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China

Meeting the Challenges of Offshore
and Large-Scale Wind Power:
Strategic Guidance



Australian Government
Aid Program



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China: Meeting the Challenges of Offshore and Large-Scale Wind Power

Joint publication of the National Energy Administration of China and the World Bank
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Preface

This publication is the result of a joint effort of the National Energy Administration of the People's Republic of China and the World Bank. The objective of this effort, implemented with support from AusAID and ASTAE, was to gather lessons learned from international experience in large-scale onshore and offshore wind power development, with a view to informing China's strategy going forward.

This effort resulted in two publications:

- The first publication, *Regulatory Review of Offshore Wind in Five European Countries*, provides a detailed description and evaluation of the regulatory approaches that various countries in Europe have taken to develop offshore wind energy.
- The second publication, *Strategic Guidance*, defines a roadmap for the promotion of offshore and large-scale onshore wind developments in China, and summarizes the messages emerging from a high-level workshop held in Beijing.

Both publications rely on investigations undertaken by Garrad Hassan and Partners Limited for the World Bank. The current publication is the second of the two. *Regulatory Review of Offshore Wind in Five European Countries*, which is a companion to this one, was published separately, under the ASTAE Technical Report Series.

This publication comprises three main parts:

- **Part A** contains the key messages emerging from the research and analytical work undertaken by Garrad Hassan and Partners Limited, the team of Chinese experts led by the National Energy Administration, and staff and consultants of the World Bank.
- **Part B** comprises the Garrad Hassan and Partners Limited study, "Implementation Guidance for Offshore and Large-Scale Onshore Wind Power Development in China," and its annexes.
- **Part C** focuses on the Workshop on Offshore and Intertidal Wind Power Development in China, which was held in Beijing in January 2009, and it includes technical notes on three main issues discussed during the workshop, remarks by senior officials from the Government of China, and the presentation by the World Bank during the event.

Foreword

This foreword is based on Mr. Zhang's remarks at the January 2009 Workshop on Offshore Wind and Coastal Wind Base Development (translated from Chinese).

In view of the escalating global problems associated with the environment, energy, and natural resources, especially the increasing signs of global climate change, wind power is receiving more and more high-level attention on a global scale, and it has reached a rapid rate of development as a result of the combined efforts of various countries. The world's installed capacity of wind power has already surpassed 100 GW, and wind power has become an essential part of the world's energy structure.

In order to promote the development of renewable energy, the Chinese government enacted the Renewable Energy Law in 2005, which defines the legal framework for renewable energy development and strongly promotes China's renewable energy development, especially in the area of wind power. By the end of 2008, China's wind power installed capacity had exceeded 10 GW, and great progress can now be seen in its manufacturing capability. To speed up the pace of wind power development, considering the characteristics of wind resources and power demand, we put forward the strategic idea of "building large bases and integrating them into super grids," and we are now in the process of planning the construction of a certain number of 10 GW wind bases.

Until now, China's main wind construction projects have been located onshore, whereas the offshore projects are still at the preparation and exploration stage. Generally speaking, offshore wind energy is characterized by higher wind speeds, especially since smaller land space incurs less environmental impact. Thus, offshore projects hold enormous potential for the future. The European Union has already made great efforts to develop offshore wind power and considers it the main priority in the area of wind energy. China has a very long coastline and vast areas of ocean at its disposal, which provide excellent conditions for offshore wind development.

The eastern coastal lands are economically highly developed, yet they suffer a shortage of fossil fuels. Thus, offshore wind power is an important local natural resource and, as such, developing offshore wind for power supply and economic growth in these areas is essential. In

comparison with onshore wind power construction, however, offshore construction is faced with larger technological difficulties and new challenges.

To be able to successfully manage offshore construction, the following must occur:

Offshore wind power planning must first be emphasized. It is necessary to maintain development between wind power and other uses of the coastline and ocean areas, such as ports, navigation, and ocean cultivation. Moreover, wind power should be planned scientifically, positioned appropriately, and constructed in an orderly manner.

Research and development (R&D) must be reinforced in offshore wind power technology, so as to further improve the reliability of the wind turbines. Furthermore, an offshore wind power engineering construction program must be formulated, which should take the shape of an offshore wind power engineering technology system.

An appropriate mechanism for offshore wind development should be explored in order to accumulate offshore wind power development experience. Research and formulation of administration policies and regulations for offshore wind farm development must also be made.

In view of the effort made in recent years, China has made great progress and has a promising future in the areas of wind power. Offshore wind power is the most promising area of wind power development in China. In the opening up of this new frontier, China's wind power industry will develop in a more formidable manner, and will make an important contribution to promoting the development of energy and science in China, as well as safeguarding the ecological environment and sustainable development for the economy and the country as a whole.

Zhang Guobao
Administrator of the National Energy Administration

Foreword

In recent years, China's achievements in wind power development have exceeded expectations and planning targets. The country's target for wind power development for 2010, set in the 11th Five-Year Plan at 5 GW, was already exceeded in 2008, with installed capacity reaching 12 GW as of the end of 2008, placing China in fourth place in the world. Wind power development is expected to continue rapidly in the coming years, with the 30 GW target for 2020 likely to be achieved much earlier. We understand that the government is considering a significant upward revision of those targets.

To implement such a significant wind power development program with unprecedented targets, the Government of China has been considering the development of wind farms in intertidal and offshore areas, in addition to scaling up to gigawatt-scale onshore wind power bases. Such an impressive development vision also necessitates the study and analysis of various important aspects, including the assessment of wind resources and construction technologies for wind farms in offshore and intertidal areas, as well as the integration of wind farms into the grid and the operation of a system with large wind power capacity. The government is well aware that the development of large wind power bases, as well as intertidal and offshore wind farms, poses several technical, operational, and financing challenges. The government also recognizes the importance of having the appropriate policy and regulatory framework in place.

Wind power development is also an important area of focus of the China Renewable Energy Scale-Up Program (CRESP), which is a joint program of the Government of China, World Bank, and Global Environment

Facility (GEF) for renewable energy policy development and investment, comprising three phases. The first phase of CRESP consists of a US\$40 million GEF grant for technical assistance and capacity building support as well as a US\$188 million in financing from the International Bank of Reconstruction and Development (IBRD) for four renewable electricity investment projects—two wind farms, one biomass power plant, and a group of small hydropower projects, mostly focusing on rehabilitation of old facilities.

In light of the synergies between the government's emerging priorities and CRESP, the Government of China asked the Bank to assist with the development of specific implementation guidance on large onshore, intertidal, and offshore wind power development. With support from our partners at the Australian Agency for International Development (AusAID) and the Asia Sustainable and Alternative Energy Program (ASTAE), the Bank was able to respond to the government's request rapidly.

This publication is the outcome of that cooperation, focusing on identifying lessons learned from international experience and providing important implementation guidance for large-scale onshore, intertidal, and offshore wind farm development. We hope that it will be a useful input to China's wind power development efforts.

John A. Roome
Director, Sustainable Development
East Asia and Pacific Region
The World Bank

Acknowledgments

This publication is the product of a joint activity of the National Energy Administration (NEA) of the People's Republic of China, and the World Bank (WB). This activity was supported by the Australian Agency for International Development (AusAID) and the Asia Sustainable and Alternative Energy Program (ASTAE). Its objective was to develop implementation guidance for large-scale onshore, intertidal, and offshore wind farm development in China.

The NEA-led portion of this activity was implemented under the leadership of Shi Lishan, Deputy Director General of the NEA, and Han Wenke, Director of the Energy Research Institute (ERI). Various Chinese experts contributed to this activity, sharing their time and insights with the team. They included He Dexin, Shi Pengfei, and Qin Haiyan of China Wind Energy Association (CWEA); Wang Weisheng and Chen Mozi of China Electric Power Research Institute (CEPRI); Yang Zhenbin of the China Meteorological Administration (CMA); Zhuang Yuexing of Zhong Hang Huiteng Wind Power Equipment Co. Ltd.; Gao Hui of Guohua Energy Investment Co. Ltd.; Wang Siyong of China Huaneng Group; Yang Xiaosheng of China Longyuan Electric Power Group Corp.; Wang Zhongjiong and Li Yongfeng of Sany Group; and Zou Hua of China National Offshore Oil Corp. Of course, none of them should be held personally responsible for any errors of fact or interpretation that remain.

Andrew Garrad, Paul Gardner, Weiping Pan, and David Williams from Garrad Hassan and Partners Limited; and Ming Hu from Alberta Electric System Operator (AESO) were the major contributors to this publication. In addition, the activity benefited greatly from the feedback provided and discussions that took place during the

Workshop on Offshore Wind and Coastal Wind Base Development held in Beijing in January 2009.

The team leading the World Bank portion of this activity—Noureddine Berrah, Richard Spencer, Ranjit Lamech, Yanqin Song, and Defne Gencer—would like to give special recognition to peer reviewers Soren Krohn and Anil Cabraal, the staff of the Project Management Office of the GOC-WB-GEF China Renewable Energy Scale-Up Program (CRESP), to editor Rebecca Kary, and to graphic designer Laura Johnson.

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The World Bank team greatly appreciates the efforts of Junhui Wu and Ede Ijjasz, who encouraged the pursuit of this topic and provided the resources to make this publication possible.

Finally, the NEA and World Bank teams would like to call attention to the leadership and guidance of Zhang Guobao, Administrator of the NEA. His inspired vision and encouragement helped steer this effort to its ultimately successful outcome.

Abbreviations and Acronyms

| | | | |
|--------|---|-------|---|
| AC | Alternating current | GL | Germanischer Lloyd (a recognized certificate) |
| ASOS | Automated Surface Observing System | HV | High voltage |
| ASTAE | Asia Sustainable and Alternative Energy Program | HVDC | High-voltage direct current |
| AusAID | Australian Agency for International Development | IEC | International Electrotechnical Commission (the basis of modern wind turbine design standards) |
| BOP | Balance of plant | IGBT | Insulated gate bipolar transistor |
| CF | Capacity factor | LIDAR | Light detection and ranging |
| CRESP | China Renewable Energy Scale-Up Program | O&M | Operations and maintenance |
| DNV | Det Norske Veritas (a recognized certificate) | PPA | Power purchase agreement |
| EPC | Engineering Procurement Construction | R&D | Research and development |
| EU | European Union | ROC | Renewable obligation certificate (tradable green credit) |
| GB | Acronym for standards issued by the Standardization Administration of China | SEA | Strategic Environmental Assessment |
| GEF | Global Environment Facility | TSO | Transmission system operator |
| GIS | Geographic information system | WPB | Wind power base |

Units of Measure

| | | | |
|----|-----------|------------------|------------------------|
| GW | Gigawatt | m | Meter |
| h | Hour | m/s | Meters per second |
| km | Kilometer | MW | Megawatt |
| kV | Kilovolt | MWh | Megawatt-hour |
| kW | Kilowatt | t | Ton |
| | | tce | Tons coal equivalent |
| | | W/m ² | Watts per square meter |

Currency

Y = Yuan

RMB = Renminbi

Part A

Strategic Messages for Offshore and Large-Scale Wind Power

Summary of Main Messages

- A few years ago, China's wind power utilization was hardly noticeable. It has made remarkable progress during the first three years of the 11th Five-Year Plan (2006–11). In 2008, China had the fourth largest installed capacity of wind power in the world and a market growing at a rate that is likely to be the largest in the world in the coming years. The government plans to scale up onshore wind in resource-rich and sparsely populated regions of the country, undertake pilot intertidal projects, and initiate development work on medium- and deepwater offshore wind farms. *The scale-up strategy is sound, but the pace should not be rushed at the expense of learning and efficiency.*
- The government has committed immense resources to onshore wind resource assessment. These efforts should be extended to intertidal and offshore resources. *It is strongly recommended that all collected data be validated and assembled in a national geographic information system (GIS).*
- The government commitment to scaling up wind power development should be twinned with a clear objective to deliver electricity at a minimum cost. Efficiency is contingent upon ensuring that wind farms are built in places where key requirements for success are present: *the best resources, adequate project designs, use of proven turbines, regulatory clarity, adequate incentives, and last but not least, appropriate operations and maintenance (O&M) practices that are carried out by skilled staff.*
- The grid is important. International experience has been good in planning wind farm operational integration. *However, grid connection and stability issues for gigawatt-scale wind bases, as envisaged in China, have no precedent anywhere in the world.* Comprehensive connection studies, with special attention to the optimum connection size and connection circuit layout, should be undertaken with the involvement of all stakeholders. Short-term operational forecasting studies and the development of short-term wind forecasting methodologies are also necessary.
- Preparing to go offshore and join the leading countries in this field is commendable. China could learn much from the successes and failures of other countries. *Clear decisions about the appropriate legal framework in advance of any substantial projects are vital.*
- The envisaged pilot and demonstration project approach for intertidal and offshore development is sound. *The aim of initial demonstration should be to gain experience in offshore specific technology and approaches—not to demonstrate turbine technology.*

Overview of Key Findings and Recommendations

The Soundness of China's Wind Power Development Strategy

China's wind power development strategy is well articulated in the 15-year plan (2006–2020) and the 11th Five-Year Plan (FYP 2006–11). It consists of a three-pronged approach:

- *Scale up onshore wind power bases (WPBs)*¹ in the northeast and northwest provinces (Gansu, Inner Mongolia, and Xinjiang). WPBs are characterized by locations with annual mean wind speeds higher than 8.0 m/s and numerous sites with several gigawatts' potential.
- *Pilot intertidal*² *offshore*, in the area between high- and low-water marks (especially off the provinces north of the mouth of the Yangtze), with wind speeds roughly estimated to be in the range of 6.0–7.0 m/s (mostly along the coastal areas of Jiangsu, Shandong, and Shanghai).
- *Initiate development work on medium- to deepwater offshore*³ with probably higher wind speeds than intertidal areas, but this assumption is based on very limited measurements in Fujian, Jiangsu, Guangdong, Shandong, Shanghai, and Zhejiang.

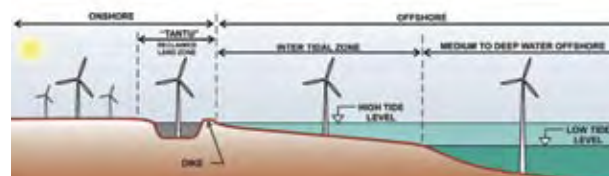
This strategy is illustrated in Figure B–1 on page 21.

The strategy is sound and has begun to yield results. By the end of 2008, China had the fourth largest installed capacity in the world, surpassing India for the first time and becoming the wind power leader in developing countries. The market is growing fast, and the government's current objective is for installed capacity of wind power to reach 30 GW by 2020. However, China's wind farms have a lower capacity factor than wind farms in countries

1. Wind power bases (WPBs): Large-scale onshore wind farms of the order of several gigawatts.

2. Intertidal offshore: Wind farms that are constructed between the low- and high-tide marks along the shore.

3. Offshore wind farms: Wind farms that are constructed in the ocean.



with equivalent wind resources, leading to lower financial and economic efficiency and nonoptimal use of resources. It must be noted that a 1 percent improvement in the capacity factor from the current 20 percent national average would increase the electricity output by 5 percent, yield savings of about 5 percent of investment cost for the same output, and lead to lower wind power prices.

This increase in installed capacity has been accompanied by an important development of the Chinese industry, which accounted for about 62 percent of the total market share (cumulative up to 2008): (a) five large-scale domestic firms manufacturing International Electrotechnical Commission (IEC)-certified turbines, (b) five foreign-owned joint venture firms manufacturing in China, and (c) more than 10 domestic firms with prototype testing under way.

However, the Chinese wind power sector and industry are still relatively new and could benefit from the lessons learned in other countries to avoid mistakes and gradually build a strong and sound manufacturing base. The pace of scale-up should not be rushed at the expense of efficiency and learning.

Principles for Developing a Scaled-Up and Efficient Portfolio of Projects

China has good and abundant wind resources and large amounts of land, intertidal and offshore areas to exploit them. The government commitment to scaling up wind power development should be twinned with a clear objective to deliver electricity at minimum cost. The pace of scale-up should not be rushed at the expense of efficiency, which is contingent upon the following five major principles:

1. Confirmation of wind characteristics
2. Adequate project design and proven turbines
3. Assurance of regulatory clarity, predictability and adequate incentives
4. Availability of skilled staff for design, manufacture, and O&M
5. Getting grid planning and development right.

Principle 1: Confirmation of Wind Characteristics

The importance of proper wind resource assessment is paramount both for identifying areas of interest to develop wind and for project-specific needs. A systematic and organized national measurement program is required. (An overview of some past and present resource assessment efforts in China is available in Part C, Section C-2.) The government recently initiated a national wind resource assessment effort to serve this purpose, for which it has budgeted US\$40 million. It intends to support a comprehensive wind database development backed by a credible protocol and measurement verification. The program is under implementation. *It is strongly recommended that the data be validated and assembled in a national GIS because systematic site-specific wind data collection is vital for the scale and pace of wind power development in China.*

Identical efforts should be made for intertidal and offshore resources. Extrapolation of existing meteorological data confirmed by the very few offshore platforms now providing data is a good start. However, before undertaking expensive offshore investments, it is necessary to assess the intertidal and offshore resources by identifying locations for detailed site-specific measurements and, as for onshore data, to collect, validate, and assemble the data in a national GIS.

Wind characteristics are also essential to build an efficient wind farm. The importance of wind speed cannot be overemphasized. An otherwise identical turbine produces twice the energy at a site with an annual mean wind speed of 9.0 m/s as at one with an annual mean wind speed of 6.5 m/s. If poor wind measurements are made, the estimates of energy production will be unreliable and investments will be in jeopardy. To date, adequate measurements have not been made for the large-scale developments in China even if their costs are very small compared to the size of investments or the lost revenue because of inadequate estimation of wind characteristics. For example, the cost of one 2 MW turbine will pay for 50 more meteorological masts (even more than 100 by European standards), and a 10 percent loss of energy production from a 3.8 GW WPB would result in lost revenue that could cover the purchase of 1,900 masts every single year, according to estimates provided by Chinese experts.

A comprehensive and systematic set of wind measurements according to the specifications provided in the “Implementation Guidance” in Part B of this publication is therefore highly recommended. It is also recommended that, even when wind farms have been developed, high-quality reference masts be left in place to determine whether the wind farms are achieving the planned efficiency goals.

Principle 2: Adequate Project Design and Proven Turbines

China gained sizable experience in designing and developing 100 MW wind farms, and projects developed by emerging national developers meet best international practice. However, the scale of several gigawatts considered for the WPBs is unprecedented. Therefore, detailed layout planning with wind tunnel studies is highly recommended to maximize the output of considered bases because the potential for wake effect losses are greater in simple or low roughness areas (sea, rolling hills, or plateaus, as found in northwest China). The WPBs may exhibit a similar behavior to that of offshore wind farms in Europe.

The wakes in large offshore wind farms in Europe appear to behave differently from the wakes in medium-size onshore wind farms. This difference in behavior is thought to be a result of the relatively low turbulence of the wind offshore, which does not mix up the flow behind a turbine in the same way that happens onshore. Figure A-1 illustrates the wake effect in offshore wind farms. The difference in energy production between upwind and downwind rows of turbines, which can result from this behavior, could easily be of the order of 20 percent, and hence urgent and detailed investigation is required.

FIGURE A-1: ILLUSTRATION OF THE WAKE EFFECT



Source: Vattenfall.

Utilizing proven and certified turbines is essential, particularly for offshore applications, because dealing with even minor problems offshore can be expensive. *International experience indicates that the use of unproven turbines has derailed offshore programs.*

The success of the momentous scale-up of wind power in China is contingent on building a domestic manufacturing base capable of supplying in the quantities and at the level of quality required. The performance and availability of Chinese turbines to date have been poorer than anticipated. In order to avoid large-scale deployment of unreliable turbines, two steps are necessary and urgent:

1. Detailed investigation of the reasons for poor performance to date, likely involving a combination of poor calculation methodology, poor availability of the turbine, and poor quality of design and manufacture
2. Development of an effective quality assurance system at all levels in China, including standards, certification, manufacturing, and R&D.

Experience from Europe suggests that much can be learned from a detailed examination of the turbine difficulties and that the results of such examinations should be made available for proposed detailed investigations.

Based on lessons learned in other countries, several measures are recommended for consideration by Chinese authorities to bring Chinese turbines up to international standards and to meet the scale-up challenge. These measures include the following:

- Exerting some competitive pressure on China's wind manufacturing industry
- Encouraging technical innovation: R&D and leap-frogging to cutting-edge technologies are essential. China should not wait for Western development. The costs for developing new turbines are affordable to large Chinese manufacturers: US\$5 million for design and US\$15 million per prototype per turbine are small, considering the production potential. Scientific investigation of the behavior of prototypes is necessary.
- Developing turbine specifications based on a Chinese wind regime to adapt turbines to "Chinese wind conditions" and reduce cost of development. The design standards that are used by the global industry are based on northern European sites and conditions. The result is that the scale-up is based on

turbines that are not optimized for Chinese site conditions, especially the WPBs. In the latter case, such an approach is unsustainable because the costs of using under- or overdesigned turbines are huge.

- Upgrading and/or designing new turbines to make them more grid friendly. Turbines should be able to control the power factor and provide fault-ride-through capability.
- Providing government support to develop domestic turbines with a capacity of more than 4 MW for eventual offshore deployment.

The importance of detailed and accurate wind measurements cannot be overemphasized. Such data are absolutely vital for accurate determination of the energy production from a wind farm, both on- and offshore.

Principle 3: Providing Regulatory Clarity, Stability, and Adequate Incentives

The Renewable Energy Law and subsequent rules and regulations gradually built a pragmatic regulatory framework for the development of wind power. The framework is based essentially on (a) a renewable energy obligation or "mandated market share" (except hydropower) for both the energy producers and the grid, referred to in China as the "renewable energy quota system"; (b) a concession system for wind power requiring price bidding for all wind farms with a capacity equal to or more than 50 MW; and (c) subsidies from a Renewable Energy Fund, sustained through a national surcharge on electricity prices, which was set as 0.2 fen/kWh in 2009.

The regulatory framework triggered China's unmatched growth in yearly installed onshore capacity. However, it may be timely to evaluate and fine-tune the concession system to ensure greater efficiency than experienced in the early stages of the program to increase clarity and ensure consistency of the price bidding with the performance-based subsidy.

Given the relative novelty of the offshore wind development program in China, the regulatory framework is yet to be built. This is understandable, since certain areas of the regulatory regimes of most of the countries that have embarked or are embarking on offshore programs are considered inappropriate. This theme is of particular importance in the area of consenting, where in many cases existing legislation designed to regulate other activities, such as oil and gas exploitation or shipping,

has been applied to offshore wind power activities. This approach could become a significant barrier to offshore wind deployment and lead to a complex and uncertain consenting route, higher project costs, delays, and ultimately potential failures. *Clear decisions about the appropriate legal framework in advance of any substantial projects are vital.*

It is therefore recommended that the government develop an appropriate legislative framework that is targeted specifically at the promotion of offshore wind. These wind projects are set to be a major part of the offshore economy and hence, for the long term, it is not sensible to try to fit them into existing legislation, but rather to create the appropriate legislation directly.

Regulation change, complexity, and excessive red tape can damage the confidence of investors, as experienced in many countries. For example, instability in the incentive framework in the Netherlands has been identified as a major issue in that national market. *Higher-level, clear, and stable regulatory requirements, incentives, and government support are required at the early stage of offshore wind power development.*

Different measures have been used to give developers an incentive to build offshore wind farms. These have ranged from tradable green credits (renewable obligation certificates, or ROCs, in the United Kingdom) through prices determined by competitive tenders (Denmark) to feed-in tariff structures that will be used to encourage German developers. The Spanish government, which has had a major success with its onshore wind farm promotional activities, but has yet to start commercial offshore operation, has undertaken a review of the tariff structures and opted for a bidding process. *It is recommended that China follow a similar approach with a fixed price paid per megawatt-hour for the energy produced, but competitive bids would be submitted for each development.*

Principle 4: Availability of Skilled Staff for Design, Construction, and O&M

China's wind energy aspirations can be met only through substantial development of expertise in engineering, construction, and O&M. Developing human resources for the envisaged scale-up in China is a daunting task. The need for the availability of an appropriate skills mix is equally important in the West, where expansion of the wind energy resource is also limited by the lack of

trained people. Some experts estimate that the use of inadequately trained personnel and poor O&M practices result in 1–2 percent energy losses in U.S. wind farms.

The following are therefore recommended:

- Undertake a strategic assessment of manpower and prepare capacity-building and training programs to upgrade and develop skills at a scale commensurate with the intended scale-up program.
- Leverage available skills by using technology and management systems wisely, for example, by:
 - ◆ Reviewing O&M practices in existing farms and preparing and implementing programs to improve O&M procedures and practices
 - ◆ Using SCADA systems and turbine condition monitoring systems to support predictive maintenance
 - ◆ Centralizing operations for several wind farms to achieve economies of scale.

