans for more. Potentially large bottleneck. • Need for vessels with higher load capacity
Existing local solution	• SBSS market leader. • Some companies trying to retro-fit existing vessels, rather than build new ones.
UK/European solution	1. Increase production capacity of local suppliers 2. Import cable installation vessels from Europe

Cable installation vessel availability

Solution 1: Increase production capacity of local suppliers

- SBSS dominates the Asian market for cable installation, and has strong capability and international links through its parent company, Global Marine Systems.
- There are a number of ship construction companies in China with advanced production facilities capable of manufacturing a large number of purpose-built vessels for the OW industry.
  - COSCO
  - ZPMC
  - CNOOC
  - CNPC

SBSS DP2 Bold Maverick Vessel

Cable damage

Challenge	Cable damage poses major risk - ~80% of insurance claims in OW industry.
Existing local solution	None
UK/European solution	1. Optimal burial depth 2. J-tubeless cable installation

Challenge Areas

- Developers
- Turbines
- Foundations
- Connectivity
- Installation
- O&M

Supply of piling hammers

Challenge	Lack local capability to produce piling hammers – currently imported from abroad.
Existing local solution	Some manufacturers in China are developing synchronized vibratory pile hammers.
UK/European solution	1. Work with international suppliers to import/build capability producing piling hammers e.g. IHC, Menck. 2. Develop vibro-hammers locally (cheaper than conventional piling hammers). 3. Adopt drilled monopile technology. 4. Adopt BLUE Piling Technology. 5. Use foundation designs that don't need to be piled, i.e. suction bucket foundations (e.g. Universal Foundation), and gravity base foundations (where appropriate to seabed conditions).

Installation vessel availability (turbines & foundations)

Challenge	• Vessels for foundation and turbine installation not expected to be an immediate issue, but beyond 2015 far more vessels will be required. • Currently maximum of 2 turbines per vessel. • Lack of bespoke vessel with batch installation capability.
Existing local solution	Chinese companies have begun to produce bespoke vessels for the Chinese market. Increase production of vessels from local suppliers.
UK/European solution	1. Adopt European vessel designs which can accommodate more turbines/foundations per vessel (work with international contractors like Swire Blue Ocean, Fred. Olsen, MPI, GeoSea, Hochtief, A2Sea). 2. Scale up vessel production by leveraging domestic manufacturing capability.

(3) Optimise utilisation

Turbine transportation and installation

CARBON TRUST

Swire Blue Ocean "Pacific Orca"

- Largest installation vessel currently in operation
- 1,200t capacity main crane, plus 40t capacity auxiliary crane
- 4,300m^2 cargo area
- Carrying capacity: 12 x 3.6MW turbines

Gaoh Offshore Deepwater Installer 1

- Designed for year-round operations (operating window = 99%)
- Carrying capacity 16 x 3.6MW turbines (deck space = 5,500m^2)
- 1,600t crane
- Floating and jack-up modes

Lack of installation experience

Challenge	Only one commercial offshore project in China.
Existing local solution	None
UK/European solution	1. Get international developers into projects (e.g. JVs with DONG, Statoil, etc.), get international installers into projects (e.g. A2Sea et al.)

Challenge Areas

- Developers
- Turbines
- Foundations
- Connectivity
- Installation
- O&M

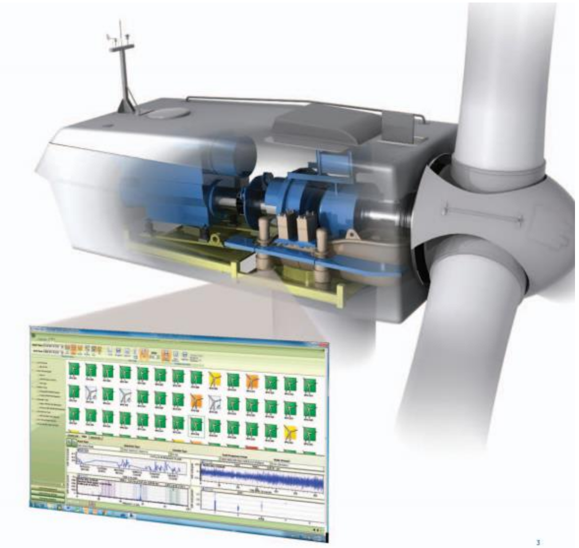
Condition monitoring systems

Challenge	Condition monitoring systems need to be improved for offshore wind turbines. Reliability data is not shared.
Existing local solution	• Transfer technology from onshore turbines. • Improve quality through in-house R&D.
UK/European solution	1. Adopt leading condition monitoring systems from Europe. 2. Engage with the Centre for Advanced Condition Monitoring, at the University of Strathclyde, and/or European condition monitoring companies. 3. Mandate sharing of reliability across industry.

Condition Monitoring Systems

Solution 1: Adopt leading CMS from Europe

- **GE: Bently Nevada “ADAPT.wind”**
  - Advanced, accurate monitoring of components and computer models
  - Provides both vibration and gearbox particulate monitoring
  - Employs predictive analytics with data-driven modelling to compare real data with normal behaviour
  - Proactively detects drivetrain issues to enable operators to plan efficiently and optimise maintenance outages
  - Data can be used to issue a clear actionable report with recommendations for operators



- **SKF: WindCon 3.0**
  - Continuously monitors critical equipment on single units or entire farms to reliably identify operating performance
  - Vibration sensors collect and analyse data which can be configured to suit the needs of the wind farm operator
  - Data collected by WindCon also enables root cause failure analysis to eliminate recurring failures
  - Web program allows turbine conditions to be monitored via any computer with internet access
  - Enables condition monitoring on an unlimited number of turbines and turbine data points

Source: www.ge-mcs.com; www.skf.com

Access vessels

Challenge	No bespoke vessels currently available.
Existing local solution	Developers (e.g. Longyuan) have designed vessels, but not built any yet.
UK/European solution	1. Adopt leading European access vessel designs.

Access Vessels

Solution 1 Examples: Carbon Trust Offshore Wind Access Competition

CARBON TRUST

Fjellstrand "WindServer":

- Innovative hull design allows very fuel-efficient travel within the wind farm
- Unlike other fuel-efficient vessels, it is very stable when stationary which is ideal for transferring engineers to turbines
- Slender waterlines and unique bow ensures minimised motion at high speeds as well as during low speed manoeuvring in the wind farm
- Generous deck space made possible by the hull's ample load capacity can accommodate practically any transfer system

Source: Carbon Trust (2013)

Transfer systems

Challenge	No bespoke transfer systems currently available.
Existing local solution	None
UK/European solution	1. Adopt leading European transfer system designs.

Lack of O&M experience

Challenge	Only one commercial offshore project in China.
Existing local solution	None
UK/European solution	1. Partner with European vessel operators, developers, turbine OEMs.