Principle 5: Getting Grid Planning and Development Right

It is recognized that the variability and limited predictability of wind could affect grid operation, especially if wind power penetration and concentration are high. In many countries, projects, particularly those offshore, have been delayed due to issues relating to grid connection, such as the lack of clarity about technical requirements, or division of responsibilities for grid financing and construction. International experience has been a good resource for planning the operational integration of wind farms. Solutions have been designed and effectively implemented in many countries, leading to increased wind power penetration in many European countries and in some U.S. states. *It must, however, be noted that grid connection and stability issues for gigawatt-scale wind bases, as envisaged in China, have no precedent globally.* China is bound to take the lead on this issue in the following ways:

- Undertaking comprehensive connection studies involving all stakeholders, with special attention to the optimum connection size and connection circuit layout
- Initiating short-term operational forecasting studies and developing short-term forecasting methodologies.

For onshore wind, a new grid code on wind power development is necessary. It should be prepared by the State Grid Corporation in consultation with industry stakeholders. The code would clarify the technical connection requirements for onshore and offshore wind farms and clarify the duties and responsibilities of all concerned parties to minimize the technical uncertainty faced by wind developers.

For offshore wind farms, consideration should be given to providing grid connections free of charge to approved demonstration projects at wind farm voltage and building an offshore wind energy grid by a new agency (or alternatively extending existing grid corporations' responsibilities to offshore).

Desired Outcomes for China's Wind Development Program

Successful implementation of the recommendations and principles above should focus on achieving the following desirable outcomes:

Effective utilization of wind resources by

- Improving wind farm capacity factors and availability
- Ensuring coordinated grid development plans and system operation
- Adequate resource assessment to achieve effective and optimal utilization.

Development of a globally competitive domestic industry through

- Promotion of quality and reliability across the entire spectrum of hardware and components
- Design and development of turbines suited to the Chinese wind regime
- Development of a credible certification system
- Innovation, rather than imitation, to bring China to the technological cutting edge.

Setting up a clear and stable policy framework and performance-based incentives by

- Developing government support and incentives for R&D and risky demonstration projects—particularly offshore
- Providing incentives based on generation output (megawatt-hours) rather than capacity (megawatts).

Achievement of Desired Outcomes in Onshore WPBs, Intertidal, and Offshore

The principles discussed above apply differently to the three components of China's wind power development program, that is, onshore WPB, intertidal, and offshore. Implementation of these principles needs to be tailored to these three components.

Developing WPBs Carefully to Consolidate Onshore Success

Success of envisaged WPBs is contingent upon recognition of their specific and unprecedented technical risks and drawing lessons from drawbacks and problems encountered during the design, construction, and operation phases of past projects. Four areas require special focus during the scale-up:

1. Site layout design philosophy

Optimization is likely to demonstrate that very large quantities of wind power generation will be better installed in a dispersed manner to produce more reliable, cheaper electricity and have a smaller impact on the electrical system. Layout design of wind farms of the envisaged scale requires effort and financial resources to ensure optimal use of resources. Two essential activities should be carried out prior to the important investments in gigawatt-scale wind farms:

- Optimal dispersion study to determine the optimal configuration of the WPB
- Wind tunnel assessment to evaluate turbine concentration in order to optimize dispersion to avoid the wake losses inherent to large sites while ensuring best economies of scale in construction and operation.

2. Electrical integration studies and grid code

Past development of wind power in China has been characterized by a lack of or limited cooperation among concerned agencies. The envisaged scale-up requires improved cooperation, systematic grid connection studies, deployment of grid-friendly turbines, and development of a grid code.

- **Grid connection and integration studies:** Optimization of connection capacity based on expected continuous output, assessment of system reliability issues, loss of generation, and operational regime.

- **Improved wind turbine generator technology:** Use of new generation of turbines with better power factor control and grid fault management capability to reduce disturbances on the grid.
- **Grid code definition:** Based on these assessments, it is important to determine the performance requirements (grid code requirements) that will be imposed on the wind turbines to reduce uncertainty. The looser they are, the greater will be the expense of the transmission system operator (TSO). There is a clear tradeoff between the expense of meeting rigorous requirements imposed on the wind turbines at the turbine level and the expense of meeting the same requirements at the grid level.

3. Wind resource assessment and site selection

This would require developing a reference database and systematic refinement and verification of available data and measurement by

- Comparing historical meteorological data with data from new measurement masts
- Equipping potential sites with an adequate number of measurement masts and collecting data for at least 12–24 months.
- Undertaking wake modeling studies.

4. Turbine choice—R&D

WPBs should be equipped with certified and “commercially proven” turbines adapted to Chinese conditions. This would require the following:

- Defining and adopting Chinese wind turbine specifications
- Improving testing and certification capacity to cope with Chinese wind class definition.

China as a Pioneer in Intertidal Wind Power Development

Development costs in intertidal areas are expected to be lower than medium to deep offshore costs. However, as the pioneer in wind power development in intertidal areas, China needs to learn by doing and innovating. Therefore, demonstration projects could be costlier than expected. The proposed approach is similar to the initiation of offshore development with special focus on systematic collection of geotechnical foundation data and assessment, because constructing foundations on muddy tidal flats and erecting turbines can be very expensive. There is a need to do the following:

- Evaluate foundation types in conjunction with the most efficient construction approach (for example, building an access road and using onshore construction methods or dredging a channel for floating platform access).
- Initiate pilot and demonstration projects.
- Identify two or three intertidal wind farm sites based on adequate geotechnical studies and carry out site-specific measurements for at least 12–24 months.
- Develop the sites efficiently at the 100 MW scale using qualified project developers with an agreed incentive package.

Managing the Risks Related to Going Offshore

Going offshore entails higher costs and risks and therefore requires careful planning and piloting to reap expected gains for China. Two major tasks should be undertaken as soon as possible and their results assessed prior to full-scale development of medium-to-deep offshore programs. They include the preparatory activities to create an enabling environment and demonstration projects. The preparatory activities include at a minimum the following:

- **Defining the legal regime and institutional arrangements:** These should assess current responsibilities and functions of institutions involved in regulating offshore activities and gradually developing a legal and institutional framework that can improve coordination for offshore wind.
- **Addressing grid development and integration issues:** This activity should define appropriate high-voltage connection points and circuits, as well as respective responsibilities, and schedule for development and completion an offshore grid code as an extension of the existing codes and regulations.
- **Developing a database and identifying appropriate sites:** This is particularly crucial for offshore development. This could be achieved through (a) the development of a master GIS that will assemble data on wind speed, undersea and bathymetric data, wave height, and so forth; (b) the initiation of wind speed measurements and computational model studies using a standardized (national) approach in consultation with industry; and (c) requirement of at least 12 months of wind measurements on site prior to preparation of the feasibility study.

- **Determining government support for a two- to three-year program:** This would preferably be done through developing prefeasibility level cost estimates for select projects and determining the level of government support and incentives.

The project demonstration and knowledge building task requires the following:

- **Pilot projects (for immediate development):** Two to four potential sites should be selected and wind measurements conducted for at least 12 months to begin pilot projects. The projects should be in the range of 30–50 MW with approximately 10 turbines. The objective at this stage is to gain knowledge and experience on foundations, logistics, erection, and maintenance. The government support is expected to be higher for these projects.
- **Planning for commercial scale demonstration projects (to be initiated in the second year):** These projects should be more carefully designed and planned with special focus on detailed wind measurements and the layout of wind turbine arrays. At least two projects that can attract developer interest should be considered and strongly supported by the government. These projects should use turbines that have been proven onshore.

Learning from Offshore Demonstration Projects

The aim of initial demonstration is to gain experience in offshore-specific techniques and approach—not to demonstrate turbine technology. Therefore, demonstration projects should do the following:

- Use proven turbines, which may have to be procured outside of China if Chinese manufacturers do not meet specified technical requirements
- Focus on learning techniques in construction and erection, maintenance practices, and cabling rapidly
- Obtain information to improve design methodology.

The aim of commercial-scale demonstration is to build “industrial capabilities” to implement large-scale projects and to operate them efficiently. They should do the following:

- Focus on committed and qualified wind developers with a proven track record
- Develop prototype vessels for the construction and installation of offshore wind turbines
- Develop the supporting industry for foundation construction
- Develop the vessels necessary for regular and reliable access, and establish maintenance practices.

Part B

Implementation Guidance for Offshore and Large-Scale Onshore Wind Power Development in China

By Garrad Hassan and Partners Limited

Summary and Key Recommendations

China has already established a vibrant wind energy industry. Exploitation of China's wind energy resource is included in its 11th Five-Year Plan. In 2009, China is likely to be the largest wind energy market in the world. A few years ago, its presence was scarcely noticeable. There are key decisions to be made over how this resource will be exploited. This part investigates the technical and institutional issues that arise in the three segments of Chinese wind power development program.

- Wind power bases (WPBs)—large-scale onshore wind farms of the order of several gigawatts
- Offshore wind farms—wind farms that are constructed in the ocean
- Intertidal offshore—wind farms that are constructed between the low- and high-tide marks along the shore.

The scale of the proposed development in China is huge and the pace of that development is fast. The purpose of this part of the publication is to learn from experiences in other countries and share those lessons with China, thereby making it possible for China to avoid mistakes made elsewhere or use techniques that have successfully allowed the development of wind energy projects on a large scale.⁴

4. Part B was prepared by Garrad Hassan and Partners Limited. Although this part can be read as a stand-alone piece, it is supported by a rather detailed report entitled, *Regulatory Review of Offshore Wind in Five European Countries* published as a companion to this publication.

Whatever specific technology is used to develop the resource, there are two common risks:

1. The ability of the turbines to deliver reliable power
2. The ability of the grid to transmit and distribute that power.

Ways of addressing each of these issues are discussed in the subsequent sections, covering detailed recommendations for offshore, intertidal, and large-scale onshore wind power development.

Offshore wind, even in the countries where there has been much activity, is still relatively immature. The capital cost per installed megawatt is at least twice that of large-scale onshore wind. In European waters, where most activity has been centered, the winds offshore are significantly higher than the winds onshore. That increased resource does, to some extent, counterbalance the increased capital cost. It is not clear that that will be the case in China. The highest winds appear to be in the inland northern areas. The issue facing Chinese offshore development is therefore different from that encountered in Europe. The cheapest installed capacity and the highest wind speeds are available inland, but they are far from the load, which is centered on the east coast. A crucial step, which the Chinese government must take in order to optimize the use of its wind energy resource, is a detailed calculation of the relative costs of offshore and wind power-based electricity delivered to the load.

Recommendations for Offshore Wind

A Central Agency for Permitting

The novel nature of offshore wind has meant that many different approaches have been used to encourage its development in the different European countries. It has become apparent in all of these countries that there are specific problems raised by the development of wind farms in the sea that are not encountered either by other maritime developments or by onshore wind farms. Much time and effort have been wasted in lengthy and unsuccessful permitting activities. A clear conclusion from the different national activities is that a central agency should be used, at least to gather essential information about all the siting constraints and, preferably, to issue licenses for offshore wind developments. That approach has been successfully followed in Denmark, where the development of an offshore wind farm, once a political decision has been taken to promote this energy source, is a relatively simple matter.

Grid Connection Arrangements

A similar conclusion has been reached about the provision of a grid connection to offshore developments. Again, different models have been followed, but a clear conclusion from international experience is that, given the relatively risky nature of offshore wind development, developers are unlikely to be able to accommodate the large capital cost associated with the grid connection at their own risk. The most successful countries in Europe have therefore decided that the provision of a free grid connection is the correct course to take. Other approaches will be possible once the industry has become more established, and third-party investors may be prepared to operate an offshore grid as a commercial entity in itself. No decision has been made in Europe as to whether it is correct to have the onshore transmission system operator also responsible for the offshore grid. Central provision of the grid connection is necessary.

Fiscal Incentives

Different fiscal measures have been used to incentivize developers to build offshore wind farms. These have ranged from tradeable green credits (ROCs in the United Kingdom) through to feed-in tariff structures in Denmark, which will also be used to encourage the German developers. The Spanish government, which has had major success with its onshore wind farm promotional activities, but has yet to start commercial offshore operation, has undertaken a review of the tariff structures and has decided that it will opt for a bidding process. The proposal

contained in this report is to follow a similar line in which a fixed price would be paid per MWh for the energy produced, but competitive bids would be submitted for each development. Given the high cost of activity offshore, and in line with the discussions above about the provision of grid access, the proposals also suggest that as much background information as possible should be gathered using central funds rather than developers' own funds. This philosophy includes the gathering of wind data and geotechnical and bathymetric data. The approach is to provide the bidders with as detailed a description as possible of the sites in order to allow them to provide the best prices.

Stakeholder Consultation

The use of a central agency to gather data and, preferably, to issue licenses, will also permit the gathering of information about the potential developments and, ultimately, the identification of appropriate sites. It is also strongly recommended that such site selection should be done in conjunction with the commercial developers, since in other jurisdictions it has been found that sites identified by central agencies may not be coincident with those that are preferred by the developers. A strong consultative voice coming from the stakeholders—developers, vessel owners, turbine manufacturers, the grid company—as well as other users of the oceans, will be an important input into the site selection process.

Systematic Site Characterization and Selection

Site selection of offshore wind farms is a time-consuming and expensive process. It is therefore suggested that techno-economic and environmental feasibility for offshore wind be assessed at a national or provincial strategic level prior to the award of any sites for development. The site identification would include competing uses of the ocean, water depth, wave height, grid connection, environmental acceptability, and absence of excessively high winds or waves. Such data would be stored in a central GIS system and be used to identify the appropriate sites that would then be subject to stakeholder discussions as mentioned above.

Strategic Environment Assessment

European experience has demonstrated the importance of undertaking a strategic environment assessment that allows long-term strategic planning for the future use of offshore regions to include offshore wind deployment. A strategic planning tool of this sort can avoid potential stakeholder conflicts and improve the efficiency of grid connections.

Proven Turbines

To achieve the scale that is possible and, indeed, suggested in the five-year plan, it will be essential to use proven turbines. The speed of development that has been witnessed in the onshore part of the market brings with it the risk that the wind farms will simply not work because the turbines have not been adequately proven in advance. Experience in Europe has shown that dealing with a relatively small problem offshore becomes a major issue, although it would scarcely have been noticed if it had occurred in an onshore wind farm. It is therefore very important that the growth of the offshore wind farm development be matched to the maturity of the domestic wind turbines available for that purpose.

Wind Data

A series of offshore masts should be erected and data from them made available to all bidders. Bidders would be able to erect additional masts if they so desire. The importance of detailed and accurate wind measurements cannot be overemphasized. Such data are absolutely vital for accurate determination of the energy production from a wind farm, both on- and offshore.

Demonstration Projects

Some demonstration projects are also recommended. Such projects have proved to be very powerful in the early development of the offshore wind industry in other countries. These projects have been shown to yield three benefits:

1. Lessons about the practical installation of turbines offshore
2. Establishment of the identity of all stakeholders through demonstration
3. Knowledge of the loading environment of the offshore turbines.

It is proposed that these initial projects be quite modest in size, perhaps 10 turbines each, and be executed as rapidly as possible with commissioning programmed for the first half of 2010. It is stressed that these projects are not projects to demonstrate offshore wind turbines; rather, they are projects to demonstrate offshore wind farms. The projects would be partly funded through capital grants. Prototype turbines should not, therefore, be used in these projects. Proven turbines should be used in their place. A successful outcome of such a demonstration project would be the rapid learning of basic lessons concerning access, cabling, construction, and operation, as well as important scientific information that

would allow improvement of design methodology. It is important, therefore, that a strong scientific element be attached to these demonstration projects.

A further set of demonstration projects would follow the initial ones described above, and they would be sized at, say, 100 turbines per project. Again, these projects should not be aimed at turbine development, but rather at wind farm development. They would be undertaken on the basis of the fiscal instruments described above, and the successful outcome would be the development of prototype vessels for the construction and installation of offshore turbines, generation of substantial interest in the supporting industry, provision of foundations and cable laying, and initial experience of commercial offshore wind farms.

Turbine Research and Development

These two steps have been successfully followed in both Denmark and the United Kingdom. In addition to these demonstration projects, there is a series of technology developments that should be undertaken in parallel, mainly aimed at the development of domestic Chinese offshore turbines. An important part of this development is the design and prototype testing of several separate, large, say, 4 MW, turbines. It is suggested that this be done by Chinese industry immediately, and that there is no merit in waiting for the development of Western technology as a steppingstone in this direction. It is considered that the development of the technology in China itself will be required in order for the Chinese resource to be adequately exploited by Chinese industry. Each of these prototype turbines should be accompanied by a scientific investigation of their behavior. It is suggested that the cost per turbine for this design effort and a single prototype test would be US\$20 million.

Infrastructure Research and Development

Turbine activity should be supported by infrastructure research and development, including foundation research and development, special vessel design, and investigation of access solutions. Access for offshore wind farms is an important part of assuring a high level of availability and therefore reliable production.

Physical Grid Connection

The grid connection and the electrical infrastructure remain vital parts of this process, and a detailed evaluation of the grid design and the grid interconnections must be undertaken. European work suggests that some large wind farms located far offshore will be connected using

high-voltage direct current (HVDC) technology. The development of HVDC technology in China is relatively new; hence, it may be sensible to rely on Western technology to develop these tools.

Certification

Various other, essentially scientific, supporting activities are also suggested and, finally, the development of Chinese certification rules for offshore wind farms is recommended.

Recommendations for Intertidal Wind

The intertidal resource is concentrated in the coastal region north of Shanghai. Adequate grid connection for a substantial quantity of wind energy exists in this area; hence, grid connection, at least in terms of capacity, is not an issue. As is the case for all large-scale connections, the interaction with the grid is, of course, important and must be carefully considered. There is no international experience of intertidal development and, hence, lessons cannot be directly learned from elsewhere. The resource in this area is large in geographical area, but the wind speeds are not well known; hence, it is recommended that an immediate measurement campaign be established in order to gain a proper estimate of the wind resource for the intertidal developments. The main engineering tasks are the design and installation of the foundations and, later, the installation of the turbines, given the very soft conditions that are prevalent on these sites. Two approaches are suggested: one is the use of barges and artificially excavated canals using standard dredging techniques, and the other is the use of a large mechanical “crawler style” plant. It is recommended that an initial costing exercise be undertaken of any viable solution and, if that costing exercise produces favorable results, a demonstration project should be constructed.

Recommendations for Wind Power Bases

The initial WPB construction is already under way, and much important data will result from initial experience with the WPBs. Despite the fact that some projects are being built, it is suggested that a rigorous investigation of the optimal dispersion of a 10 GW WPB be undertaken on an urgent basis. There may be considerable advantages both electrically and aerodynamically in dispersing these large projects over a wider area than presently envisaged. Such dispersion will ease the electrical integration

challenges and will increase the efficiency of the wind farms and, hence, improve their economics. Such a study can be undertaken using data from the WPBs themselves and through statistical approaches using measured wind data. The outcome will define the optimal configuration for WPB design in the future.

Grid Connection

The electrical integration of the WPBs is also amenable to analytical treatment. A statistical investigation should be undertaken into the interaction of the WPBs with the local and national grid, thereby allowing a proper specification of the grid upgrades required and also identification of the level of generation support that arises. Recommendations are also provided that describe systematic connection studies that should be undertaken for each of the WPBs.

Grid Code

The technical connection requirements for any form of generation are normally described in a grid code. Depending on the jurisdiction, the grid code may be statutory or it may be advisory. There is a great deal of activity at present under way in Europe concentrating on the development of appropriate grid codes for large-scale connection of wind farms. A clear understanding of these requirements is necessary, from a technical standpoint and from a commercial standpoint. It is strongly advised that concentrated effort should be devoted to the development of an appropriate grid code for the connection of WPBs and, for that matter, offshore projects to the grid. This is an area where very helpful input is available from the various working parties addressing this very issue, in both Europe and the United States.

Grid-Friendly Turbines

Some of the regulatory requirements that may come from the development of a grid code may call for technical innovations in the wind turbines that are not presently available from domestic Chinese manufacturers. It is therefore also suggested that the Chinese manufacturers devote considerable effort to the development of these new facilities, which should make the wind turbines more “grid friendly.” An obvious example of such a quality is a low-voltage ride-through capability and dynamic VAR support. Such facilities are now commonly available from Western suppliers, but are not yet available in China, and will be needed in order to provide satisfactory connections to the grid.

Resource Measurements and Wind Assessment

As with the offshore projects, the importance of proper wind resource assessment is paramount. If poor wind measurements are made, the estimates of energy production will be unreliable and investments will be in jeopardy. To date, adequate measurements have not been made for the large-scale developments in China. The cost of one 2 MW turbine will pay for 100–200 meteorological masts. A 10 percent reduction in the energy production from a 3.8 GW WPB would result in lost revenue equivalent to 1,500 masts every single year. A comprehensive and systematic set of wind measurements is therefore recommended, and specifications are given. It is also recommended that, even when wind farms have been developed, high-quality reference masts should be left in place, so that it will be possible to determine whether the wind farms have actually produced according to their estimates.

Energy Prediction—Wakes

The wakes in large-scale offshore wind farms in Europe appear to behave differently from the wakes in medium-size onshore wind farms. This difference in behavior is thought to be a result of the relatively low turbulence of the wind offshore, which does not mix up the flow behind a turbine in the same way that happens onshore. The difference in energy production, which can result from this behavior, could easily be of the order of 20 percent; hence, urgent and detailed investigation is required. This observation is included here, since it is thought that the WPBs may exhibit a similar behavior. Various courses of action are suggested:

- Build the rows of the WPBs in a progressive manner, allowing measurements to be made on the performance of the WPBs as each row is built.
- Develop a large wind farm using small turbines that can be used for experimental purposes.
- Develop computational techniques to model this effect.

The loss of 10 percent production from a 3.8 GW WPB that receives US\$60/MWh for its energy is equivalent to a loss of US\$60 million per year; therefore, the investment in some R&D activities is very well worthwhile. It is also strongly recommended that detailed measurements on the WPBs be undertaken as a matter of course.

Turbines for Chinese Conditions

The scale of development proposed in the WPBs is huge. The design standards that are used by the global industry are based on northern European site conditions. There is no such thing as “a Chinese site condition.” Rather, there will be a range of site conditions that characterize the different Chinese sites that are being developed. It is clear that some of these will be markedly different from those assumed in the IEC standards. The result is that turbines are being deployed in the WPBs that are not designed to be optimized for the conditions that are found there. Such an outcome is to be expected when volumes are small, but for the volume anticipated for the WPBs, this is an unsustainable position. It is possible that the turbines are underdesigned for some aspects of the site conditions and overdesigned for others. Without detailed investigation of these parameters, it is hard to say what the outcome will be, but it is possible that savings in costs of energy could be of the order of 10–15 percent if proper design parameters are incorporated and the turbines optimized for the conditions.

Short-Term Forecasting

The large-scale integration of wind energy into the grid requires the wind farms to appear as much as possible like conventional power stations. To some extent, this can be done by improvements to the electrical systems, as described above, and to some extent it can be done through the use of “short-term forecasting.” This term is used to describe estimation of hourly power production from wind farms from one hour to one day ahead. Impressive progress has been made in these techniques in Europe, so it is strongly recommended that pilot projects using short-term forecasting for the WPBs be initiated immediately. Experience elsewhere has demonstrated that data from such forecasts can be used to help the transmission system operators take a constructive view of wind farm integration.

Proven Turbines

Ultimately the WPBs will all use domestic Chinese turbines. The performance and availability of these turbines to date have been poorer than anticipated. In order to avoid large-scale deployment of unreliable turbines, various steps are necessary. The turbines can be improved through several routes, and recommendations for each are suggested. The development of a strong and well-informed Chinese certification agency is considered to be an important step. Detailed investigation of the reasons for poor performance to date is suggested: a

combination of poor calculation methodology, poor availability of the turbine, and poor quality of design and manufacture. Experience from Europe suggests that much can be learned from a detailed examination of these difficulties. The data describing them should be made available for such investigations.

Turbine Supply Agreements

The contractual arrangements between developers and manufacturers in China are substantially different from those seen in the West, and suggestions are made as to how those contracts could be improved to pass availability and performance obligations on to the manufacturers.

Operational Data

Evidence from the West is that good operational and load data from a large-scale operating wind farm are of vital importance and, when properly analyzed, can lead to substantial improvements in the performance of wind farms collectively and wind turbines individually. Such data are often kept confidential, so it is recommended that careful thought be given to the availability of these data, so that they can be used for the benefit of the industry as a whole.

Training

The Chinese wind energy aspirations can be met only through substantial development in manufacturing, technology, and people. It is clear that proper infrastructure must be put in place that will deliver the staff that are needed to deliver this potential. This problem is equally important in the West, where expansion of the wind energy resource is also limited by the lack of trained staff. Substantial wind farms in the United States appear to be losing 1–2 percent of their energy as a result of poor O&M practices and, in particular, through the use of inadequately trained staff. It would be surprising if the same thing were not true, perhaps to an even greater degree, in China.

Western Due Diligence

Finally, some specific recommendations are made about the technical and commercial requirements that will be needed if at some stage there is an intention to attract Western finance to the development or ownership of Chinese wind farms.

Detailed Implementation Guidance

Policy Context in China

In order to appreciate the challenges that are being faced by the Chinese wind energy industry, it is useful to understand the level of political commitment that has been provided to wind energy by the Chinese government. A short, broad summary is provided below.

The Outline of the 11th Five-Year Plan for National Economic and Social Development enacted by the 4th Session of the 10th NPC states that “*preferential fiscal, tax, investment and MMS policies to encourage renewable energy production and consumption, and increase the proportion of renewable energy in primary energy consumption*” will be implemented as a priority. The outline points out that upscaling the construction of wind farms encourages wind power industrialization, promotes wind power technical progress, improves local wind power equipment manufacturing capacity, reduces wind power costs, and enhances its market competitiveness.

Priorities for wind power development include the following:

- Fully take advantage of the wind energy resources in northeast China, north China, and northwest China, and build large and very large-scale wind farms.⁵ Construct 30 large-scale wind farms of more than 100 MW and 5 WPBs of 1 GW. Prepare and construct WPBs of 10 GW in Gansu, Inner Mongolia, and along the Jiangsu and Shanghai coast.

5. Large scale, in this context, is greater than 100 MW, and very large is 1 GW and above.

- Take advantage of the relatively well-developed coastal areas in Jiangsu, Shanghai, Fujian, Shandong, and Guangdong to expedite the development and utilization of wind energy resources and construct gigawatt-scale WPBs that connect with each other, especially in Jiangsu and Shanghai coastal areas. The total installation will be more than 1 GW in Jiangsu and Shanghai coastal areas by 2010.
- Construct numerous large-scale 100 MW wind farms in regions with good wind energy resource and power markets.

Specific priorities have also been expressed as follows:

- Support the development of domestic industry to manufacture wind power equipment in combination with large-scale wind farm construction, especially gigawatt-level WPB construction. Assist two domestic wind turbine manufacturers with strong technological innovation capabilities and improve the technical abilities of the domestic technical manufacturing capacity, together with the manufacture of the required spare parts. Establish national test wind farms, and support wind power equipment testing and certification competence.
- Conduct offshore wind power experiments. Construct model offshore wind farms in offshore water, mainly in the Jiangsu, Shanghai, and Guangdong coastal areas to gain experience of offshore wind power investigations, design, construction, installation, and O&M. Gradually develop the technology of offshore wind power equipment based on real experience of offshore wind power operation.

International Context

Wind energy in China is still relatively new. Hence, these major plans and aspirations are all the more startling. In numerical terms, it is useful to note that the total global installed capacity of wind energy is approximately 100 GW and that the new global capacity in 2007 was 20 GW. In 2007 China was the world's second largest market, whereas in 2006 it was the fifth largest. Table B-1 provides some details of the global markets.

Different Development Approaches

Although the policy statements above addressed just on- and offshore development, it is helpful to divide the proposed Chinese activities into three segments:

1. Onshore (WPB)
2. Offshore
3. Intertidal.

The terms *onshore* and *offshore* are well understood. *Intertidal* requires some explanation. The intertidal category, which has not occurred elsewhere in the world, is the development of regions along the coast where there is a large area inside the tidal range. It is *not* an extension of the offshore activity; rather, it has characteristics of its own. The soil conditions in these areas are likely to be "muddy." Hence, foundations may be difficult. There is a range of soil conditions along the shore, and proper characterization of them will be an important part of assessing the viability of the sites. There is no precedent for this type of development elsewhere that can be used directly to help inform the development of these projects. There are, however, probably some similar locations elsewhere in the world, for example, in Gujarat in India where the Chinese experience could be applied if it is successful.

These three types of development have different qualities. The best wind regimes are those found inland in the northeast and northwest of the country. However, the main electrical load is in the east along the coast. The intertidal sites and the offshore sites are therefore closer to the load. The capital cost of construction of the offshore sites and probably the intertidal sites will be higher than that of the WPB sites. The delivery of the energy from the WPB sites will, however, be much more costly than the delivery of the energy from the other two types, since transmission over a very long distance is required. An important determinant of the cost of energy delivered

TABLE B-1: RELATIVE SIZE OF INTERNATIONAL MARKETS

| | New MW in 2006 | New MW in 2007 | New MW in 2008 |
|---------------|----------------|----------------|----------------|
| United States | 2,454 | 5,244 | 8,358 |
| China | 1,347 | 3,304 | 6,300 |
| Spain | 1,587 | 3,522 | 1,609 |
| Germany | 2,233 | 1,667 | 1,665 |
| India | 1,840 | 1,575 | 1,800 |

Source: Global Wind Energy Council (2006, 2007, 2009).

will be the wind speeds available on the sites—and they are not yet well established. Proper assessment of the wind speeds, particularly offshore and in the intertidal zones, is vital for appropriate selection of the category of sites to be developed.

Figure B-1 illustrates the geographic distribution of priority areas for WPB, intertidal, and offshore development in China. Published estimates of wind speeds in China have been derived from fairly crude computational models. They nevertheless give a broad overview of the resources.⁶ Published estimates indicate that the wind speed offshore increases from north to south. In the south, although the mean wind speed may be higher, there is also the risk of a typhoon; hence, the southernmost offshore sites are not attractive. The likely areas for intertidal development are shown in Figure B-1. Some of the WPB locations are significantly closer to the loads than others, and it is assumed that these will be developed first. The optimal selection will, however, depend not only on distance to the load, but also on the electrical connections available.

If the requirement is to deliver energy at minimum cost to the eastern load, a comparison of cost of energy from the three sources must be made. This comparison is shown in schematic form in Figure B-2. It is stressed that this figure does not present such a comparison; it is simply an illustration. It is suggested that an action should be taken to undertake a detailed investigation of the differences in cost of the various types of development and hence derive the optimum mix.

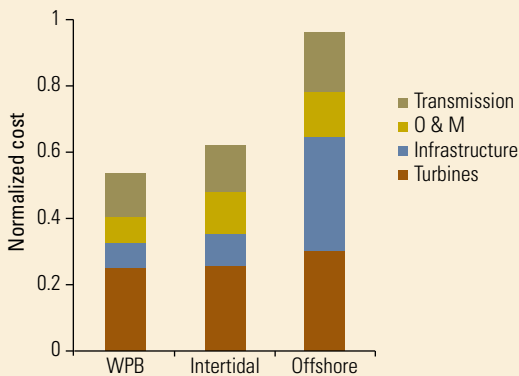
6. Examples of such estimates are available at the UNEP/NREL Solar and Wind Energy Resource Assessment Program Web site at <http://swera.unep.net>.

FIGURE B-1: WIND POWER BASE—INTERTIDAL AND OFFSHORE WIND FARM SITES



Source: Garrad Hassan and Partners Limited.

FIGURE B-2: SCHEMATIC REPRESENTATION OF COMPARATIVE COST OF THE THREE SOURCES OF WIND-GENERATED ELECTRICITY DELIVERED TO THE LOAD



Source: Garrad Hassan and Partners Limited.

An important question is therefore why China should develop the more expensive offshore resource when it has plenty of good onshore sites. The answer lies in the total cost of energy, including the wind resource, the capital cost, and the transmission.

Importance of Sustained Strong Political Commitment

A prerequisite for a successful offshore wind market is a good level of support from government. Such support is important for renewables as a whole but, given the relatively risky nature of offshore wind, it is particularly important in this area. This requirement, to a large degree, is beyond the control of any particular industry as the attitude of an administration will be shaped by broader policy and strategic objectives.

Effective industrial coordination and lobbying can play an important role in specific regulatory issues, but in the absence of genuine political ambition to deploy renewable energy and specifically offshore wind, little progress can be made. The situation in the Netherlands best exemplifies negative experience in this regard, whereas political support for offshore wind in Denmark, Germany, and the United Kingdom is considered strong.

Offshore wind energy is more expensive than onshore wind energy and is almost certain to remain so. In some crowded countries, for example, in northern Europe, offshore wind energy may be the only way in which very large-scale wind energy production can be introduced

into the national energy mix. In other countries, such as in southern Europe, the United States, and China, where onshore space is much more freely available, the onshore option is likely to remain the most competitive, even at a very large scale. Even in crowded countries, it has been necessary to introduce specific measures for the encouragement of offshore wind to ensure that offshore wind energy development is not simply left until all the onshore capacity has been used up. Moreover, in most European countries, the wind speeds offshore are higher than the wind speeds found in the majority of the wind farm sites onshore. Hence, the improved resource offshore helps to offset the additional capital costs associated with going offshore a little. In China it seems that this characteristic is unlikely since there are plenty of very energetic onshore sites with a lot of space, and the argument of increased energy density will not hold up.

Because pure economic pressures are unlikely to be sufficient to precipitate large-scale activity offshore, specific political measures will be needed to encourage development. Offshore wind development requires both significant capital and technical resources. In order to mobilize these two key ingredients, investors must have confidence in the political commitment of the government.

The targets and policies put in place must contain a clear, long-term commitment. Substantial industrial investment is needed to reduce the costs of offshore development. Without long-term commitment from the government, it will be difficult to justify the capital investment needed, and offshore wind will remain unnecessarily expensive or will not be developed at all. China appears to be ahead of other countries in this respect, as shown in the introductory discussion. Gaining experience at a moderate scale now will put China in a good position to develop large-scale projects when required—either in the immediate future or a little later. Once large-enough Chinese domestic turbines are available and have been proven on land or in near-shore applications, China will have the option to omit the intermediate stage and move straight to large-scale deployment.

That commitment to offshore wind energy must be clearly demonstrated in order to kickstart the industry.

The Way Forward

This section of Part B summarizes some basic questions about the philosophy of wind energy exploitation in China.

Parallel Development of the Three Segments

In order to optimize the exploitation of China's wind potential, the key task, as described above, is to determine the relative cost from the three different types of development. Essentially it is necessary to balance good wind resource, low capital cost, and high transmission costs (the WPBs) against higher capital cost, probably poorer wind resources, and lower transmission costs (offshore and intertidal). In order to determine the minimum cost of each approach and hence the optimum mix, considerable detail will be needed about each one. It is therefore necessary to develop all three strands in parallel—it does not make sense to explore them sequentially. Full-scale exploitation may, however, be sequential.

Grid

The aspirations expressed in the 11th Five-Year Plan mean that large-scale grid reinforcement and extension are required. It has been assumed that funds will be made available for such activity. Rigorous investigation and substantial capital expenditure are needed to realize these aspirations, and rapid deployment of resources will be needed to keep up with the installation of turbines.

Wind Speed Assessment

The importance of good wind speeds cannot be over-emphasized. A change in annual mean wind speed from 6.5 m/s to 9 m/s produces twice as much energy. There are WPB sites with mean wind speeds in the region of 9 m/s. The intertidal values are not yet accurately known but they are likely to be in the region of 7–7.5 m/s. Offshore speeds may be higher than intertidal.

However undesirable it may be, all engineering problems can be corrected through additional expenditure. Poor wind resource assessment and energy estimation cannot. There should therefore be a general improvement in the quality and quantity of wind measurement assessment both on- and offshore. The huge investments envisaged can easily be undermined by poor performance resulting from inadequate wind speed assessments.

Offshore

China is fortunate to have abundant wind resources and large amounts of land available to exploit it. Although useful lessons can be learned technically and institutionally from European experience, in resource terms it is sensible to compare China not to any particular European country, since each country is so small, but to Europe as a whole or to the United States. Looking at Europe and

the United States, there has been little or no offshore development compared to the level of onshore activity. Onshore development is and will always remain easier than offshore. The capital cost of offshore development is at least twice that of onshore. Offshore O&M costs are higher (perhaps three times) and accessibility, which is not a problem onshore, becomes a major issue.

It will be necessary to decide whether China will encourage the participation of foreign investors in offshore wind. Offshore wind is an international business, albeit with the majority of important players located in Europe. However, specific capabilities in project development and management and construction are not evenly distributed through the active markets. Significant benefits can be accrued through the opening of national markets to foreign companies with the specific skills required to deliver offshore wind projects. The prominence of Danish utility, DONG, in the UK market is an example of how such openness can accelerate deployment. Changes will have to be made to the regulatory and commercial structure if foreign investors are to be attracted. At present Chinese projects are not “bankable” in Western terms.

Rapid Deployment versus Reliable Turbines

Rapid deployment of offshore wind farms and WPBs will be dangerous in terms of availability. Experience in Europe has shown that turbine reliability can be improved much faster onshore than offshore and nothing additional is learned by experiencing these problems offshore for the first time. The government must decide on its policy of rapid deployment versus effective deployment. What will be gained by large numbers of unreliable turbines being deployed either in the WPBs, or worse, offshore? Proven turbines are needed for both approaches. The severity of a problem when it occurs offshore is, of course, much greater than when it occurs onshore. It is a mistake to put in jeopardy the offshore potential by premature turbine deployment whereby the initial offshore wind farms look unnecessarily unreliable. There has been much criticism of the early offshore wind farms from wind energy detractors that could have been avoided if deployment had been delayed. Turbines should be thoroughly demonstrated onshore and achieve a high level of reliability before they are deployed offshore.

Minimum-Cost Electricity— Increased Government Expenditure

It has been assumed that the goal is minimum-cost electricity. This assumption has resulted in the recommendation that a bidding process will be needed offshore and, in order to deliver minimum cost, much information

and infrastructure will be delivered at government cost. The approach described will likely lead to minimum cost electricity generated from the wind farms. It will, however, require substantial capital cost expended by government or a government agency. Other approaches are, of course, available in which the cost of all aspects of the development are left to the market. Whatever approach is adopted, international experience has demonstrated time and time again that an effective incentive must encourage good operation, not rapid deployment. That is, it should encourage megawatt-hours generated, not megawatts installed.

Demonstration Projects

In the spirit of accelerating development and minimizing mature production cost, it is suggested that China undertake offshore demonstration projects, provided that reliable turbines are available for use that have been proven onshore. Once these demonstration projects have been completed, China could then leap over the other intermediate steps and develop large-scale solutions.

Development of Chinese Turbines and Science

It is not recommended that China wait for the development of Western offshore wind turbines. It is noted that various Chinese manufacturers are frustrated by the low level of technology transfer that has been achieved for onshore turbines. The same situation is likely to arise offshore. If China wishes to be in a position to exploit its offshore potential, it must start the development of the large turbines now. For offshore applications, and for the WPBs, it is vital that detailed scientific tasks be undertaken in parallel with the manufacture and installation. It has been assumed that development of a Chinese technology base is an essential part of the process and, if that is the case, then serious scientific investigations and associated investment are required. The rapid deployment of technology that is not understood and cannot be improved by Chinese companies is not a tenable approach.

Given the huge Chinese market, considerable pressure should be applied to the manufacturers to develop turbines optimized for the Chinese conditions. This task will require investment but will lead to improved performance and reduced cost. The philosophy should be Chinese designs for Chinese applications.

Roadmap for Offshore Wind Power Development

This section provides a roadmap for offshore and intertidal wind power development in China, and builds on international experience in wind power development.⁷ The recommendations provided in the roadmap draw on lessons learned from international experience and suggest a set of actions to allow the efficient promotion of offshore wind energy in China. The actions include regulatory issues, installation and construction issues, R&D, and industrial capacity. In each case, examples of experience are provided and then suggested actions are identified. These various actions are also provided in a summary graphical form—a roadmap for the various groups of actions listed below. It is anticipated that if China follows this roadmap, it will avoid many of the problems that have already been encountered elsewhere in the world in the initial steps toward commercial offshore wind energy activity.

Background on International Experience with Offshore Wind

Before presenting the roadmap, some general background information about the offshore wind industry is provided. This industry is still relatively new even in the countries where there has been significant action. To date the developments have been limited to northern Europe, with major activity in Denmark and the United Kingdom. Other active countries are the Netherlands and Sweden.

7. Extensive coverage of international experience in offshore wind power development is available in the report on *Regulatory Review of Offshore Wind in Five European Countries*, which was issued as a companion to this publication. This publication builds on the lessons and analysis recorded in that report.

The development of national markets has been highly varied in terms of structure and results. This is partly a result of a lack of industry maturity, but perhaps more important are differences driven by national policy objectives and existing legislative arrangements. This section provides an overview of the historic development, current status, and future prospects of the offshore wind market in general.

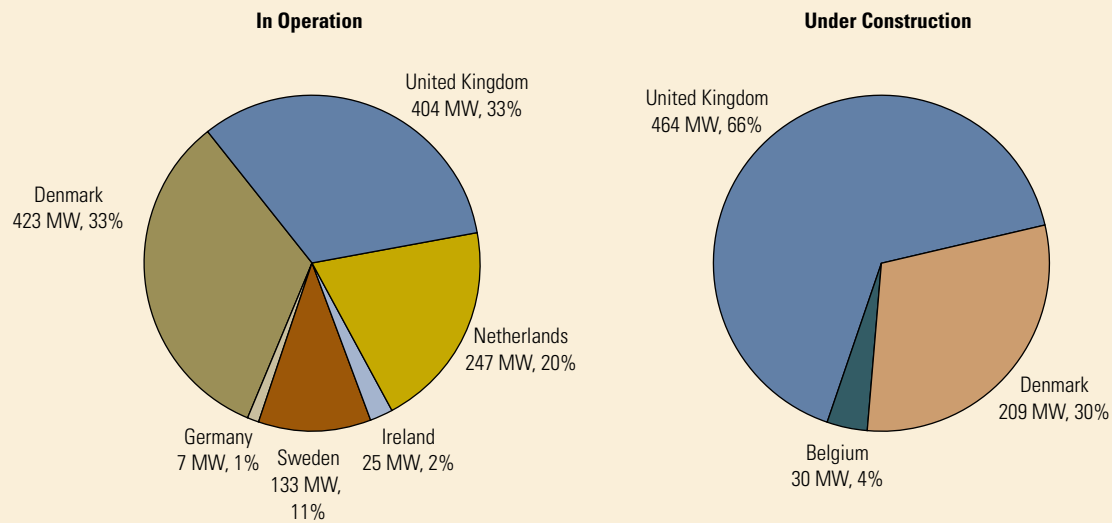
A total of 1,240 MW of offshore wind farms are currently in operation around the world, with a further 704 MW under construction at the time of writing. Figure B-3 presents a breakdown of these totals by national market.

With the exception of a small demonstration project in Japan, all offshore wind projects built to date or currently in construction are located in Europe, as shown in Figure B-4.

Offshore wind projects constructed to date can be categorized into two groups corresponding to two sequential phases of industry development—R&D and demonstration. Today the first quasi-commercial projects are being contracted ready for construction over the coming years. As evidenced by Figure B-5, this industry is currently undergoing a period of rapid growth. The majority of construction is taking place in the United Kingdom.

From R&D to Demonstration

The first offshore deployment of a wind turbine took place at Nordersund, Sweden, in 1990. Over the next decade, a series of R&D deployments followed in Denmark, Sweden, the Netherlands, and the United Kingdom that were largely publicly funded with significant academic involvement. This phase ended perhaps in 2002 with the

FIGURE B-3: WORLD OFFSHORE WIND INSTALLED CAPACITY, JUNE 2008

Source: Garrad Hassan and Partners Limited.

construction of the 160 MW Horns Rev offshore wind project, which constituted a major ramp-up in the scale of deployment, with the previous largest offshore project being 40 MW.

The demonstration phase has continued since then, with a significant further deployment in Denmark (Nysted—166 MW) followed by several projects in the United Kingdom. These demonstration projects can be categorized as being funded primarily commercially with some level of capital and revenue support from government. Figure B-5 clearly shows the transition between these phases in 1999 to 2001.

FIGURE B-4: LOCATION OF EUROPEAN OFFSHORE WIND PROJECTS, JUNE 2008

Source: Garrad Hassan and Partners Limited.

A False Dawn

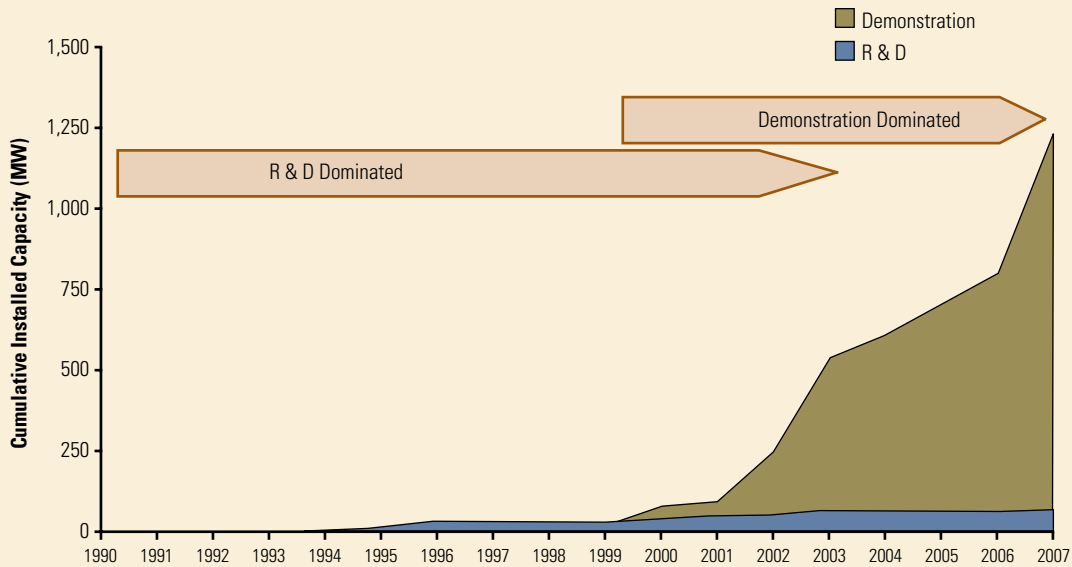
Following what may be described as the “Danish surge” in the early years of this decade, consisting of the demonstration projects at Horns Rev and Nysted, the growth rate of the industry slowed substantially for the three-year period from 2004 to 2006, with just one project completed in each of these years—all in the United Kingdom (Scroby Sands, Kentish Flats, and Barrow). Since then, construction momentum has recovered thanks largely to renewed activity in the Netherlands and Sweden, which has augmented ongoing efforts in the United Kingdom.

It is noteworthy that, despite the strong growth rate currently exhibited, the offshore wind industry was widely anticipated to deliver substantially greater installed capacities in the years 2004–06. As recently as 2005, the total installed capacity for offshore wind by the end of 2007 was predicted by BTM Consult, a leading industry analyst, to be 3.6 GW, whereas the actual total was only about one-third of this figure.

There are three main reasons for this false dawn:

1. With the benefit of hindsight, offshore growth projections since 2000 have been optimistic primarily because of an overestimation of learning effects and associated cost reductions.
2. Since the early demonstration projects, costs have in fact increased, which has meant that many marginally economic sites have become infeasible under current conditions.

FIGURE B-5: CUMULATIVE OFFSHORE WIND CAPACITY SINCE 1990



Source: Garrad Hassan and Partners Limited.

- Wind turbine manufacturers have stopped offering Engineering Procurement Construction (EPC)⁸ contracts for offshore wind farms, forcing developers to take on more technical and commercial risks within a multicontract framework, and offshore contractors have yet to step in to fill this void. The latter point is related to the mixed early project experience, which is discussed further below and has led to the lengthy delay of many of the more advanced offshore wind projects while contracts were renegotiated.

Rising Costs

Figure B-6, based on published cost data, illustrates the unanticipated upward trend in offshore project capital costs.

There are four principal reasons for this trend:

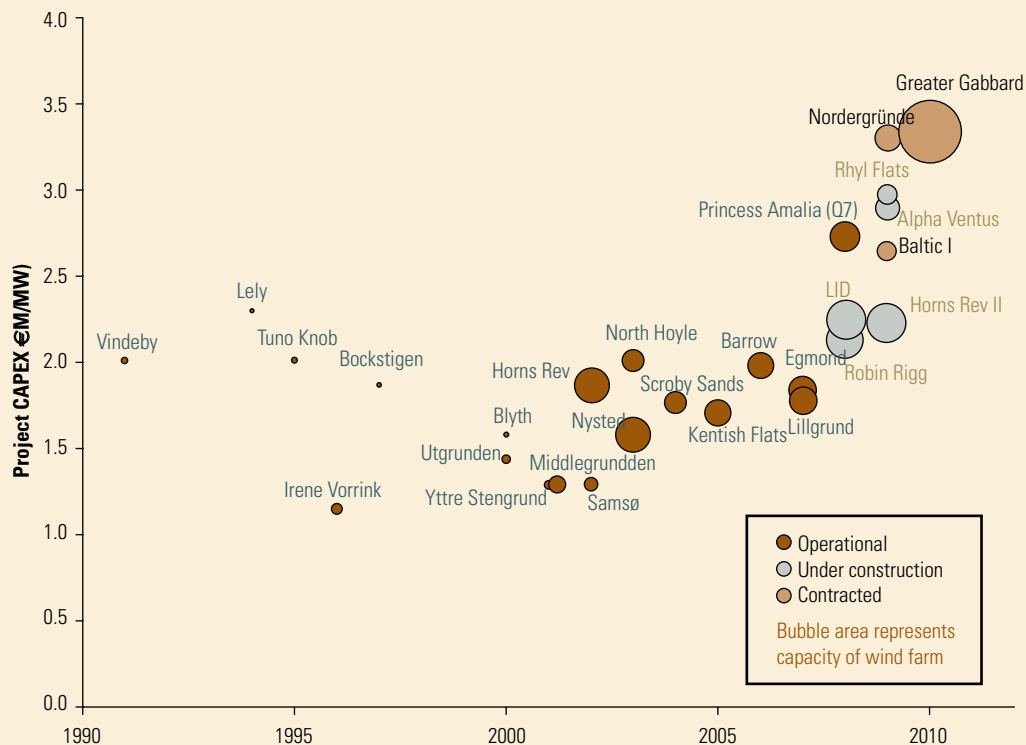
- High early competition and losses.** The initial high degree of optimism in the future for offshore wind led to fierce competition between turbine manufacturers and installation contractors for the early demonstration phase projects. In an attempt to establish a good market position, optimistically low

EPC contract prices were offered. Be it the result of a deliberate policy of “loss-leading” or inadvertent cost optimism, the principal contractors unlikely turned a profit on these early contracts. This result has subsequently led to somewhat of a backlash—with contractors readjusting tender prices to ensure profit margins are met.

- Wind turbine market.** Since 2005 there has been a significant rise in turbine prices for both onshore and offshore wind projects. This has been to a large extent the result of supply not keeping up with demand, leading to low competition. In particular, shortages of key wind turbine subcomponents, such as gears, large bearings, transformers, castings, forgings, and carbon fiber, have limited the supply capacity growth rate in the face of steeply increasing demand.
- Offshore wind turbine market.** Currently, the market for offshore wind turbines is largely coincident with that for onshore projects in terms of both products and players. Given the additional risks associated with supplying machines offshore and the high demand for turbines onshore, manufacturers currently have a limited incentive to bid competitively for supply contracts to offshore wind projects. If the choice is between 250 MW in the North Sea and Texas, the choice of Texas is clear!

8. Engineering Procurement Construction: Used to imply a single point of responsibility to deliver a turnkey project.

FIGURE B-6: PUBLISHED CAPITAL COSTS FOR OFFSHORE WIND PROJECTS



Source: Garrad Hassan and Partners Limited.

- 4. Balance of plant (BOP)⁹ supply chains.** Certain balance-of-plant items and equipment required for offshore wind projects are currently in short supply. Of particular note are installation vessels, subsea cables, and project transformers. This shortage has led to low competition and high prices in specific parts of the BOP supply chain.

All of these causes may be mitigated over the next few years through market forces redressing imbalances in the supply chain and, of course, now the “credit crunch.” In addition, a true bifurcation in wind turbine design is likely to be required, which will result in offshore-specific products and, to a greater or lesser extent, supply chains. This will allow the establishment of a separate offshore wind market, which is not subject to overwhelming supply competition from the onshore wind industry. Both of these mitigating factors are likely to require additional governmental support if they are to gain enough momentum to achieve a substantive impact. It is clear that the supply constraints took place before there was any substantial manufacturing capacity in China.

9. Balance of plant: Project elements other than the turbine.

The Future—Sink or Swim

Following the first two phases of industry development outlined above (R&D and demonstration-dominated), it can be seen that a third phase is emerging that may be termed as commercial expansion. Such projects will be those that benefit from some form of revenue support, but are not eligible for capital support. The UK Round 2 and German Pilot Projects may be considered the first to be built in this third phase, although it is notable that both are likely to be subject to increased levels of revenue support in the absence of the anticipated downward cost trend for offshore wind technology, so that in fact, this transition is perhaps somewhat arbitrary. A more notable difference between Phase 2 (demonstration) and Phase 3 (commercial) projects is likely to be their scale, with the latter typically reaching an installed capacity of several hundred megawatts.

New markets for offshore wind are likely to reach a level of commercial viability and regulatory maturity within the next decade. In Europe, these are likely to include France and Spain, where recent legislative and policy changes indicate some degree of potential for significant

deployment. Beyond Europe, prospects are currently unclear, although there has been significant, albeit nascent or sporadic, offshore wind project development activity in the United States, Canada, Korea, Taiwan, and China as evidenced by this report. However, unless there is substantial activity in China, it is considered likely that the vast majority of new offshore wind projects to come online in the next decade will be built in Europe, with the majority of these being established in UK or German waters.

Another possibility in the coming years is the reemergence of EPC contracting with the entrance of specialist contractors prepared to target project management risk as a means of generating profit. All other things being equal, this is likely to have the effect of increasing project prices as interface and management risk is passed from owner to contractor. However, this may enable owners to realize their offshore project pipeline more quickly, since they will not have to manage such risks in-house.

The potential is good for reduction in project costs through technical innovation. Several areas may be targeted on this front, including wind turbine design and installation methods. Some evidence of the former has surfaced with the emergence of a limited number of new offshore-specific wind turbine designs and manufacturers. In addition, technology demonstration projects, such as Beatrice in the United Kingdom and Alpha Ventus in Germany, for deeper-water development are designed to accelerate the deployment of new approaches to design and installation and have the potential to make a significant contribution in this regard.

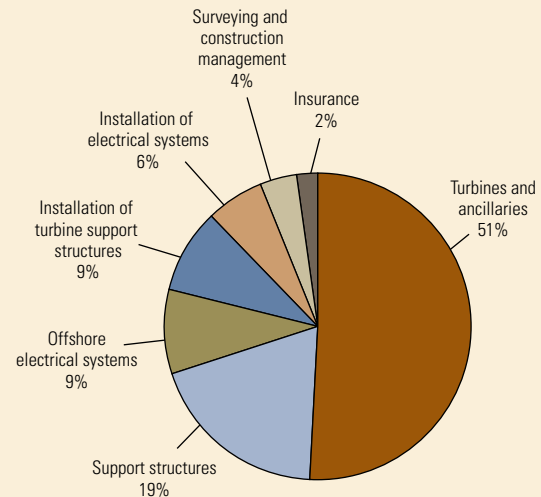
Finally, it is anticipated that an increased level of competition will develop within certain parts of the project supply chain with new entrants and equipment coming online as the industry gathers momentum. This would only happen if a consistent market is developed that is free from the stop-start characteristics that have existed to date.

Technical Parameters for Offshore Wind Farms

This section provides an overview of technical considerations involved in the development, construction, and installation of offshore wind farms. A detailed description of the construction of offshore wind farms is provided in Annex B-1. Figure B-7 illustrates the breakdown of capital costs for developing a typical offshore wind farm.

The same does not apply to the foundations of the turbines.

FIGURE B-7: BREAKDOWN OF OFFSHORE WIND FARM CAPITAL COSTS



Source: Garrad Hassan and Partners Limited.

Figure B-8 shows the range of foundation options that are available for offshore wind farms.

Turbines

Turbines that can be used for an offshore wind farm are the same as those used for an onshore wind farm. They must be maritized, but otherwise the principle of operation is unaltered. In practice, however, the economics dictate that they should be larger in order to reduce infrastructure cost. The infrastructure cost is a much larger proportion of the total capital cost for an offshore wind farm than for an onshore wind farm. Figure B-7 shows the cost breakdown for an offshore wind farm. For an onshore wind farm, the turbine is typically 75 percent of the total capital cost.

Foundations

Table B-2 provides a list of operational wind farms and the foundation solutions that have been used in each. It is clear that in reasonably shallow water (<20 m) monopiles have been the most popular option. However, as the depth increases, it is likely that other solutions will be adopted, as shown schematically in Figure B-8.

Water depth and seabed conditions are the two most important parameters for defining the appropriate foundation. Distance offshore does not play a role in the

TABLE B-2: OFFSHORE FOUNDATION CHOICES

| Location | Date of Commissioning | Distance from Shore (km) | No of turbines | Turbine type & rating | Water depth (m) | Foundation type |
|-------------------------------|-----------------------|--------------------------|----------------|-------------------------|-----------------|------------------|
| Vindeby, Denmark | 1991 | 1.5 > 3.0 | 11 | Bonus 450 kW | 2.5 > 5 | Concrete gravity |
| Lely, Netherlands | 1994 | 1 | 4 | Nedwind 500 kW | | Steel monopile |
| Tuno Knob, Denmark | 1995 | 6 | 10 | Vestas 500 kW | 3 > 5 | Concrete gravity |
| Dronten, Netherlands | 1997 | 0.4 | 28 | Nordtank 600 kW | 5 | Steel monopile |
| Bockstigen, Sweden | 1998 | 4 | 5 | Wind World 500 kW | 6 | Steel monopile |
| Utgrunden, Sweden | 2000 | 8 > 12.5 | 7 | Enron Wind 1,500 kW | 7.2 > 10 | Steel monopile |
| Blyth, United Kingdom | 2000 | 0.5 | 2 | Vestas 1,800 & 2,000 kW | 7.5 | Steel monopile |
| Middlegrunden, Sweden | 2000 | 2 | 20 | Bonus 2,000 kW | 2 > 5 | Concrete gravity |
| Yttre Stengrund Sweden | 2001 | 6 | 5 | Neg Micon 2,000 kW | 9 | Steel monopile |
| Horns Rev, Denmark | 2001 | 17 | 80 | Vestas 2,000 kW | 6.5 > 13.5 | Steel monopile |
| North Hoyle, United Kingdom | 2003 | 7 > 8 | 30 | Vestas 2,000 kW | 10 > 15 | Steel monopile |
| Nysted, Denmark | 2004 | 12 | 72 | Bonus 2.3 MW | 10 | Concrete gravity |
| Arklow Bank, Ireland | 2004 | 14 | 7 | GE 3.6 MW | 5 > 8.5 | Steel monopile |
| Scroby Sands, United Kingdom | 2004 | 2.5 | 30 | Vestas 2 MW | 4 > 12 | Steel monopile |
| Kentish Flats, United Kingdom | 2005 | 12 | 30 | Vestas 3 MW | 5 | Steel monopile |
| Barrow , United Kingdom | 2006 | 8 | 30 | Vestas 3 MW | 20 | Steel monopile |
| OWEZ, Netherlands | 2006 | 10–18 | 36 | Vestas V90 | 22 | Steel monopile |
| Beatrice , United Kingdom | 2007 | 25 | 2 | REpower 5M | 45 | Quadropod |
| Burbo Bank, United Kingdom | 2007 | 6 | 25 | Siemens 3.6 | 8 | Steel monopile |

Source: Garrad Hassan and Partners Limited.

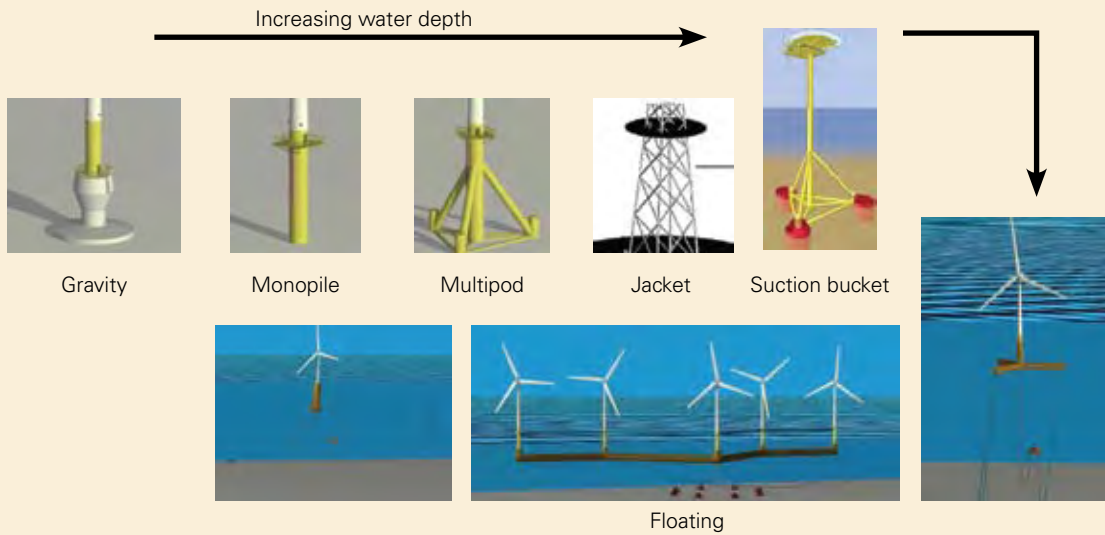
foundation design, but it has an important influence on the electrical design. The transmission system needed to take the energy from the farm to the onshore grid connection can be a major part of the capital cost. It is therefore interesting to consider the range of these two parameters for the wind farms that are being considered by the various European countries. Figure B-9 plots all the operating and the planned offshore wind farms in terms of water depth and distance to shore. It is clear that there are quite strong national differences. For example, the UK wind farms tend to be in shallower water, closer to shore, and the German ones are further offshore and are likely to be in deeper water. It should be noted that, to

date, there is no German offshore wind farm, but many are planned. The reason for this difference of approach is largely the location of Germany's offshore nature conservation areas. The Wattensee (a national park), which follows the North German coastline, has precluded construction near to shore.

Substations

Sometimes the substation is located onshore and sometimes it is located at the wind farm site. For larger wind farms and for wind farms that are far offshore, the substations are likely to be located at the wind farm.

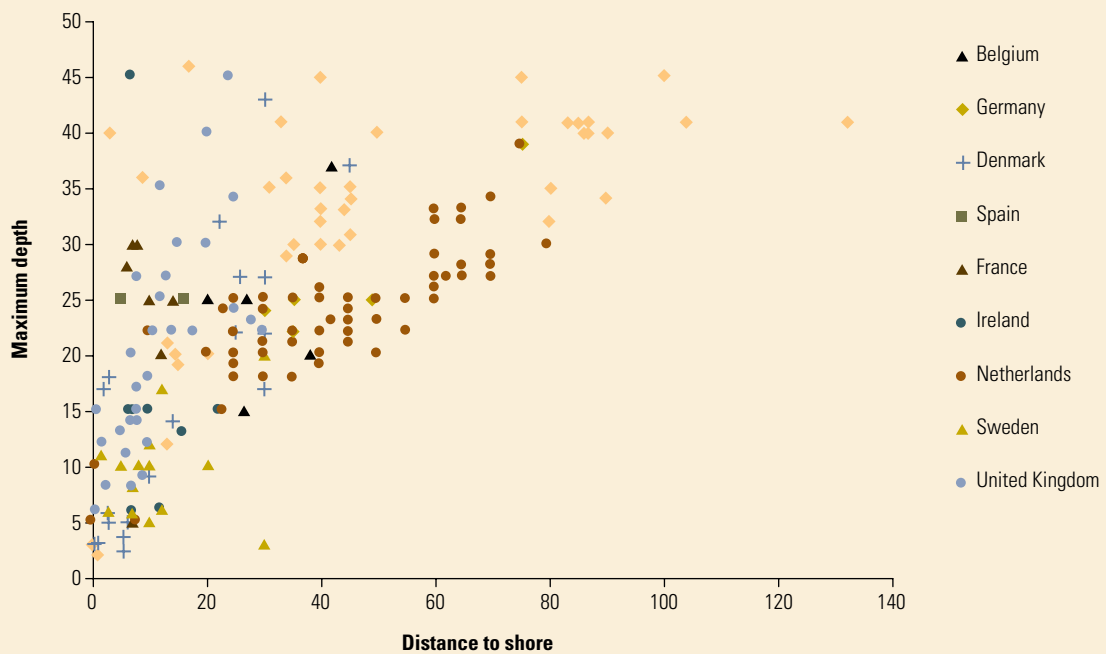
FIGURE B-8: FOUNDATION OPTIONS



- Offshore foundation is determined by the seabed condition and the water depth.
- Currently gravity and monopile are the most frequently used options.

Source: Presentation by Garrad Hassan and Partners Limited.

FIGURE B-9: WATER DEPTH AND DISTANCE OFFSHORE OF EUROPEAN OFFSHORE WIND FARMS



Source: Garrad Hassan and Partners Limited.

Vessels for Construction, Installation, and O&M

Much effort has been devoted to the development of special vessels for the installation of the turbines and the foundations. It is notable that China has been a major supplier of these special vessels.

Availability of wind farms is of great importance whether on- or offshore. Onshore, high availability is regularly achieved in the West, but only through regular attendance at the sites. For the present generation of turbines, good availability is therefore directly related to good accessibility. A minor fault offshore, which would scarcely be noted onshore, can therefore become a major problem simply because of poor access. In recent years considerable R&D resource has been focused on the development of offshore access methods in order to allow maintenance teams to attend faulted turbines.

The Roadmap

The proposed roadmap for the development of offshore wind is described below. The tasks are divided into four groups:

1. Group A: Institutional Tasks
2. Group B: Preparatory Tasks
3. Group C: Demonstration
4. Group D: Underlying Research and Development.

An overall timeline for the tasks is provided in Figure B–10. Some actions do not fit logically on such a timeline.

In each subsection that follows, the tasks are identified based on experience elsewhere and for each of the Groups B, C, and D a separate roadmap illustration is provided.

Group A: Institutional Tasks

Guiding Principle: Ensuring and Maintaining Policy and Regulatory Stability

Changes to government policy and the regulatory regime for offshore wind can cause a loss of financial confidence, delaying investment decisions and, consequently, deployment. Experience in Denmark following the cancellation of four planned offshore wind farms in 2002 can be said to have damaged the confidence of

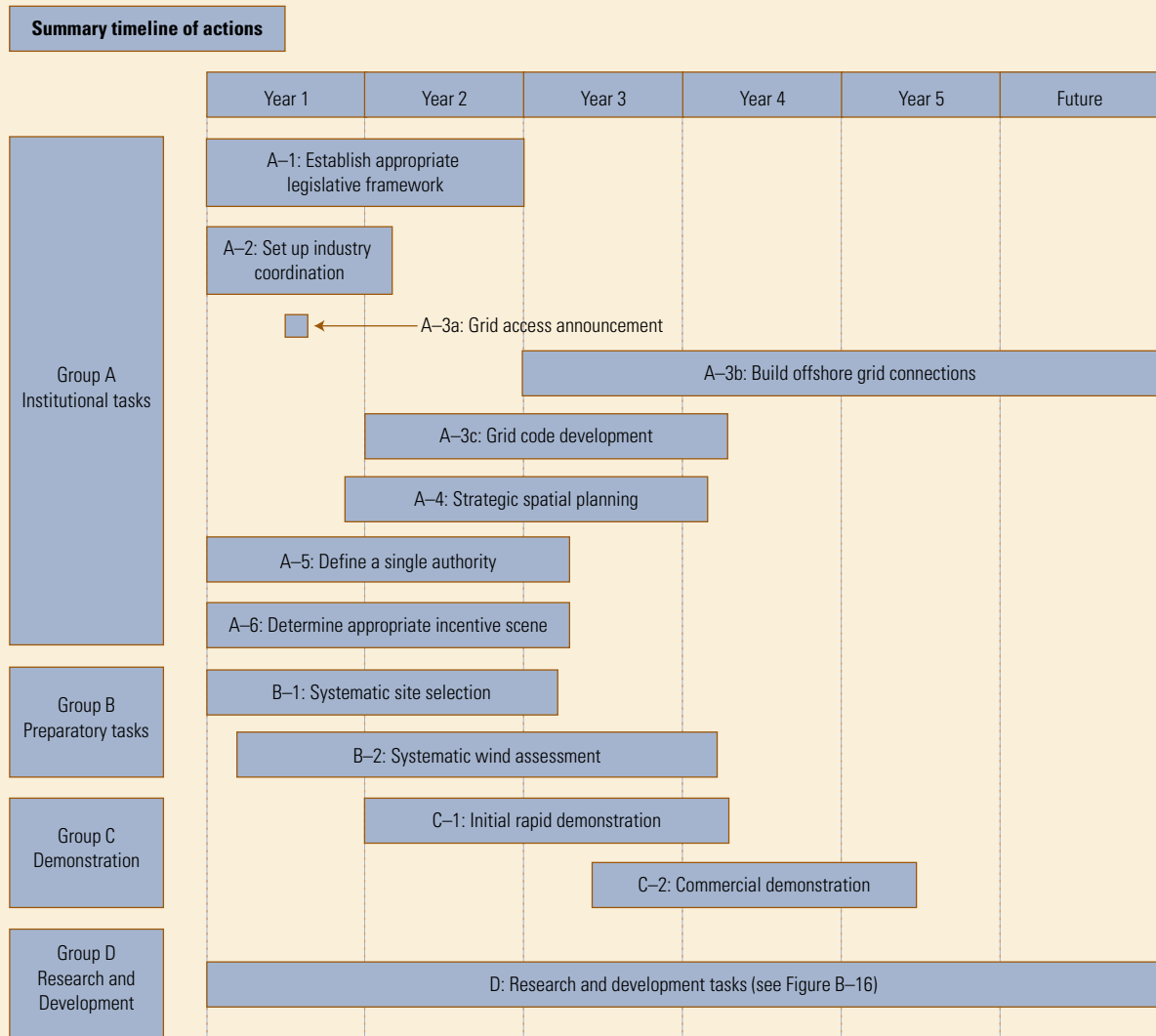
developers in that market from proceeding quickly with sanctioned sites. Instability in the incentive framework in the Netherlands has been identified as a major issue in that national market. Proposed reforms to the incentive regime in the United Kingdom can be considered as unsettling for renewable energy in general, but for offshore wind, the additional revenue support it will create has to be viewed as positive for that technology. Offshore wind energy requires substantial and long-term investment and cannot develop in a regulatory or commercial regime in which the rules are constantly changing. Any non-Chinese investors will be particularly sensitive to this potential problem, but it will also affect the Chinese domestic investors.

Repeated reform of regulations can be avoided if they are well drafted and well consulted in the first instance. New markets for offshore wind should draw heavily on experience in other countries. A stable regulatory regime engenders higher investor confidence. Repeated changes in the regulatory regime have been experienced in all of the active countries and have materially slowed the development of the industry. Appropriate regulatory approaches are suggested elsewhere in this section. Decisions should be taken and a consistent set of rules established for the long term. Long-term and consistent commitment should be made to engender the industrial commitment that is required to develop this industry.

A.1: Establish Appropriate Legislative Frameworks

Given the relative novelty of offshore wind technology, certain areas of the regulatory regime for most of the national markets examined are considered to be inappropriate. This theme is of particular importance in the area of consenting, where in many cases, existing legislation has had to be utilized that was designed to regulate other activities, such as oil and gas exploitation. This approach can lead to a complex and uncertain consenting route that can add to project costs, delays, and potential failures. Where existing legislation is a significant barrier to offshore wind deployment, legal reform is necessary. In some countries there has been much debate over whether, from a regulatory standpoint, an offshore wind farm is an oil and gas platform, a lighthouse, a ship, or a harbor in order to determine the appropriate legal framework. There has also been some debate about whether the projects should be covered by electricity production legislation or shipping/transport legislation. Clear decisions about the appropriate legal framework in advance of any substantial projects are vital. Although this approach

FIGURE B-10: SUMMARY OF TIMELINE OF ACTIONS



Source: Garrad Hassan and Partners Limited.

would be ideal, the actual approach to date has been to adapt offshore oil and gas and shipping legislation to provide the starting point for new wind-specific legislation.

There is a strong argument for considering this matter on a large scale. In Europe it has initially been addressed on a national basis, but efforts are now being made to use a European-wide approach. The same arguments will apply in China and a national rather than a provincial approach may be preferable provided, of course, that it is positive.

The government should construct an appropriate legislative framework that is targeted specifically at the promotion of offshore wind (although it might be sensible, at the same time, to consider the other marine renewables, such as wave and tidal devices). These wind projects are set to be a major part of the offshore economy and hence, for the long term, it is not sensible to try to fit them into existing legislation, but rather to create the appropriate legislation directly. For short-term demonstration projects, a more pragmatic approach may be required.

A.2: Effective Industry Coordination

Offshore wind development can be stifled in the absence of effective industry coordination. In the Netherlands, the wind lobby has been unable effectively to create an incentive for the government to make the changes necessary to accelerate offshore wind deployment. This has been caused in part by the lack of strong and influential industry associations that should be the primary lobbying vehicle for industry. This result is contrasted with experience in Denmark, where a united, and coordinated industry body has effectively lobbied government to bring about the development programs and regularity reforms necessary for a successful offshore wind industry. In the UK, sites suggested for offshore development by the government have not been coincident with those that the commercial developers have identified. A concerted dialogue between the various parties is required for optimum results.

The development of a strong, united, and influential industry voice provides the coordination necessary to deliver a detailed and constructive input to government policy on and regulation of offshore wind deployment. A consultative group made up of the key stakeholders wishing to promote the offshore wind industry should be formed and used to provide detailed regulatory input. Such a group should include turbine manufacturers, wind farm developers, grid operators, offshore infrastructure providers, vessel owners, fabrication yards, consulting engineers, and certification agencies. Input can then be provided to the legislative procedure that will ensure that a viable process is developed.

A.3: Grid Access

Grid access is a significant barrier to deployment in all of the national markets considered. While the detailed reasons for this differ, a general conclusion is that, where the regulation of grid infrastructure is not aligned to national policy objectives with respect to renewable energy, delays in offshore wind deployment are likely. A good example of this can be found in the United Kingdom, where the grid regulator prioritizes protection of consumer rights and is tasked to minimize cost over the delivery of renewable energy for provision of grid connection to offshore wind farms. Various models have emerged. Central supply of a grid connection has been adopted in Germany and Denmark. In these countries the supply of the grid is part of the license for the development of a wind farm. The tariffs are set for delivery at the grid connection point that is at the project site.

In Denmark this approach has led to relatively easy grid connection in a small country used to a high level of central control. In the early stages of offshore wind development this model looks to be the right one to follow. The latest approach in the United Kingdom is to set up an offshore TSO that will build the grid and will be able to operate it on a commercial basis but with a limit placed on its financial rate of return. This operator may be the national operator or it may be another commercial body. It must be properly funded and provided with adequate authority so that it promotes rather than delays installation. It may be that, with strong utility involvement in offshore wind farm development, some developers will find it more attractive to be allowed to build and own the grid. There is an important commercial debate about the technical specifications of these grids: Should they be of a high-redundancy design or should they be of minimum capital cost? If central provision is followed, a very clear specification of the grid will be required so that the developer may make a clear assessment of its production risk. Alternatively, the interconnection agreement between the project and the grid operator must include “take-or-pay” provisions.

There are now some preliminary steps being taken toward the development of a “super grid” specifically for the development of European-wide exploitation of offshore wind energy. Given the large number of different regulatory regimes that are involved in this work, it will make only slow progress. China could adopt the principle of a super grid and promote a Chinese equivalent on a fast track. Also, given the large-scale aspirations of the Chinese wind strategy, such an approach appears attractive, and is also formally the standard approach for onshore projects, although in practice the grid connections are often provided too slowly for the satisfaction of the commercial developers.

ACTION A-3A: GRID ACCESS ANNOUNCEMENT

Access to the grid is a significant barrier to offshore wind energy, unless its regulation is aligned with renewable energy policy objectives, and responsibility for costs and for construction are clearly delineated at an early stage. For countries in which there is a strong central approach to regulation, the central provision of the grid connection as part of the granting of a license for the development of the wind farms has proved successful. The Chinese government should announce its intention to provide the grid connections free of charge.

ACTION A-3B: CONSTRUCTION OF OFFSHORE GRID CONNECTIONS

To accelerate the development of offshore wind and to avoid duplication of effort and to encourage optimum planning, it is suggested that an offshore wind energy grid be planned and built by the central government, and the connections to the wind farms should be offered at the wind farm level. Alternatively, the existing grid company's authority can be extended offshore. It may be appropriate to allow a competent third party to provide the connection, but it must be reliable in both operation and delivery, and the grid must be free of charge to the wind farm developer. The grid company should provide the connection at the wind farm voltage. The grid company should include take-or-pay provisions in the interconnection agreement. The Chinese government is advised to consider the development of an offshore grid intended especially for the development of large-scale offshore wind developments along the lines being discussed in the European Union.

ACTION A-3C: GRID CODE DEVELOPMENT

Incorrect or incomplete understanding of the technical grid connection requirements has caused unnecessary delay and commercial risk. A clear grid code for offshore wind farm connections should be developed by the State Grid Corporation and other stakeholders as necessary. The same grid code can be used for the WPBs.

Further detail on the recommended approach for grid connection and development is available under Task A.6 below.

A.4: Strategic Spatial Planning

Long-term planning for the future use of the marine environment at a national level can play an important role in avoiding conflicts with various user groups while meeting policy objectives on energy. This route has been adopted to the fullest extent in Denmark and to a lesser degree in the United Kingdom and Germany. Such an approach is also a mechanism for avoiding conflicts between various sites and allow for economic grid integration of significant wind capacity. To some degree, the European Union Directive on Strategic Environmental Assessment will enforce this approach (for EU states).

Long-term strategic planning for the future use of offshore regions can improve the prospects for offshore wind deployment through the avoidance of potential stakeholder conflicts and improvement in grid connection efficiency. China should follow the general

guidelines established in the European Union for Strategic Environmental Assessment (SEA) but should try to accelerate the process. The slow execution of the SEAs in the European Union has hindered the development of the offshore wind siting. Clear strategic guidance is required to ensure that the proposed sites meet all the physical planning requirements.

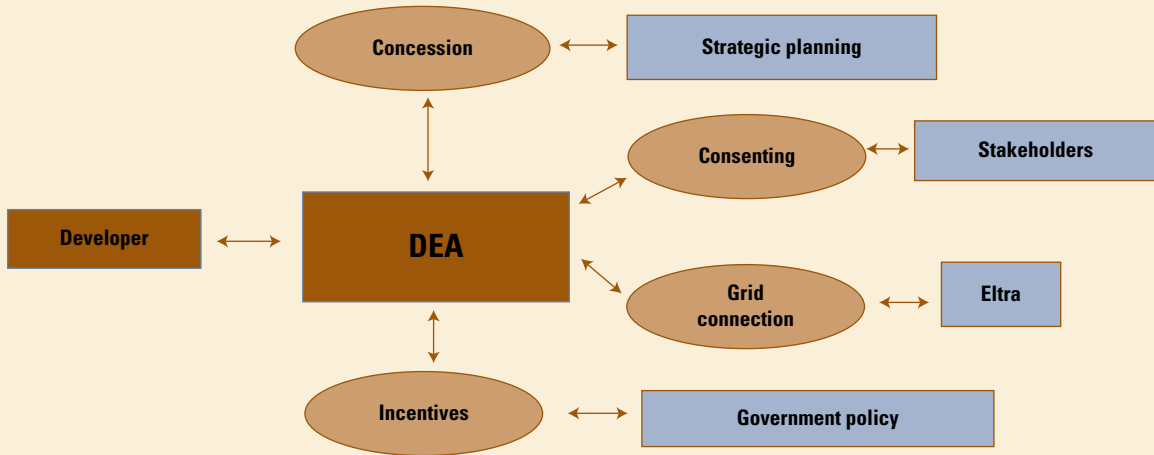
A.5: Establish a Single Authority

Simplification of the regulatory regime for offshore wind provides more clarity for project developers and confidence for potential investors. The channeling of responsibility for the administration of offshore wind through a central agency offers the opportunity for a more efficient system through the reduction of conflict and alignment of strategic policy objectives. Of the national markets reviewed, only Denmark has created such a system, and it has done so perhaps at the expense of industrial control over deployment rates and the location of future sites. Lack of such control seems to be a small price to pay for the rapid and efficient deployment that has resulted. The Danish model is an effective framework to follow in China.

In Denmark, the "one-stop shop" approach has been taken to the extreme, with a single government agency in control of virtually all aspects of offshore wind regulation. More modest success has been achieved in the United Kingdom, where a central coordinating body deals with the majority of the required consents. Figures B-13 and B-14 show the system adopted by Denmark and the system adopted by the United Kingdom. These figures demonstrate graphically how the appointment of the Danish Energy Agency to act as a single authority greatly simplified the Danish approach. It is important to note the location of the "developer" in each of these two diagrams. Under the Danish system (Figure B-11), the developer is fed information, and under the UK system (Figure B-12), the Developer must seek such information.

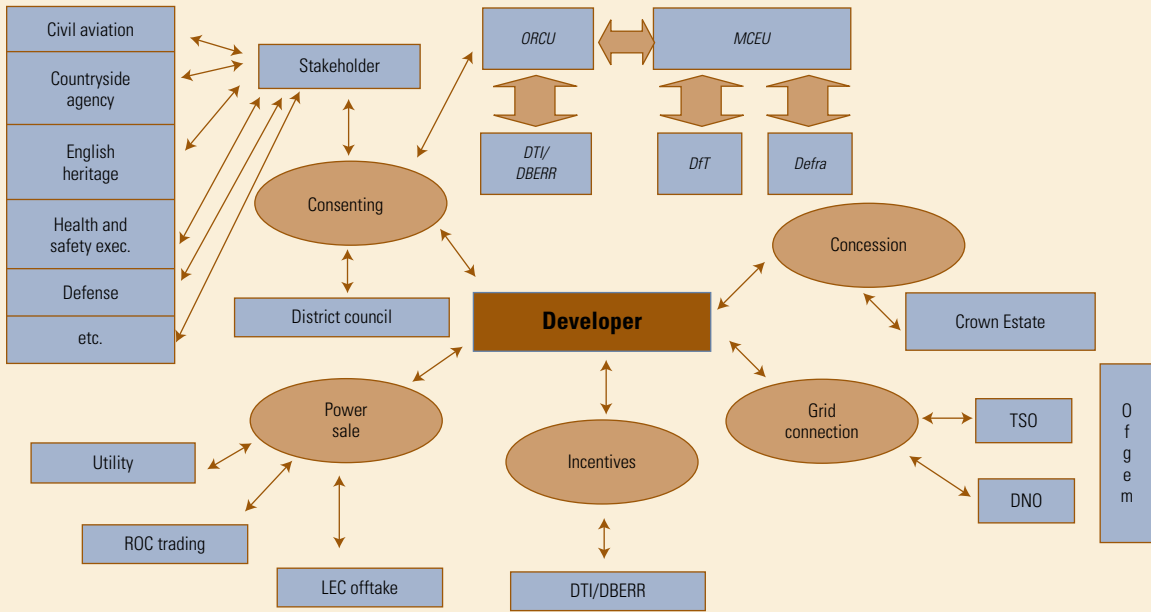
In every country there are many uncoordinated bodies with responsibility for and interest in offshore activity. If it is possible to provide a single provincial or even national authority, this will certainly accelerate development. The establishment of such an authority that is able to issue permits and provide licenses for the development of offshore projects is ideal. The establishment of a body that at least provides a central database of information about the different bodies and authorities that have an interest in the offshore matters is vital. Simple determination of who these bodies are and what their authority is has been a major cause of delay and complication in the various active countries.

FIGURE B-11: THE DANISH SYSTEM



Source: Garrad Hassan and Partners Limited.

FIGURE B-12: THE UK SYSTEM

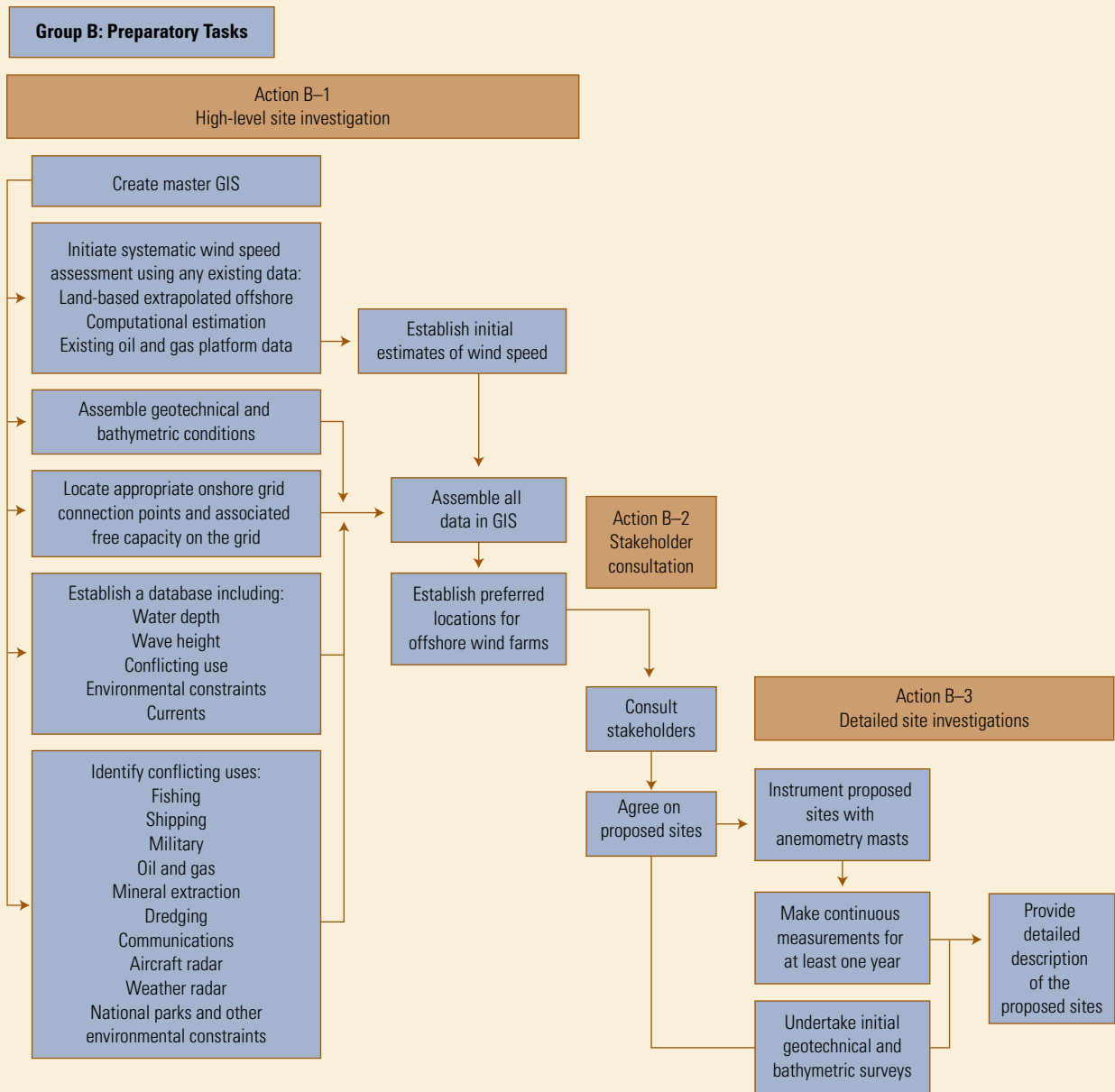


Source: Garrad Hassan and Partners Limited.

Simplification of regulation provides the necessary clarity and confidence to industry to move forward with development of offshore wind. Significant efficiency gains can also be made through the administration of the regulatory regime by a single government agency through the mitigation of user conflicts and alignment of government

strategic objectives. Ideally, for a substantial program, a single agency should be established that is able to provide licenses and permits for the development of offshore wind farms. A more modest program will rely upon existing agencies. As a lesser alternative, a single agency should be charged with providing a central database that

FIGURE B-13: ROADMAP FOR PREPARATORY TASKS



Source: Garrad Hassan and Partners Limited.

contains a definitive list of all the interested agencies. The establishment of this central database should be a first step toward the establishment of a single executive authority.

A.6: Determine Appropriate Incentive Scheme

In broad terms, two systems of revenue support for offshore wind energy have been deployed to date, each with the stated aim of encouraging deployment of generating capacity. One is the provision of a fixed tariff, and the other is certificate trading.

The fixed tariff approach adopted in Denmark, Germany, and the Netherlands has the virtues of simplicity and predictability—mitigating risks associated with revenue security. Disadvantages include the sensitivity of deployment rates to the exact level of the tariff, since once the tariff has been fixed, any change in capital cost will affect the viability of individual projects, resulting in possible cancellation. Hence, there is no self-correcting mechanism for achieving government targets and no potential for increasing costs to the consumer through the subsidy of uneconomic sites. A variation on the theme of

the fixed tariff has also been adopted where a fixed tariff is offered, but under a competitive bidding approach. The danger of the bidding approach is that the winning projects then fail to deliver them either because they have been too aggressive in their bids or the costs have risen unexpectedly. Such an approach must therefore be accompanied by a careful vetting process and also by a substantial financial penalty for failure to deliver. This approach looks likely to be adopted by the Spanish government in its initial scheme for offshore wind.

A system of tradable renewable energy certificates with an annually increasing quota, as adopted in the United Kingdom, has the advantage of a self-correcting link to government targets and in theory the deployment of the most economic projects, providing value to the consumer. The principal disadvantages of such a system are its complexity and exposure of project revenues to a fluctuating market. In addition, as has been experienced in the United Kingdom, nondifferentiated support can lead to the stalling of a more expensive technology such as offshore wind and unreasonably high returns for cheaper renewables such as onshore wind, where a restriction on the deployment volume of the latter exists. This problem can be dealt with, at least to some degree, through differentiating the value of certificates depending on the technology, although it is suggested that this devalues the market virtues of the system outlined above. The establishment of separate targets for offshore wind is the first stage in ensuring that the offshore potential is developed in parallel with the onshore resource but if a market approach is followed the market must also make this distinction. This goal is likely to be achieved in the United Kingdom by offering 1.5 ROCs for every megawatt-hour generated offshore compared with one ROC for the same energy onshore. The ROC is essentially a tradable green credit as explained elsewhere in the main report.

Experience has shown that both systems can work, although on balance a feed-in tariff is thought to offer a more reliable instrument for encouraging deployment because of the simplicity and long-term certainty of the system.

Given the variety of incentive schemes that have been attempted in Europe and their limited degree of success, it is instructive to consider whether any of the schemes that have been adopted elsewhere have been truly effective.

China should design and build an offshore grid appropriate for full-scale exploitation of its offshore wind

resource. The grid should be built to connect the various proposed sites (see Action B-1) either to one another if they are close by or to the shore if they are spread out. The grid construction can be undertaken in parallel with the site developments and hence can be progressive. The grid should supply connection to the individual wind farms in the form of a substation with appropriate step-up transformer. A separate study should be undertaken to determine whether the appropriate technical solution is transmission to shore at wind farm voltage or at a higher voltage. The optimum solution will depend on site capacity and distance to shore. The initial grid should provide a direct connection to the shore for the most promising of the proposed sites. The offshore grid will then develop in parallel with the offshore wind farm developments. Based on the experience with offshore wind energy in Europe, a bidding process is suggested as outlined below.

A bidding process should be adopted in which the bidders are provided with the following:

- The location and details of the proposed sites. The offer of the proposed sites will indicate that there is no strategic objection to the use of these sites for offshore wind farm development.
- Wind data for the proposed sites collected on the onsite masts for at least one year. The data will be provided in both raw and processed form. These data will be provided in good faith, but will carry no guarantee of accuracy.
- Wave and tidal data as collected by the on-site mast. These data will be provided in good faith, but will carry no guarantee of accuracy.
- A Strategic Environmental Assessment that indicates that there are no identified environmental obstacles and that there is a presumption in favor of granting a permit.
- A guarantee of connection of the proposed site to the land-based grid through the offshore grid together with a definite timetable for connection containing a date certain.
- A detailed technical specification of the grid to be built and a functional technical specification of the wind farm to be connected.
- A draft interconnection agreement that contains a take-or-pay provision to mitigate the risk of failure to provide the grid connection and to provide a clear level of guaranteed connection.
- A draft power purchase agreement (PPA) for at least a 20-year term.
- A statement that the metering will be at the wind farm voltage.

- An undertaking that the bidder, if successful, will have the exclusive right to exploit the proposed site or a parcel of it to be determined in advance of the bidding process.
- A list of qualifying requirements for the bidder or the bidder's consortium that is able to demonstrate its financial technical capability of executing the project.
- Minimum performance requirements expressed as minimum annual energy per megawatt installed and minimum availability of the plant.
- Default definitions and requirements.

The bidders will be entitled, during a two-year window, to make any further investigations that they deem appropriate. For example, they may make their own wind measurements and their own geotechnical investigations. They will also determine that their construction and operation methodology does not contravene the environmental assumptions that have been used in the initial assessment of the proposed site.

In response the bidders will provide the following:

- An energy-only price it requires in order to develop and operate the site for a minimum of 20 years
- An estimate of the capital cost of the project, an estimate of the energy yield expected from the project, and an estimate of the annual O&M cost to operate it together with supporting data for these values
- A bid bond for 1 percent of the capital cost, which will be returned if the bidder is unsuccessful
- Proof that the bidder is qualified to bid.

Based on the submissions received, the government may accept or reject the bidders and will, provided the bids have qualified, accept the lowest bidder. The successful bidder will then be required to submit a further bond for an additional 1 percent of the capital cost that will be returned on commissioning of the project on a timescale to be agreed. A potential problem with this approach is failure of the successful bidder to deliver the project. Care must therefore be taken to ensure that the bonds required are adequate to ensure performance.

The approach described above is believed to lead to minimum cost electricity generated from the wind farms. It will, however, require substantial capital cost expended by the government or a government agency.

Once the basic framework of the offshore wind industry is established and there are clear and credible goals set for its development, commercial opportunities will

be identified for the construction and operation of the offshore grid. There is likely to be commercial interest in the construction of such a grid if the grid operator is allowed to charge a small margin above what is conventionally allowed for the regulated returns of such an investment. Commercial arrangements could be entered into in the form of a "use-of-system" charge. Experience elsewhere, when such an approach has been suggested, shows that if there is adequate confidence in the market as a whole, companies would be prepared to enter into such an agreement and that the construction and operation of the grid could be undertaken as a third-party exercise. It should be stressed that this has not yet been done anywhere; it is only a matter of conjecture. It will not, however, be possible to benefit from such an approach until the offshore development is set in motion and confidence has been gained in it.

A.7: Achieving Scale

China has large-scale aspirations for wind energy in general and, although the particular goals for offshore wind have yet to be identified, presumably for offshore wind energy as well. To date the European efforts can be considered as first steps toward commercial exploitation of offshore wind, but they are really only adjuncts to the main effort of onshore wind development. Little thought has yet been given to the way in which true scale can be achieved in Europe.

In order to achieve scale, it is suggested that China undertake the demonstration projects as described below but, provided that reliable domestic turbines are available for use that have been proven onshore, it then leap over the other intermediate steps and attempt an immediate large-scale solution.

Group B: Preparatory Tasks

A schematic presentation of the Group B preparatory tasks is shown in Figure B–13.

B.1 Systematic Site Selection

The award of concessionary rights for the development of an offshore wind project site can lead to slow build rates if the award is made to an inappropriate party or the site itself is unviable (economically or environmentally). Early experience in the United Kingdom has led to some projects being delayed, or even abandoned, because of unforeseen techno-economic or environmental "showstoppers" discovered after the site award. This danger can be avoided through early strategic planning work to identify appropriate development regions. In Germany, the vast majority of development work

implemented to date has been led by small independent companies. Since these organizations do not have the financial strength to construct the projects and may not have invested sufficiently during the development phase to mitigate key technical risks, these projects are likely to be sold to larger players, delaying project deployment. It should be noted however, that Garrad Hassan and Partners Limited considers a mix of small “nimble” companies and major public utilities to be healthy for any particular national market and the regulatory regime should allow for such a mix. Offshore site investigation is at least two orders of magnitude more expensive than onshore investigation. Hence, there is a clear advantage of initial site identification and prequalification being undertaken centrally. In the United Kingdom, where site selection is of a competitive nature, there are examples of two US\$1 million meteorological masts being erected within a few kilometers of one another by competing developers with a commensurate waste of resource. Experience has also shown that site identification by government may miss sites that are considered optimum by private developers and vice versa. Close collaboration between the two parties is therefore to be encouraged.

ACTION B-1: HIGH-LEVEL SITE IDENTIFICATION

Techno-economic and environmental feasibility for offshore wind should be assessed at a national or provincial strategic level prior to the award of any sites for development. The system for such award would benefit from allowing for a mix of large companies and small entrepreneurial developers to stimulate growth.

Government should therefore undertake centralized investigations of potential sites on a national and/or provincial basis. The intention of these initial investigations would be to identify the prime sites for development that

- Are economically viable with good wind conditions and reasonable geotechnical conditions for construction
- Have water depth of between 15m and 20m
- Have significant wave heights of less than 3m
- Do not conflict with other existing commercial or other established use
- Have reasonable grid connection options
- Are environmentally acceptable
- Do not experience excessively high storm wind speeds or wave loads.

Such investigations should contribute to a master GIS that can be used for site selection. The purpose of this

assessment will be to provide site locations that are very likely to be suitable for offshore wind farm development, so that time and funds will not be wasted by developers in the assessment of sites that are either strategically or environmentally unsuitable.

A detailed study must be undertaken to provide a layer within the GIS that charts all the competing commercial and strategic activities in the offshore waters, such as fishing, shipping, defense, oil and gas, mineral extraction, and communications.

Existing data that describe the geotechnical and bathymetric conditions should be assembled into another layer of the GIS. Site investigations are further discussed in Annex B-2.

The environmental characteristics of the potential sites will be provided in an additional layer. Broad-brush environmental investigations in the general form of a Strategic Environmental Assessment should be undertaken to allow at least the scope of environmental issues to be identified and to rule out any sites where there are likely to be major environmental concerns.

An initial systematic resource assessment should be undertaken using all methods available: land-based measurements that can be extrapolated to offshore, measurements on existing offshore oil and gas platforms appropriately adjusted for height and exposure, and computational models that can be used to undertake estimates of the wind potential. A first estimate of the offshore potential should be made using these existing data and tools, and the results should be used to identify the locations of a network of offshore masts to be installed at a later stage when the competing interests have also been identified.

The initial investigations should be assembled into a GIS and used to identify and rank the various sites.

The Crown Estate in the United Kingdom has been charged with the responsibility of gathering data that already exist elsewhere in other agencies and placing them in a single database. The time to develop such a GIS would be about one year. The actual time and the associated cost will depend very strongly on the commercial arrangements that are entered into with the other agencies and their willingness to cooperate. Such a GIS must be considered a “live” project that will be continually updated.

ACTION B-2: STAKEHOLDER CONSULTATION

Once the initial site data have been collected and the various layers of the GIS have been assembled, optimum sites will be identified and a draft map provided. This map of proposed offshore wind farm locations and their associated capacity should then be used as a basis for consultation with possible developers and other stakeholders. The initial proposed sites should be revised in the light of the stakeholder consultation to form a definitive list of the proposed sites.

ACTION B-3: DETAILED SITE INVESTIGATIONS AND MEASUREMENTS

Once the proposed sites have been identified and the stakeholder views have been assessed, anemometry masts should be erected. The masts should be at least 80 m above mean sea level and be distributed throughout the proposed sites. Within the possible development areas masts should be positioned with a separation distance of no more than 50 km. The mast should be instrumented at four levels to allow the shear profile to be computed. Measurements of the local water current speeds and the wave climate should be made. The geotechnical conditions that are recorded during the mast exploration and installation should also be recorded. These data should be used to define the basic characteristics of the sites. The network of masts should be preserved in locations unaffected by the development of the wind farm projects so that they can gradually provide a valuable reference data set. They must be properly maintained. The data should be made available to potential developers in both processed and raw form.

The total capital cost of each mast will be of the order of US\$750,000. Each mast should be in position for at least one year. Experience in Europe suggests that an additional year should be allowed for permitting, construction, and erection. This period may be shorter in China if the permitting procedures are more streamlined. In order to accelerate the deployment of the projects, it is suggested that these masts and the resulting data should be supplied to developers free of charge.

Group C: Capital Support and Demonstration

A schematic representation of the Group C demonstration tasks is given in Figures B-14 and B-15.

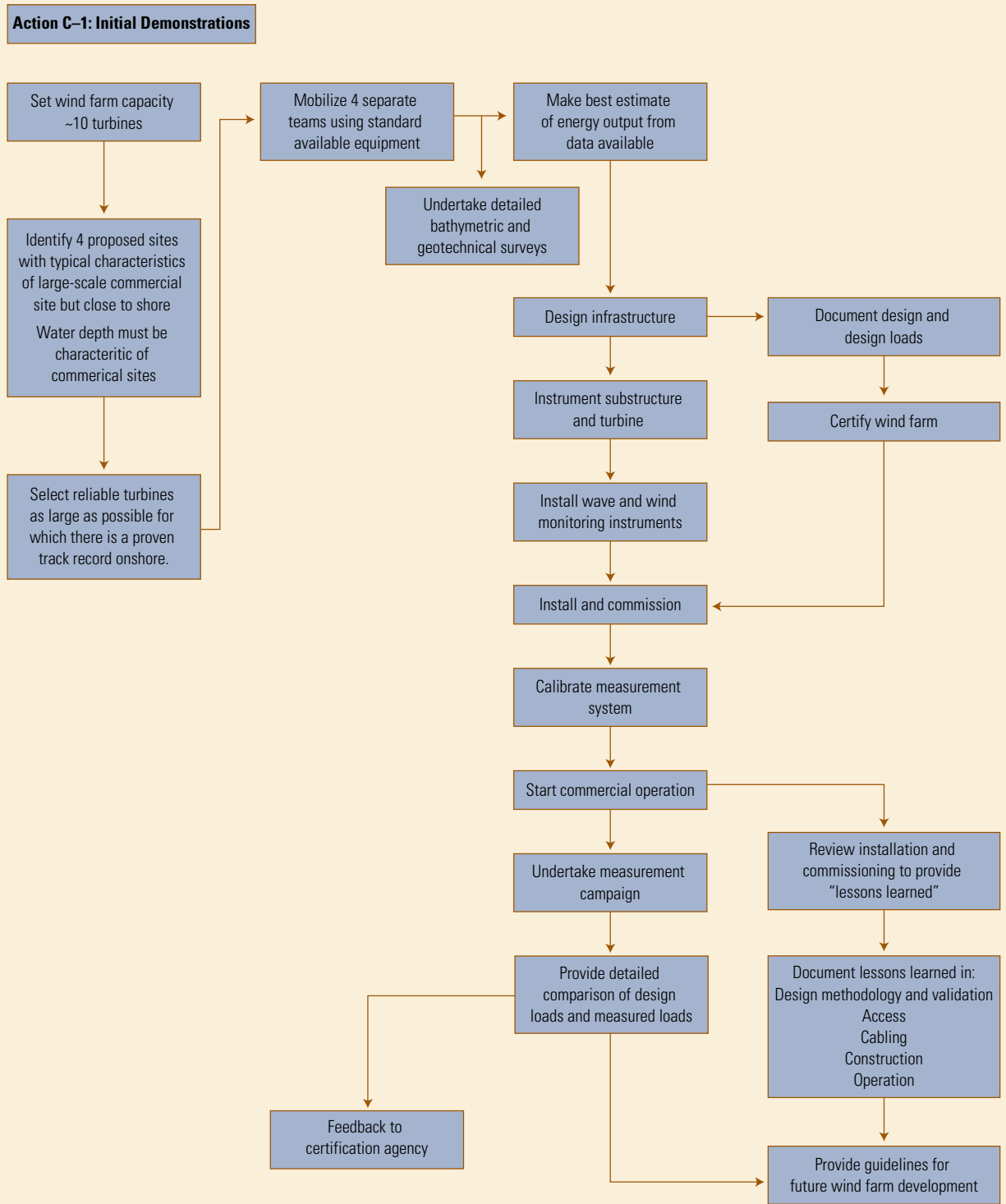
Capital support for offshore wind projects, to date, has been provided through two avenues. Grants for R&D and demonstration projects have been essential for early deployment, and evidence for such provision has to a

greater or lesser degree been found for all national markets considered. Second, Denmark, Germany, and, to some degree, the United Kingdom have opted to provide ongoing capital support to projects through the transfer of grid connection costs, including export cables and offshore substations, to the relevant network operator. The former approach has allowed valuable technical experience to be accrued during the early years of offshore wind, whereas the latter has provided ongoing alleviation of the marginal project economics faced by developers, thus increasing deployment incentive. The free supply of grid connections has allowed additional ad hoc support to be provided without specific acknowledgement of this additional support. A superior approach is to determine the extent of the grid construction in a clear and unambiguous policy, as discussed below.

The early demonstration projects have been shown to have three different benefits: 1) lessons about the practical installation of the turbines offshore, 2) establishment of the identity of all the stakeholders through demonstration, and 3) knowledge of the loading environment of the offshore turbines. The latter allowed a proper assessment of the design requirements for future offshore turbines and validation of the computational tools developed for modeling purposes. Successful examples of this approach were seen at Blyth Harbour in the United Kingdom and at Horns Rev in Denmark. This activity will also be valuable for the determination of certification requirements for the future. A full understanding of turbine behavior is vital for reliable long-term designs to be provided.

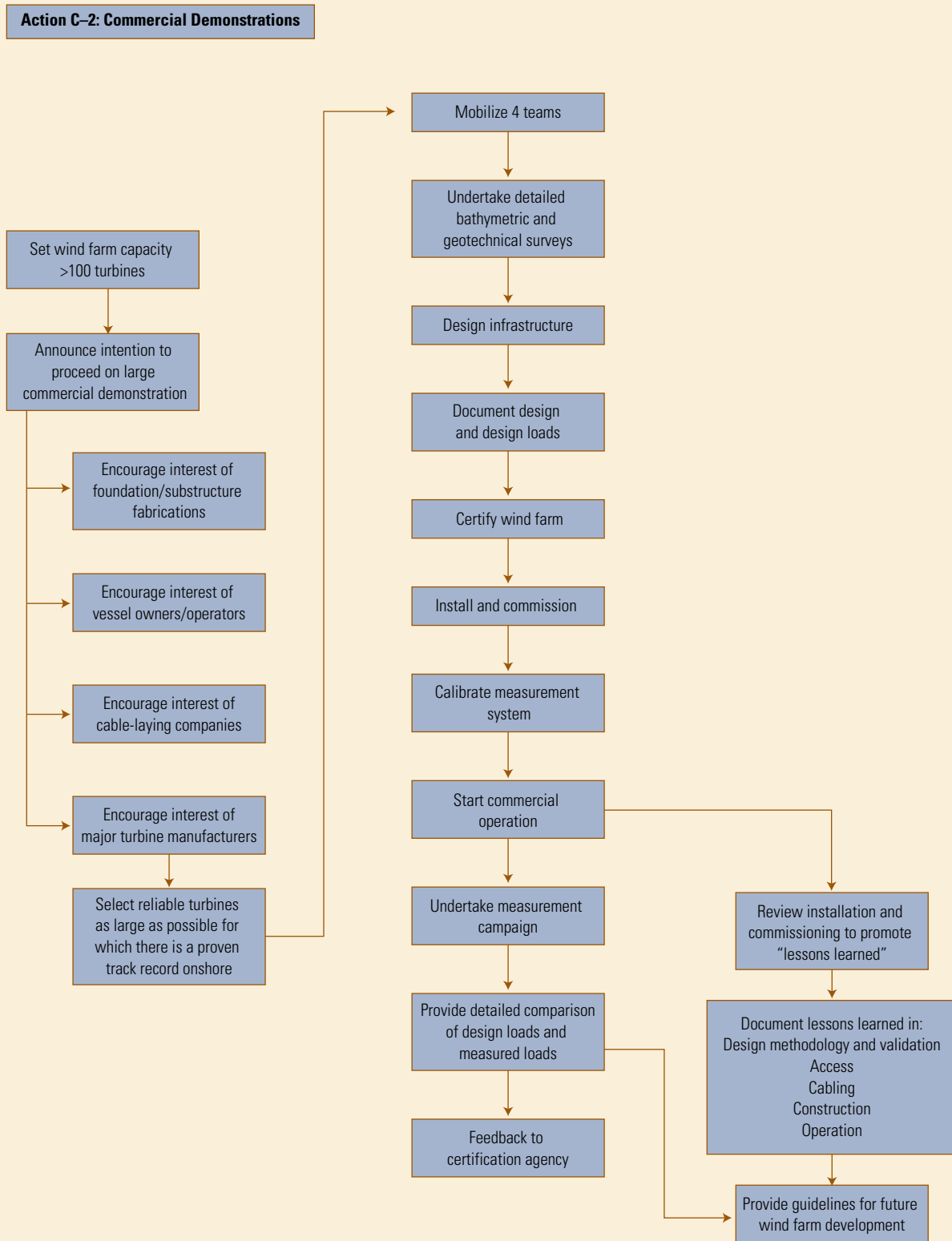
Early experience in Europe has shown that a major danger with initial offshore wind farm deployment is the temptation to deploy turbines offshore too early in their development. A good example is the experience at Horns Rev. Many of the initial problems experienced with offshore wind operation (as opposed to construction and installation) would have occurred in onshore applications of the same turbines. The severity of a problem when it occurs offshore is, of course, much greater than when it occurs onshore. It is a mistake to put in jeopardy the offshore potential by premature turbine deployment whereby the initial offshore wind farms look unnecessarily unreliable. There has been much criticism of the early offshore wind farms from wind energy detractors that could have been avoided if deployment had been delayed. Turbines should be thoroughly demonstrated onshore and achieve a high level of reliability before they are deployed offshore. Turbine reliability can be improved much faster onshore than offshore, and nothing additional is learned by experiencing these problems offshore for the first time.

FIGURE B-14: SCHEMATIC REPRESENTATION OF INITIAL DEMONSTRATION TASKS



Source: Garrad Hassan and Partners Limited.

FIGURE B-15: SCHEMATIC REPRESENTATION OF COMMERCIAL DEMONSTRATION TASKS



Source: Garrad Hassan and Partners Limited.

Capital support for the first offshore wind projects in any national market is important in order to achieve early momentum. Transfer of grid connection costs to network operators is an important support mechanism in markets where such costs are prohibitively high. Demonstration projects are required in order to kickstart the industry. Several stages of demonstration are needed to encourage the establishment of the turbines and the supporting industrial infrastructure. These steps are set out below.

ACTION C-1: INITIAL DEMONSTRATION

Some initial, relatively small-scale demonstration projects are suggested. These projects should be undertaken in locations that are typical of the large-scale commercial projects with respect to geotechnical, wave, current, wind, and bathymetric conditions. There should be a sufficient number of these initial demonstration projects to allow a representative number of developers and, more important, offshore contractors to participate. For each project design, calculations and methodology should be reported in detail in order to permit detailed comparison with measured results. These demonstrations are not intended to demonstrate the turbine technology, but rather to gain experience of the offshore elements of the work: foundation design and construction and turbine installation, as well as cable laying, for example. These projects should use only turbines that have already demonstrated availability onshore in excess of 98 percent on a long-term basis. They should not use prototype turbines. If no Chinese manufacturer can meet this requirement, it may be necessary to use foreign turbines. Proven foreign turbines should be used in preference to unproven Chinese turbines, since the purpose of the project is not to demonstrate the turbines, but rather to learn from the offshore deployment. Chinese turbines may well be substituted at a later stage when they are sufficiently well proven.

These projects can be undertaken before any special-purpose vessels have been constructed. Hence, the construction will be done with whatever equipment is readily available. No detailed resource assessment would be required, although as accurate an assessment as possible should be obtained. The water depth must be at least 15 m. Four projects of this type should be undertaken each with a different team. The notional size of each project should be 10 turbines. In order to gain maximum benefit from these projects, they should be executed as rapidly as possible—commissioning

could be programmed for the first quarter of 2010. Careful consideration should be given to the foundation design. In each of the projects, one of the turbines should be comprehensively instrumented to capture its dynamic behavior, and wind and wave characteristics should be recorded simultaneously. The data recorded should be used to validate the computational models that have been used for the project and turbine design.

A successful outcome of such a demonstration project would be rapid learning of the basic lessons on access, cabling, construction, and operation, as well as important scientific information that will improve the design methodology. An adequate budget should be set aside for the proper monitoring of the performance of these projects.

ACTION C-2: COMMERCIAL-SCALE DEMONSTRATION PROJECTS

The government should gauge the number of potential serious interested parties and try to provide a demonstration project for each. Projects should be sized at, say, 100 turbines per project. These projects should be based on a rigorous resource assessment and should follow commercial lines in all technical details. In order to ensure proper interest in these projects, a capital contribution should be made to the cost, as well as the provision of a commercial tariff (discussed elsewhere). There would be considerable benefit in the involvement of foreign parties in these projects, since such an arrangement would provide direct access to experience gained elsewhere.

The successful outcome of these projects would be the development of

- Prototype vessels for the construction and installation of offshore wind turbines
- Substantial interest in the supporting industry for the provision of monopiles and other foundations, as well as cable laying
- Foundation design methodology specialist resource
- Initial experience of O&M of offshore wind farms and the development of vessels necessary for regular and reliable access.

These industries are necessary prerequisites for the development of a commercial offshore industry.

Group D: Underlying Research and Development

A schematic representation of the R&D tasks is provided in Figure B-16.

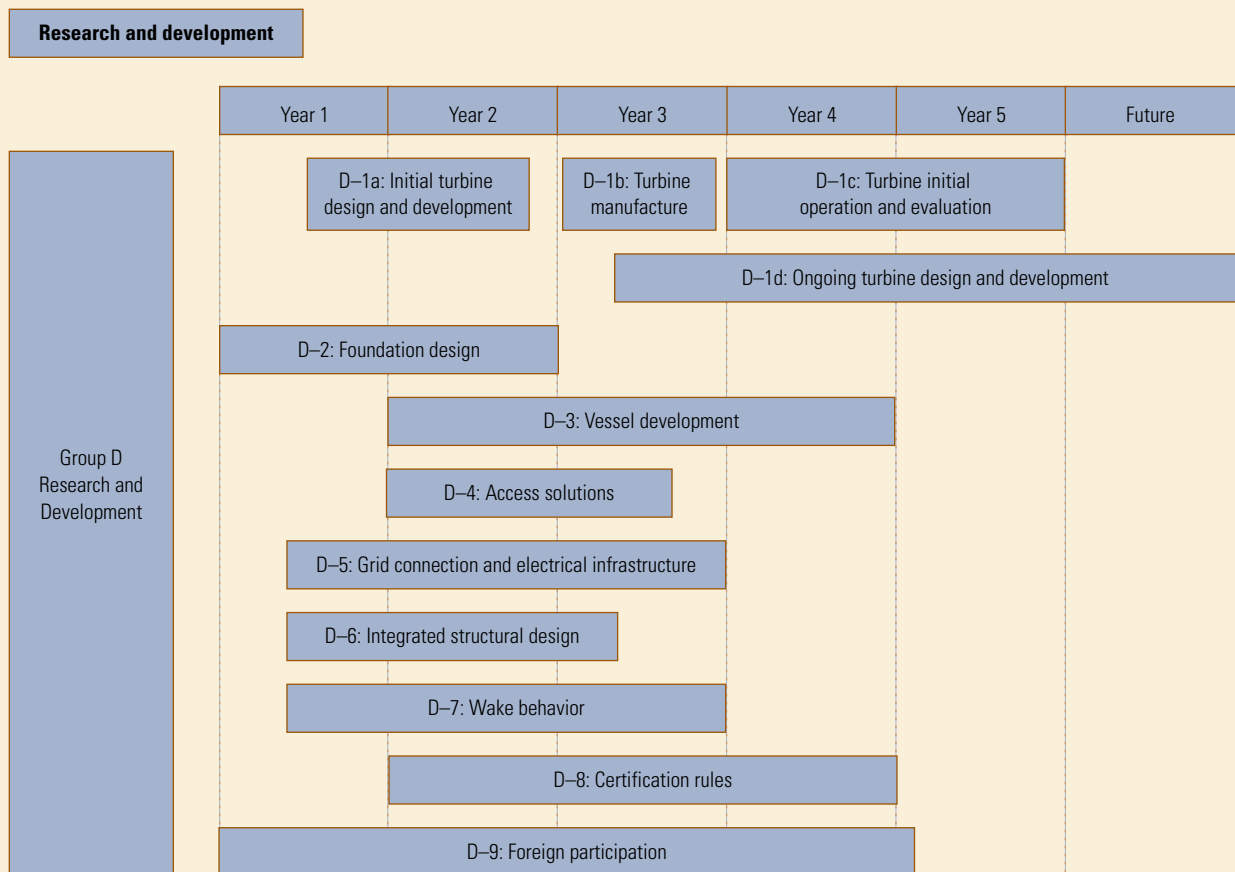
The principal barrier facing the offshore wind industry currently is high cost. Although the main reasons for this are not inherent to the technology but rather are commercially driven, experience has shown that there is significant potential for cost reduction through technical innovation. While ongoing R&D and demonstration projects such as Beatrice in the United Kingdom (demonstration in relatively deep water) and Alpha Ventus in Germany (demonstration of new turbines of approximately 5 MW) will play an important role in this regard, a continued effort is required within the offshore wind industry to bring down capital and operational costs. Careful consideration should be given to the desired outcome of such R&D projects. The recommendation here is that the

initial demonstration should be focused on infrastructure and support—essentially the nonturbine elements of the offshore projects. They should not be considered as turbine development projects but as offshore wind farm projects. A clear decision about these priorities is essential to avoid a possible serious failure.

Arguably, the most important future technical development for offshore wind will be the inception of truly offshore-specific wind turbine designs. Funding and project sites will be required for this and the markets that provide them are likely to benefit more from the derived lessons.

The turbines presently used for offshore wind farm applications are essentially marinated versions of onshore turbines. For large-scale commercial production of offshore wind-generated electricity, the turbines may be very different. Globally there is relatively little effort being

FIGURE B-16: SCHEMATIC REPRESENTATION OF RESEARCH AND DEVELOPMENT TASKS



Source: Garrad Hassan and Partners Limited.

put into the development of these turbines, and hence there is an opportunity to develop leading technology in this area. The onshore turbine designs are largely constrained by social rather than technical limits and these are all removed when offshore. The cost of the turbine is a smaller (50 percent) part of the cost of the whole farm compared to the onshore wind farms (75 percent), and hence, if turbines can be increased in size, there may well be a saving to be made in the total wind farm cost. At present the Chinese turbines are in the size range of 1.5–2 MW at the largest. These turbines should be used for the proposed demonstration projects if they have been proved to be sufficiently reliable. In Europe there are offshore turbines under or just about to start demonstration in the 5–6 MW range. It is not necessary to use these larger turbines if the water is relatively shallow (less than 15 m). For deeper water, it is likely that the larger turbines will be required. It is therefore necessary for the Chinese industry to develop these larger turbines if it is going to realize the full potential of its offshore resource. China could wait for the development of European turbines and use that technology as the foundation of its own offshore turbine development. This would be a low-risk approach. However, experience onshore has shown that it is not the correct approach, since the Chinese industry appears to be frustrated in the development of its own technology by the lack of real technology transfer in the onshore industry. Development of domestic offshore turbines now therefore seems sensible.

In offshore projects the foundation and supporting infrastructure are a much more important part of the cost of a wind farm, and hence, in addition to the efforts in cost reduction through turbine development, it will also be

important to introduce innovation in the design of foundations, the installation techniques that are used to erect the turbines, the design and construction methods used for the electrical connections, and the development of suitable vessels to allow installation of offshore wind turbines in large volumes. In Europe some effort is now being put into the development of foundation solutions for deeper-water sites. This does not, however, seem to be appropriate for the Chinese market, since plenty of shallow sites appear to be available for exploitation. However, if after the completion of the systematic site assessment described above in Action B–1 a shortage of such sites emerges, it will also be a topic for exploration in China. Table B–3 presents the recommended R&D actions for various aspects of offshore wind farm development and indicative costs of those efforts. It also provides an assessment of whether Garrad Hassan and Partners Limited sees merit in waiting for international developments or whether China should move forward on its own.

Finally, a crucial observation that has been made in the early operation of offshore wind farms in Europe is the difficulty in estimating availability. The availability of onshore wind turbines is generally in excess of 95 percent. This value is kept high through frequent visits of maintenance teams. Availability of offshore turbines is therefore a combination of the accessibility of the turbine by the maintenance crew and the availability of the turbine itself. There is considerable effort in progress in Europe now on the development of techniques for access to offshore turbines in rough sea conditions. Similar activities should be initiated in China. The suggested timescale for these projects is shown in Figure B–16.

TABLE B-3: R&D ACTIONS FOR VARIOUS AREAS

| Action | Comment |
|--|--|
| <p>Action D-1: Turbine R&D Technical innovation should be encouraged in order to bring down the costs of offshore wind energy in the medium and long term. This can be facilitated through continued funding of R&D projects with a focus on offshore-specific technological solutions. Government should encourage and partially fund the development of Chinese domestic turbines with a capacity of more than 4 MW for eventual offshore deployment. Successful outcome of this project would be the development of at least two types of large-scale offshore turbines ready for commercial exploitation within a three-year horizon.</p> | <p>Cost per turbine: Design: US\$5 million Prototype: US\$15 million</p> <p>No merit in waiting for Western development.</p> |
| <p>Action D-2: Foundation R&D R&D should be undertaken to develop appropriate foundation solutions for the combination of soil and sea conditions that are found in China. The systematic site selection process described above will determine the environmental conditions that prevail. There are various types of foundations presently in use: gravity, monopile, tripod, and tri-pile. Suction caissons have also been tested, but so far without success. It is fair to say that there is no universally agreed solution and that there will be different preferred solutions for different sites. The optimum solution will also depend on the availability of appropriate manufacturing facilities for the particular solution. There is a great deal of scope for cost reduction and integrated design activity in this area.</p> | <p>Cost per foundation: Design: US\$0.2 million Prototype: US\$1 million</p> <p>No merit in waiting for Western development.</p> |
| <p>Action D-3: Vessel Development China is already leading the way in specialist offshore wind farm installation vessels. Several Chinese vessels are already operating in the European market. Development of specialized vessels has a very strong effect on cost and therefore deserves considerable attention. For successful cost-effective, large-scale implementation, such vessels are essential.</p> | <p>Cost per vessel Design: US\$2 million Fabrication on a commercial basis.</p> <p>China is already leading the world; hence, continue as now.</p> |
| <p>Action D-4: Access Solutions The sea conditions in the area of likely activity should be determined in detail and an investigation performed of the various access approaches that can be used for a particular location: helicopters and small vessels should be investigated. There is room for major innovation in the development of new access methods. An access method that improves the accessibility of a turbine is likely to be very valuable both for application in China and abroad.</p> | <p>Use Western approaches already in operation. Apply on initial demonstration projects.</p> |
| <p>Action D-5: Grid Connection and Electrical Infrastructure The electrical aspects of a large offshore wind farm are a major part of the cost. Innovative solutions for both the internal infrastructure and the grid connection will be beneficial and are under investigation in the West. The use of HVDC methods may be appropriate. The uses of a complete system design in which some functions that are often located at the turbine level are relocated at the interconnection level may also be a possibility. These may have to use voltage source HVDC because of the large capacitive charging current if alternating current (AC) is used. Offshore grids using HVDC do not exist yet and so technical development is required. Investigation of the appropriate location for the grid and turbine transformers is also important. The location of the grid transformer determines the nature of the interconnection. A complete system design approach should be developed.</p> | <p>Cost of design element US\$3 million</p> <p>Development of HVDC may have to wait for Western developments. Domestic HVDC may develop for other applications as well.</p> |
| <p>Action D-6: Integrated Structural Design At present offshore wind farms are a collection of turbines that are erected together in the sea. As indicated above, there is no real activity yet on the development of "real" offshore turbines, and similarly there is no real effort on the integration of designs for the whole structure. The development of design methodology and then actual integrated designs is likely to be very beneficial and should be initiated. For example, the subsea structure should be designed as an integral part of the turbine structure; the whole design should be reviewed for erection and installation compatibility.</p> | <p>Cost per turbine and substructure Design: US\$0.25 million Prototype: US\$2 million</p> <p>No merit in waiting for Western development.</p> |

(continued)

TABLE B-3: R&D ACTIONS FOR VARIOUS AREAS (CONTINUED)

| Action | Comment |
|--|---|
| <p>Action D-7: Wake Behavior</p> <p>The wakes in large-scale offshore wind farms are not well understood. The wakes appear to persist much longer in these farms than the current models predict. Energy predictions are therefore inaccurate, at least compared to normal commercial onshore wind farms. It also seems that some unexplained and substantial loads can occur from time to time. Systematic investigation of both the wake behavior and the resulting loads is required to allow appropriate design of future wind farms and hence associated cost or risk reduction. Full-scale load and energy measurements should be undertaken coupled with computational model development. This activity may be shared with the similar task identified in the WPB program.</p> | <p>To be undertaken in international cooperation</p> <p>Full-scale measurements: US\$2 million</p> <p>Computational work: US\$0.5 million</p> |
| <p>Action D-8: Certification Rules</p> <p>In parallel with the development of the technology, appropriate certification rules should be developed. These certification rules should draw heavily on those that are already appearing for the European developments. The European rules are still in draft form, but are evolving continually. The Chinese certification agencies should collaborate in the development of these rules and ensure that the rules that are adopted in China are consistent with those adopted elsewhere. Although consistency of approach is important, proper distinction must be made between the differing site conditions found around the world, and the Chinese conditions must be properly identified and documented.</p> | <p>To be undertaken in international cooperation</p> <p>Cost US\$2 million</p> |

Source: Garrad Hassan and Partners Limited.

Roadmap for Intertidal Development

Most of the technical issues associated with the development of intertidal projects have been described above, in the context of offshore wind farm development. The loading on the intertidal turbines will be the same as that for WPB turbines; there will be no appreciable wave loads. The turbine sizes are also likely to be similar. Connection to the grid along the east coast appears to be relatively simple. The challenges specific to intertidal development are what foundations to build and how to build them and how to install the turbines.

As for any wind project, the economics of the intertidal developments will depend on the installation cost and the wind resource. The wind resource for the intertidal project locations is not well known and must be established as a priority.

The possible foundation solutions for offshore and intertidal wind farms have been investigated and compared with one another and also with the conventional onshore spread footings. The onshore solutions follow accepted Chinese and international practice. The proposed offshore solution will depend strongly on the local geotechnical data, but is likely to follow the monopile approach that has been adopted in most European offshore wind farms. The foundations that will be adopted for reclaimed land are likely to be the conventional pile cap solution, assuming good enough road access for the major plant can be provided.

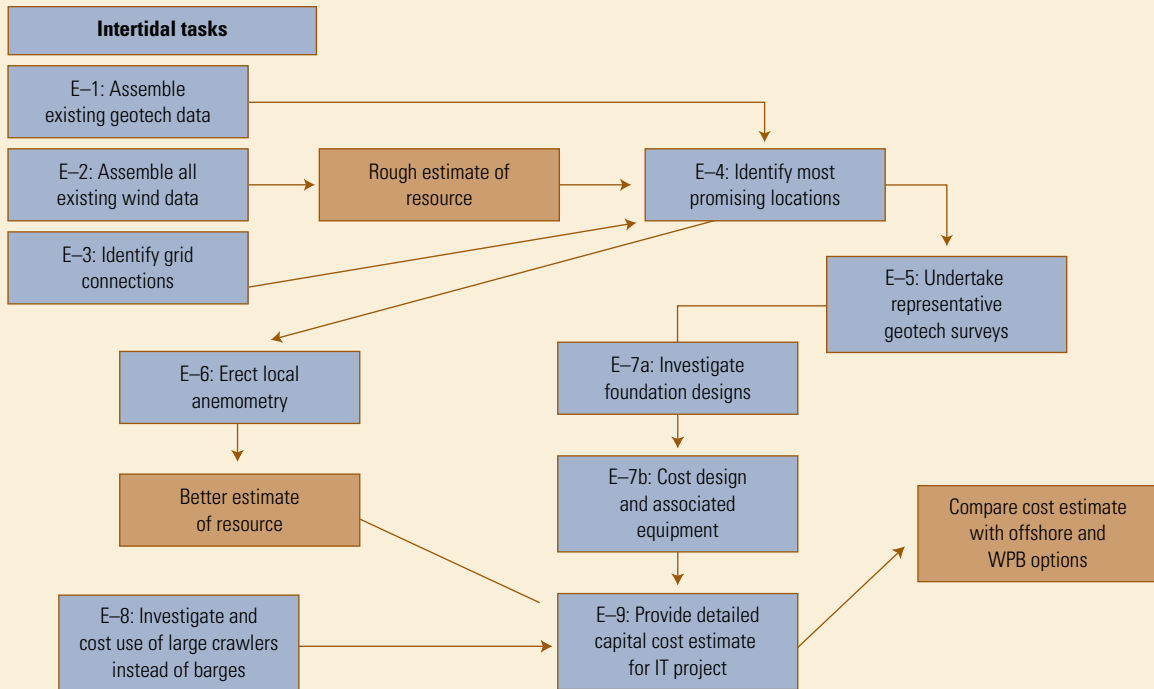
The emphasis in this section is initial consideration of the possible solutions for the intertidal zone that has not been reclaimed. A promising option appears to be a monopile installed using a small jack-up barge. Monopile or piled foundations are both possible. Both have their advantages and disadvantages. Monopiles require specialist fabrication and installation, which may prove to be viable only if many wind turbines are installed. Piled foundations are only practicable if site tracks and working platforms can be constructed above water level. The monopiles involve well-established conventional technologies, while the cap and piling are likely to be expensive. All these assumptions and conclusions are based on very limited data that must be tested through the following actions.

Group E: Intertidal Actions

The actions that would be required to allow a proper cost comparison to be made between intertidal wind farm development, and offshore and WPB development, are described in Figure B-17.

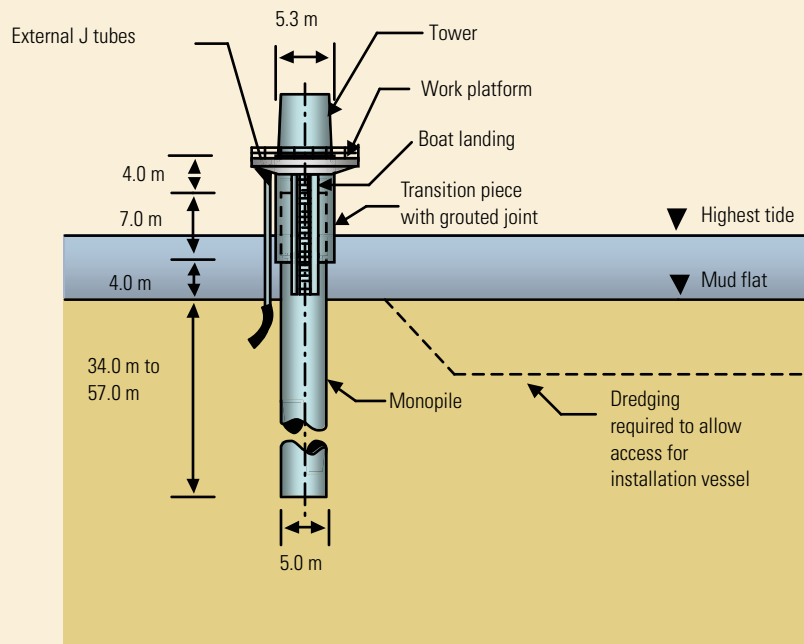
This list of tasks is of a preliminary nature, and is related to the particular foundation design illustrated in Figure B-18. A similar approach would be needed for the other design options, such as using crawlers rather than barges for access and installation.

FIGURE B-17: RELATIONSHIP BETWEEN INTERTIDAL TASKS



Source: Garrad Hassan and Partners Limited.

FIGURE B-18: SCHEMATIC DESIGN OF A POSSIBLE INTERTIDAL FOUNDATION



Source: Garrad Hassan and Partners Limited.

Key Actions for Intertidal Wind Farm Development

The actions recommended for developing intertidal wind farms are as follows:

ACTION E-1: ASSEMBLE GEOTECHNICAL DATA

Assemble existing geotechnical data available in the intertidal zone. Check these data against the assumptions used in preliminary designs.

ACTION E-2: ASSEMBLE EXISTING WIND DATA

Assemble all existing wind data in the intertidal zone and use it to estimate the likely wind speeds in the zone in order to obtain initial approximate estimates.

ACTION E-3: IDENTIFY GRID CONNECTIONS

Identify likely grid connection points in the intertidal zone.

ACTION E-4: IDENTIFY PROMISING LOCATIONS

Using the results of Actions E-3 and E-2, identify the most promising locations for the development of the projects.

ACTION E-5: UNDERTAKE REPRESENTATIVE GEOTECH SURVEYS

Undertake initial geotechnical survey of the conditions at the most promising locations. In addition provide at least the following information:

- Investigation of the cost and availability of
 - ◆ material for construction of site tracks and working platform
 - ◆ existing practices for reclamation of land
- Investigation of possible site layouts and tidal ranges.

ACTION E-6: ERECT LOCAL ANEMOMETRY

Erect anemometry masts on the most promising sites using the specifications set out in Action H.

ACTION E-7: INVESTIGATE AND DETERMINE COSTS FOR SUITABLE FOUNDATION DESIGNS.

Given the knowledge derived from the above tasks, determine the costs of the different foundation designs and identify the least-cost one, based on the information at hand. Various access options have been addressed and the optimum appears to be the development of “access canals” as opposed to access tracks. These access canals will be provided by local dredging. The availability of local dredging capacity should be checked and an investigation of the cost and availability of the following equipment should be made:

- Small jack-up barges
- Dredging equipment
- Monopiles.

ACTION E-8: INVESTIGATE AND DETERMINE COSTS OF CONSTRUCTION OPTIONS

When better data to describe the characteristics of the mud are available, some investigation should be made of the possibility of using large crawlers in place of the jack-up barges. Initial evaluation suggests that the combined weight of the crawler and the large wind turbine components (tower, monopile, and nacelle) will be too great for the bearing capacity of the mud. It is nevertheless considered that such an approach does merit some serious evaluation perhaps in conjunction with a Chinese manufacturer of large plant.

ACTION E-9: PROVIDE DETAILED CAPITAL COST ESTIMATE

Based on all information obtained, provide detailed costs estimate for large-sale intertidal developments that will allow comparative costs to be made with the offshore and WPB solutions.

Wind Power Base Roadmap

The term *large scale* is subject to local interpretation and, as shown in the discussion of the policy context in Section B-2, in China is likely to mean a scale considerably greater than what is understood by the term in Europe. Offshore wind farms of gigawatt scale are now being considered in Europe, and projects of a similar size are under consideration onshore in the United States, albeit as a group of separate projects. Certainly the proposed development of a 10 GW WPB is outside the experience of any country onshore or offshore. Since there is no direct precedent, in this study, “large project problems” have been considered.

Given this scale, Garrad Hassan and Partners Limited believes that the some of the same issues are likely to be encountered both on- and offshore—they will be problems of scale rather than location.

The tasks are divided into five groups:

1. Group F: Basic philosophy
2. Group G: Electrical integration
3. Group H: Wind resource
4. Group I: Turbines
5. Group J: Infrastructure and support.

An overall timeline for the tasks is provided in Figure B-19. Some actions do not fit logically on such a time-line.

In each subsection that follows, the tasks are identified based on experience elsewhere. Figure B-20 shows how the various tasks are connected and what outputs are expected from them.

Group F: The Basic Philosophy

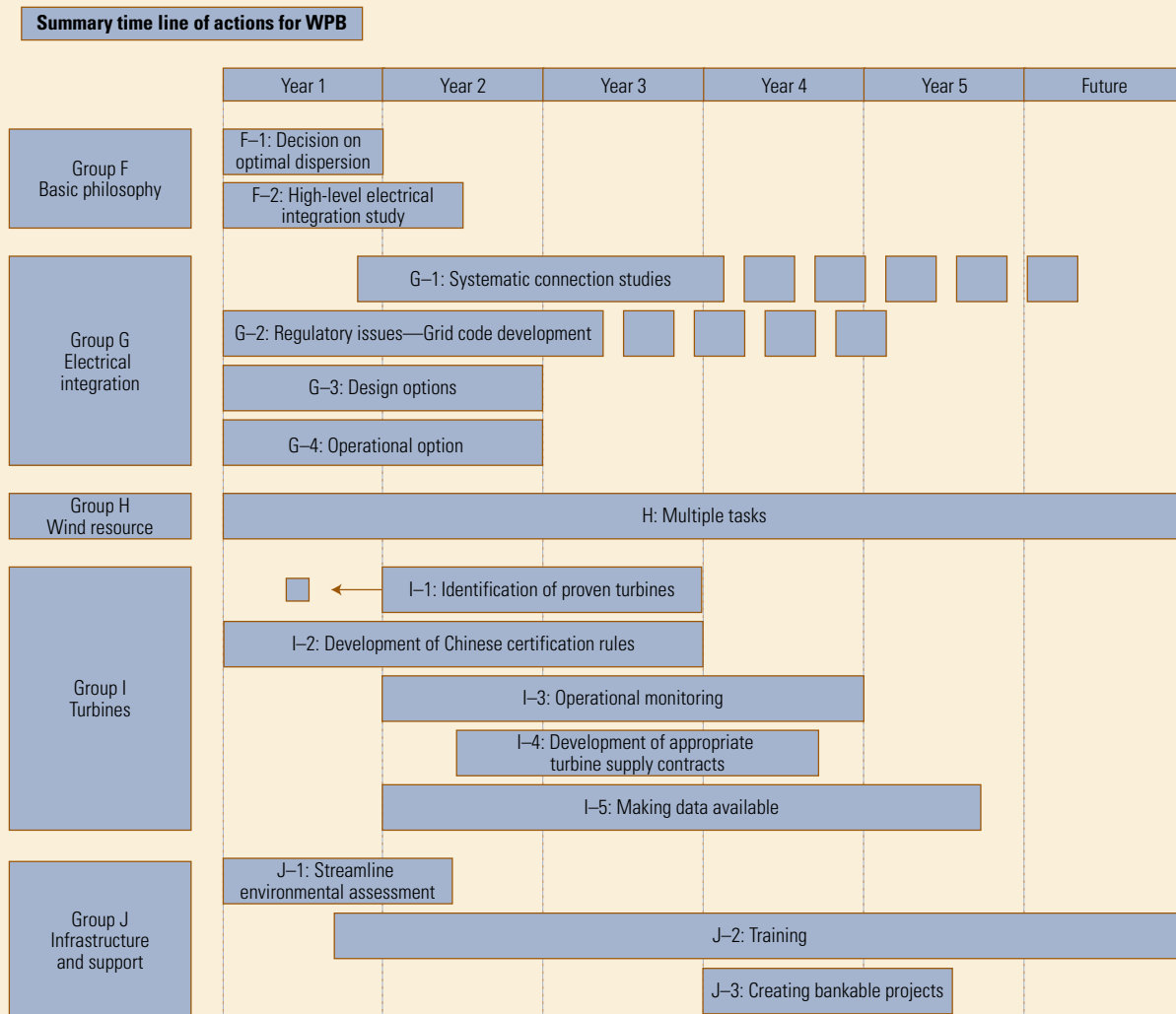
F.1: Decide on Optimal Dispersion

In order for wind energy to reach its full potential, it is necessary for it to be considered on the same scale as other forms of generation. It is therefore natural to consider the possibility of a 10 GW project. China has other power station clusters of similar dimensions. However, in considering the details of such a possibility, it is necessary to remember the basic physics that underlies the process of conversion of the kinetic energy in the air into electrical energy in a wire. Such consideration is amenable to rigorous objective investigation and modeling and hence to a process of optimization. Optimization is likely to demonstrate that very large quantities of wind power generation will be better installed in a dispersed manner. This approach will produce more reliable, cheaper electricity and will have a smaller impact on the electrical system. It would still require a major investment in grid infrastructure, and it is this investment that is the key to unlocking China’s wind potential.

A rigorous objective investigation of the optimal dispersion of 10 GW of wind is proposed as an urgent study based on the assumption that a major grid reinforcement investment is available. Such a study will include a model of the grid characteristics and infrastructure cost and will model the behavior of a single concentrated WPB and a progressively dispersed WPB with the same energy output (and hence, because of wake losses, probably a smaller installed capacity). The outcome will define the optimum configuration for the WPB design.

Such a task could be completed in one year and would cost about US\$0.5 million.

FIGURE B-19: SUMMARY OF TIMELINE OF ACTIONS FOR THE WPB



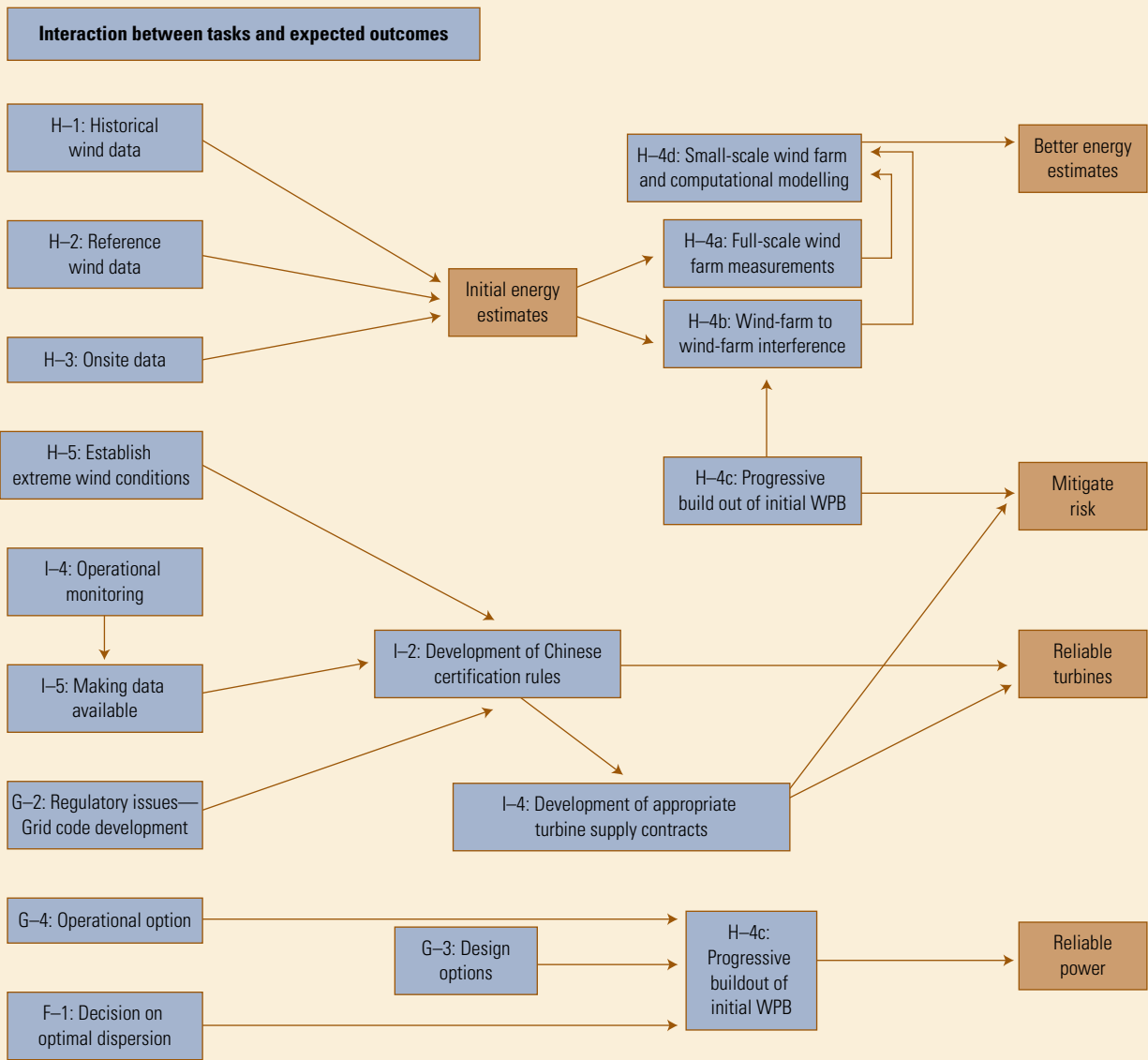
Source: Garrad Hassan and Partners Limited.

F2: Study Options for Grid Integration—High Level

Wind energy is variable, but it does not suffer from sudden disconnection of large amounts of generation as does conventional generation. It has different characteristics that must be accommodated in the grid system. The connection of 10 GW into a system in a single place sounds like a daunting task, but that may simply be how it is seen with European eyes. Very high levels of generation, when considered as a proportion of total generation, have already been included in Spain, Denmark, and Germany. The scale of conventional generation in China is huge. Investigation of this process is amenable

to rigorous modeling using standard electrical engineering techniques. There is now a good understanding of how individual wind turbines work electrically and also how they connect and behave in groups. Good electrical models are available. It is essential to undertake a comprehensive modeling exercise of the behavior of these turbines connected at the candidate points once the dispersion of the WPB has been decided. This is a large but perfectly feasible exercise. It should, however, be undertaken in considerable detail as a precursor to any major implementation steps.

FIGURE B-20: INTERACTION OF SOME WPB TASKS AND THEIR EXPECTED OUTCOMES



Source: Garrad Hassan and Partners Limited.

A rigorous statistical investigation should be undertaken into the interaction of the WPBs with the grid and thereby allow proper specification of the grid upgrades required and also the level of generation support/benefit that arises. Such a study should be undertaken in conjunction with the introduction of short-term forecasting as described below in Action H-6.

Group G: Electrical Integration

The challenge is to transport the energy from the WPB locations in the north and the west to load in the east of the country.

G.1: Systematic Connection Studies

There is no comparable experience of connecting concentrated blocks of, say, 10 GW of wind farms to a network, but a review of the issues suggests that the following points should be carefully considered. These points should be addressed in any connection study.

The continuous rating of the connection should be determined, given that this very extensive wind farm may not generate its rated output frequently, if ever. There will, therefore, be an optimum connection size.

The connection circuit topology will be determined by the maximum loss of generation that the power system can accept. This will be driven by the security standards of the power system. Redundancy in the wind farm collection circuits will probably be limited to switching to other partly loaded circuits, but this matter should be confirmed.

The wind turbine generator technology used and the robustness of the variable speed equipment will determine the ability of the wind farm to control power factor and provide fault-ride-through capability. If the proposed wind farms cannot control the power factor at the point of connection effectively or are not robust in the event of faults, then power electronic reactive power devices (STATCOMs and SVCs) may be required at each subwind farm. Optimization of the location of these devices will be an important cost factor.

It is important to determine the performance requirements (grid code requirements) that will be imposed on the wind turbines. The looser these are, the greater will be the expense of the TSO. There is a clear trade off between expense of meeting rigorous requirements imposed on the wind turbines at the turbine level and the expense of doing the same at the grid level that will be required to build a grid connection if the local requirements are flexible.

G.2: Regulatory Issues

The regulatory issues depend on the point at which the wind farm power collection system becomes part of the main interconnected network. It would be usual for the wind farm developer to pay all costs for the connection up to this point. Beyond that point it would be usual for the wind farm operator to pay for the use of assets through use of system charges. This arrangement will, of course, be colored by the normal commercial procedures that are adopted in China.

It will be important to confirm that the design and operation standards for such a large development reflect the particular characteristics of wind farms. These include:

- Ratings and topology of connection
- Voltage limits of connection circuits
- Requirement for voltage/power factor control of the subwind farms

- Fault-ride through capability
- Requirement to provide frequency response from the wind turbines
- Requirement of the main power system to provide frequency response and reserve. How are these services to be paid for? This is known as Balancing Power in the Nord Pool (the Scandinavian power market where there is considerable penetration of wind power) and may become an important commercial question.

The Chinese grid code should be reviewed and revised to ensure proper compatibility of the WPB with the system and that there are no unnecessary constraints placed on the WPB design. A consultative process should be put in place between the TSO and the likely WPB developers. The outcome should be a very clear technical specification of the grid requirements.

G.3: Study Design Options

It is understood that connection at 750 kV AC has been decided upon for the large-scale transmission of important loads over long distances. However, it may be useful to confirm that alternatives have been considered, for example an HVDC link.

An important question with the 750 kV connections is how much synchronous generation must be kept in operation. This will be depend on the following:

- Steady-state voltage regulation (the 750 kV circuits will generate significant reactive power if lightly loaded)
- Stability: transient, dynamic, and voltage
- The performance of the wind turbines.

The conventional design process would follow

- Determination of circuit topology following Security and Quality of Supply Standards
- Studies to examine steady-state operation (load flows)
- Studies to examine fault-level contributions and protection (fault studies)
- Studies to examine stability (transient and dynamic stability studies)
- Electromagnetic studies.

Particular issues for the very large wind farm include:

- Performance required of the wind turbines
- Reserve and response required from the conventional synchronous generation.

It may be useful to make a clear distinction between current source and voltage source HVDC. Current source uses thyristors and is suitable for long-distance transmission (>3 GW) from the WPB areas. China is encouraging the major equipment manufacturers (ABB, Siemens, AREVA) to develop 800 kV current source HVDC equipment with even higher ratings. Voltage source uses insulated gate bipolar transistors (IGBTs) and can supply wind farms. It is suitable for offshore transmission (maximum rating at present approximately 1 GW). All three major manufacturers either already do (ABB and Siemens) or will offer this equipment next year (AREVA).

G.4: Assess Operational Options

The operation of the wind farm and the synchronous generation in the network must be considered. If the wind energy can be injected into a large (200 GW) system with no constraints, the impact on conventional generation is likely to be limited. However, if it is necessary to modulate the output of synchronous generation, costs will be incurred and commercial issues are likely to be raised. It appears that there are 3–5 GW of synchronous generation available to “match the building of wind power.”

A systematic investigation of the effect of the development of the WPBs on the existing synchronous generation is required. This investigation should determine the cost of both the potential changes in the operational envelopes of the existing generation and the cost of any new equipment that may be needed to support the wind energy activity.

Group H: Wind Resource

It is impossible to overemphasize the importance of systematic wind measurements. If poor or inadequate wind measurements are made, the estimates of energy production will be unreliable. Exploitation of wind energy on the scale envisaged with the WPBs should not be undertaken without meticulous investigation of the resource. Attention should be paid to both local wind measurements and historical reference data.

If there are problems with the turbines or the civil or electrical infrastructure, they can be corrected by spending additional funds. If there is a problem with the energy estimate, usually through poor wind measurements, nothing can be done. It is important to put the cost of wind measurements into proper context. A single 40 m mast with instrumentation may cost US\$40,000. The cost of a single 2 MW turbine installed on the site might

be US\$3–4 million. One turbine therefore pays for 100 masts.

Failing to undertake proper wind measurements could easily result in a deficit of 10 percent on energy. A 10 percent reduction on energy (see Action H-4 below) in a single 3.8 GW WPB would result in lost revenue of US\$60 million, or the cost of 1,500 masts every single year.

There is no excuse for poor or missing instrumentation.

H.1: Historical Wind Data

An initial task that can be undertaken immediately is to make a detailed inventory of the historical wind data that are already available. Experience has shown that although meteorological services may state that they have long histories of reliable wind data, this is very rarely the case. The CMA does, in principle, have such data and they should be gathered, archived, and thoroughly analyzed. If there are data available, they will be very valuable. If there are any proposals to modernize, move, update, or in any other way change the instrumentation or its mounting, it is vital that the new equipment be operated in parallel with the old for at least six months. Failure to do so will mean that any historical data that have been collected at such stations will be immediately valueless. This problem has appeared on a regular basis in other countries when the meteorological services are modernized or the sites are otherwise developed. For example, in the United States there was a systematic program of improvement to the national network of wind speed measurements. The old, analog Automated Surface Observing System (ASOS) system was replaced by new, digital instrumentation. During the replacement program, there was no overlap between the old and the new instruments, and hence, since consistency could not be guaranteed, the long-term historical data were rendered useless and could not be adopted for correlations. Similar problems, but of a less systematic nature, have occurred in various European meteorological services. This problem appears partly because there is no other industry that has such a keen interest in mean wind speeds. For wind energy the difference between a site mean wind speed of 7.0 and 7.3 m/s is large. For other applications—for example, building integrity—such a difference is immaterial. It is noted that exactly this problem appeared in the analysis of the Huitengxile WPB.

Long-term weather stations are a valuable asset and should be protected.

ACTION H-1:

The following tasks are therefore suggested:

- Perform a detailed inventory of the historical wind data that are already available
- Set up protocol to ensure that these data are not corrupted and if any changes are made, “overlapping measurements” will be made.

H.2: REFERENCE WIND DATA

A systematic investigation of the likely sites is essential.

ACTION H-2:

The following steps are recommended. A valuable reference data set will result:

- Regions in which WPBs are likely to be established should be identified and computational assessments performed of them.
- Areas within these regions where specific wind farms are likely to be built are identified.
- Locations near to these areas that are exposed to similar wind conditions but are far enough away from them to avoid interference with the measurements after the wind farms are built are identified.
- Reference anemometry masts of at least 80 m height are built on these sites and then carefully maintained as a long-term reference data set. The masts should be instrumented with anemometry at 20 m intervals over their height. Temperature, pressure, and wind directions should be measured at each mast;
- The masts should use the sensors defined above specified to IEC standards. Great care should be taken not to use “homemade” or other amateur instrumentation. Good-quality commercial/scientific instruments must be adopted and must be properly maintained. All instruments must be traceable to recognized standards.

A substantial network of this sort, which is accessible to all developers, will be of great value. Care must be taken to ensure that this network of masts is both properly installed and properly maintained. These data will allow rigorous evaluation of the performance of the WPB in operation.

H.3: On-Site Data**ACTION H-3:**

For individual projects, it is recommended that:

- There be an absolute minimum of one year of high-quality data collected on masts of at least 80 m in height
- Within each wind farm site within the WPB in complex terrain, no wind turbine be located further than 1 km from a mast
- In simpler terrain, say, in open rolling pasture, this limit can be raised to 2.5 km
- Masts covering the area may be lower at say 40 m in height. These measurements may be complemented by remote sensing investigations using LIDAR or SODAR.

Data must be gathered from these masts for at least one full year before estimates can be made of the energy production at these sites together with associated uncertainties. Data should include temperature and pressure, as well as wind speed and direction.

H.4: Energy Estimates

Recent experience in large offshore projects and in large projects in Texas suggests that the wake losses in big wind farms in areas of low turbulence are significantly larger than originally anticipated. For large projects, evidence suggests that errors could be on the order of 5–10 percent.

In smaller wind farms in turbulent wind regimes, the natural mixing of the air reenergizes the wakes, and they die away quite quickly. In large wind farms in low turbulence regimes, this does not happen. At present there is no reliable means of predicting this effect. It is present under conditions of high density of turbines and low ambient turbulence—exactly the conditions that will be present at the WPBs. Some pragmatic approaches have been developed and are able to broadly reproduce the effect that can be substantial. There is also growing evidence that the “wind farm-to-wind farm” wakes may have been underestimated. All of these data suggest that it is preferable to achieve large levels of installed capacity through dispersed wind farms rather than through a concentrated approach. Figure B–21 shows an example of the conventional calculation (triangular symbols) of the wake effect from a wind turbine in an offshore wind farm and the measured effect (circular symbols) in the same wind farm. It also shows the calculations using a modified calculation procedure (rectangular symbols). It is clear from this figure that the new approach is needed

and that the potential discrepancy is very large (20–40 percent). It has been developed but is still largely unvalidated. At present it is still a matter of conjecture as to whether a large onshore wind farm in low turbulence air (such as is experienced in a WPB) will behave in the same way, but it seems likely.

If a 3.8 GW WPB that receives US\$60/MWh for its energy suffers from an unnecessary additional wake loss of 10 percent, in one year it will lose the following:

$$10\% \times 30\% \text{ (CF)} \times 3,800 \text{ (MW)} \times 8,760 \text{ (hours/annum)} \\ \times 60 \text{ (US$/MWh)} = \text{US\$60,000,000 or Y 430,000,000}$$

This sum of money is huge and demonstrates the value of investment in a good understanding of the physics of these systems is.

ACTION H-4A: FULL-SCALE WIND FARM PERFORMANCE MEASUREMENTS

Proper allowance must be made in the prediction of energy from the WPBs. For the initial projects, it is recommended that an additional wake loss be included that may be calculated on a pragmatic basis. Careful measurements should be made in the initial subprojects of the WPBs to detect this characteristic. These measurements can then be used to validate new methodologies for wake loss calculation for later projects.

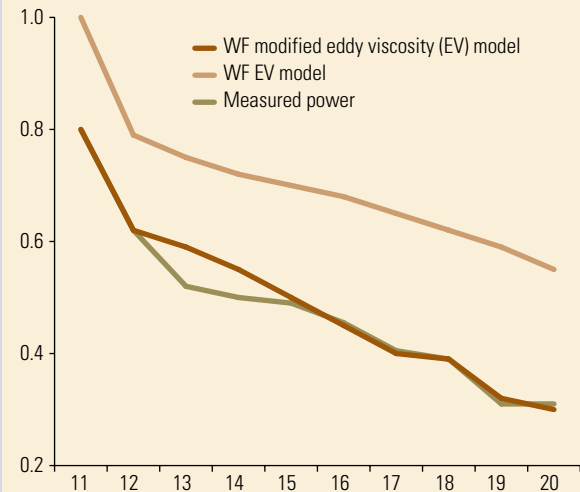
ACTION H-4B: WIND FARM-TO-WIND FARM INTERFERENCE

Additional experiments should also be initiated that allow the measurement of “wind farm-to-wind farm” wakes. Such experiments will require the ability to “switch off” the upwind wind farm and commercial provisions for reimbursement under these conditions should be anticipated.

ACTION H-4C: PROGRESSIVE BUILDOUT OF SUBPROJECTS

As a first stage towards the goal of Action H-4b and as a possible mitigant for the risks associated with the uncertainty associated with the performance of these WPBs it suggested that construction of the subprojects that make up each element of the WPB could be built row by row. So that if there are, say, four projects that make up four sections of a WPB and each successive project is downwind of the other subproject and furthermore each subproject consists of, say, six rows, then the first step could be the construction of Row-1 of each of the subprojects; then Row-4 of each project and then Row-6, and so forth. At each stage energy measurements could be made. Such an approach will allow a systematic buildup of the effect of the wakes to be developed.

FIGURE B-21: CALCULATION OF WAKE EFFECTS IN LARGE WIND FARMS



Source: Garrad Hassan and Partners Limited.

A possible approach would be to build some temporary wind farms with a large number of small turbines—perhaps 500 3 kW domestic Chinese turbines could be used. Each would cost, say, US\$5,000 and could be resold at the end of the experiment. The total cost, including data acquisition and data analysis, might be of the order of US\$6 million. The experiment would run for one year and after that the turbines could be sold to their final users. If this experiment allowed a better understanding of the wake losses in WPB, its cost would be very modest compared to the lost generation calculated above—a US\$6 million *one-off* cost compared to US\$60 million *annual loss* for each 3.8 MW WPB.

ACTION H-4D: SMALL-SCALE WIND FARM AND COMPUTATIONAL MODELING OF WPB BEHAVIOR

Identify a suitable site, equip it with appropriately sized wind turbine models, and make performance measurements using typical spacing arrangements for WPBs. Provide a dataset for validation of computational models. In parallel develop computational models for large-scale wake effects.

H.5: Design for WPB Conditions

Commercial wind turbines are all designed according to IEC international standards. These standards were derived for northern European conditions and have served the industry well by improving the quality of design assumptions and also providing a standard set

of design conditions. It is clear, however, that conditions in many important markets—for example, South America and Texas, as well as China—are different. In some respects, these conditions may be more severe than in northern Europe and hence the turbines may not be adequate for the purpose. In other respects they may be more benign, in which case the turbines are unnecessarily expensive. They are certainly different. Figure B–22 shows the standard distribution of mean wind speeds used in the IEC standard (the Rayleigh Distribution) and also a set of data measured at Xiaocao Lake in China. It is quite clear that these two distributions are of a radically different shape. The volume of turbines now being delivered into China provides a strong argument that it is now sensible to design turbines for the site conditions. A set of WPB design criteria should be produced.

In addition to the determination of annual mean wind speed distributions, it will also be important to determine the extreme wind speeds. These are typically characterized by the once-in-50-years, three-second gust, as defined in the IEC standard. This parameter offers some scope for specific development of turbines for the Chinese market since the values of the parameters that define site Classes 1, 2, and 3 under the IEC standard are unlikely to be appropriate for Chinese sites. They were defined in order to characterize the typical wind farm sites in northern Europe and have been adopted globally, largely as a result of the absence of any other definition.

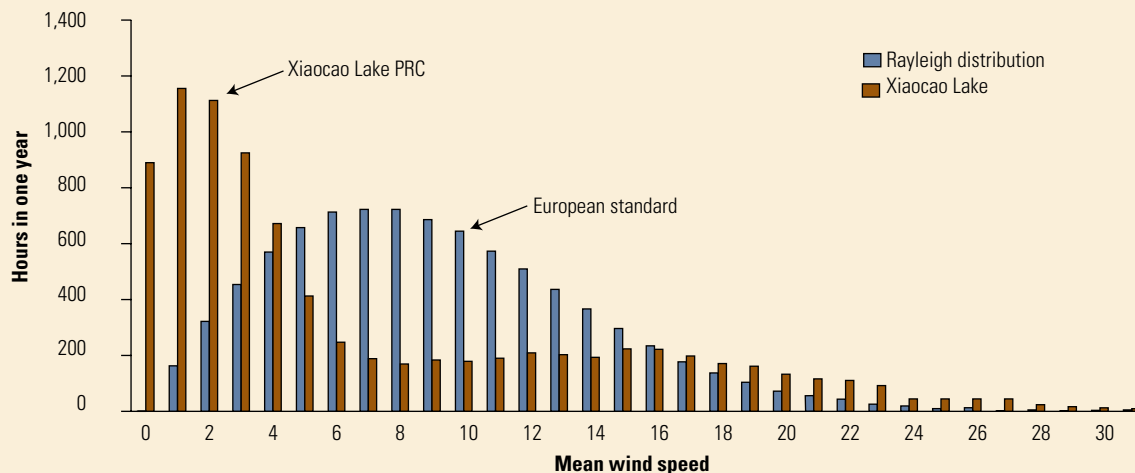
In general terms, the extreme three-second gust is assumed to be seven times the annual mean wind

speed. This approximation works quite well in northern Europe, but is not suitable for China. In some parts of China (for example, in the southeast in the typhoon belt) the extreme wind speed may be closer to 10 times the mean, and hence the IEC class designed turbines will be underdesigned. In other parts (such as Inner Mongolia) the extreme may be closer to four–five times the mean, in which case the turbine will be overdesigned and more expensive than is necessary. The design of turbines with specifications suitable for specific Chinese applications is considered to be a useful task that could have important economic implications, increasing the areas of exploitable wind energy, reducing the turbine and infrastructure cost and reducing risks. Any wind measurement campaigns that are put in place should include the facility for the measurement of the extreme conditions.

Without further detailed information about the WPB sites, it is difficult to be certain of the potential cost savings. However, if it is assumed that a typical WPB site has Class 1¹⁰ mean wind speeds and Class 2 extremes, a savings of 10 percent on turbine cost is conceivable. If, in addition, some advantage can be taken of the mean wind speed distribution, then a further 5 percent cost saving would be possible. However, if Class 2 turbines are being put in areas where Class 1 extremes are likely, the turbines are in danger.

10. Classes 1, 2, and 3 are terms used to describe different sites in the IEC standard. Class 1 has the highest mean wind speed at 10 m/s, Class 2 has a mean wind speed of 8.5 m/s. The extreme wind speeds are 70 and 59.5 m/s, respectively.

FIGURE B–22: COMPARISON OF RAYLEIGH DISTRIBUTION OF MEAN WIND SPEEDS IN EUROPE AND IN XIAOCAO LAKE



Source: CGC.

ACTION H-5: DEVELOP WIND TURBINE SPECIFICATIONS FOR WPB CONDITIONS

In order to optimize the development of the Chinese domestic industry for supply to the Chinese domestic market supply, a proper specification for the turbines for WPB conditions should be developed. A detailed appraisal of the mean wind speeds, the extreme wind speeds, the turbulence intensity, and the shear profile should be made at a range of WPB sites and a commensurate technical specification, independent of the IEC classes, should be drawn. Such an approach may well allow significant savings in the WPB cost.

H.6: Short-Term Forecasting

It has now become common in countries with a high level of penetration for the TSO to require short-term forecasts (hour by hour up to three days ahead) for any substantial wind farm. In some countries (Spain, United Kingdom, Ireland) this has been done on a wind farm-by-wind farm basis. In other areas (Texas, California, New York State, Greece) it has been done on a system-wide basis. Short-term forecasting technology has developed rapidly over the last few years. Figure B–23 shows an example of the forecast produced for a portfolio of 450 MW of wind farms for each hour one day ahead. That is, the line marked “actual” is the average power that was produced each hour for the period shown and the “forecast” line is the prediction of that power made on an hour-by-hour basis one day in advance. This shows that wind power is variable but predictable. The appreciation of this quality is essential for the proper integration of wind power into the Chinese grid. Confidence in such

techniques will greatly enhance the confidence of the state grid in its integration of the WPBs.

ACTION H-6: PILOT SHORT-TERM FORECASTING

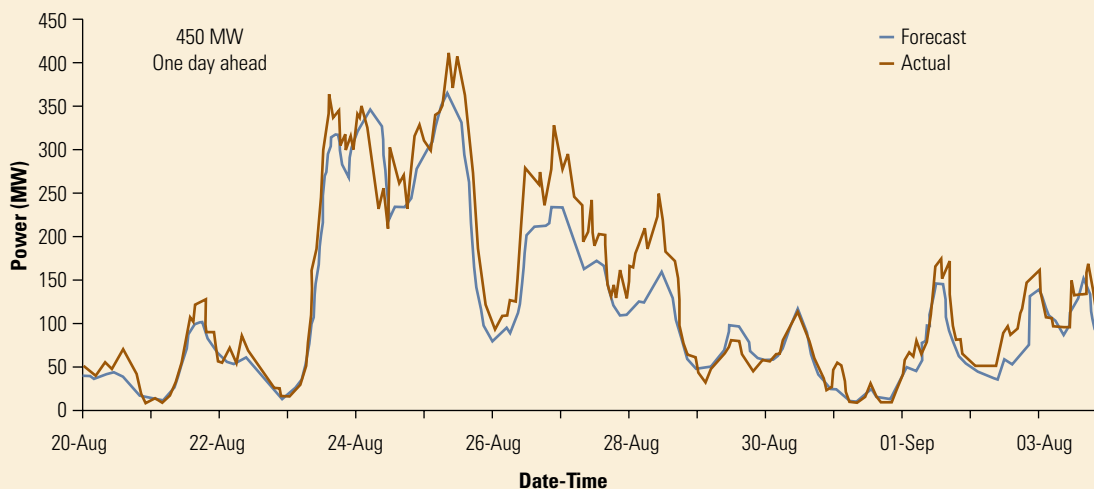
Government should initiate some pilot short-term forecasting demonstrations in order to allow the TSOs to gain experience of and confidence in these techniques. Experience elsewhere has shown that the forecasting tools often perform better than is anticipated by the TSOs. Hence, their early use can ease the passage of large-scale introduction of wind energy into the grid. It is suggested that experience is gained in short-term forecasting of operational wind farms (that is, not in waiting until the WPBs are operational) in a range of conditions prior to the start of operation of any of the WPBs. These forecasts should be initiated and specified in consultation with the TSO. Short-term forecasting is likely to be a requirement for the WPBs and should greatly ease their integration into the system.

Group I: Turbines

I.1: Use of Proven Turbines

It is understood that the intention is to use Chinese turbines in the WPBs. There is still relatively little operational experience of these turbines. There is therefore a major risk that the turbines will not be ready for large-scale exploitation. Experience in the West of a rapid progression from prototype, to large-scale commercial use has been unsuccessful. A good example of such a problem was the initial deployment, in the 1990s, of the Zond (later part of Enron Wind) Z-750 turbines. After reasonable

FIGURE B–23: AN EXAMPLE OF SHORT-TERM FORECASTING



Source: Garrad Hassan and Partners Limited.

experience of one 750 kW prototype, Zond deployed 143 in the first large-scale wind farm in the United States. The wind farm did not work satisfactorily for a further five years. Initial deployment of the wind turbines offshore in Denmark suffered in exactly the same way. The V-80 deployment in Horns Rev is a good example. These turbines should have been proved in benign circumstances before installation in a difficult regime. This is a common problem when there is a very strong commercial incentive that outweighs engineering common sense.

A systematic process is adopted that only allows the use of proven wind turbines on large-scale commercial wind farms. This may slow the development of the WPBs, but in the long term, it will have a positive effect on the large-scale exploitation of wind energy in China.

It may be useful to consider the definition that Garrad Hassan and Partners Limited has developed for a commercially proven turbine. This definition has been adopted by a number of the larger equity investors in large-scale wind farms. For a turbine that is a genuine evolution from another commercial turbine, the new turbine under consideration may be considered “commercially proven” if all the following conditions are met:

- It is manufactured by a company capable of performing all the contractual and commercial obligations.
- It carries a current, valid GL, DNV, or other recognized certificate.
- There are 100 turbines in operation.
- There is at least one turbine with more than 4,000 h of operation.
- There is a fleet of turbines with a cumulative number of turbine hours in excess of 50,000.
- The average availability of the fleet is greater than 95 percent.

In this context, it must be demonstrated that the relevant turbine(s) has the ability to achieve the projected availability. For a turbine that is not a genuine evolution from another turbine, the required number of cumulative hours for meeting condition number 5 in the list above should be 100,000 hours.

These definitions may also be used as an indication of the likelihood of obtaining project finance for a wind farm. The present Chinese approach, which appears to be to offer large-scale PPAs to unproven turbines, would not attract Western-style project finance, since the turbines do not meet these criteria.

I.2: Development of Chinese Certification Rules

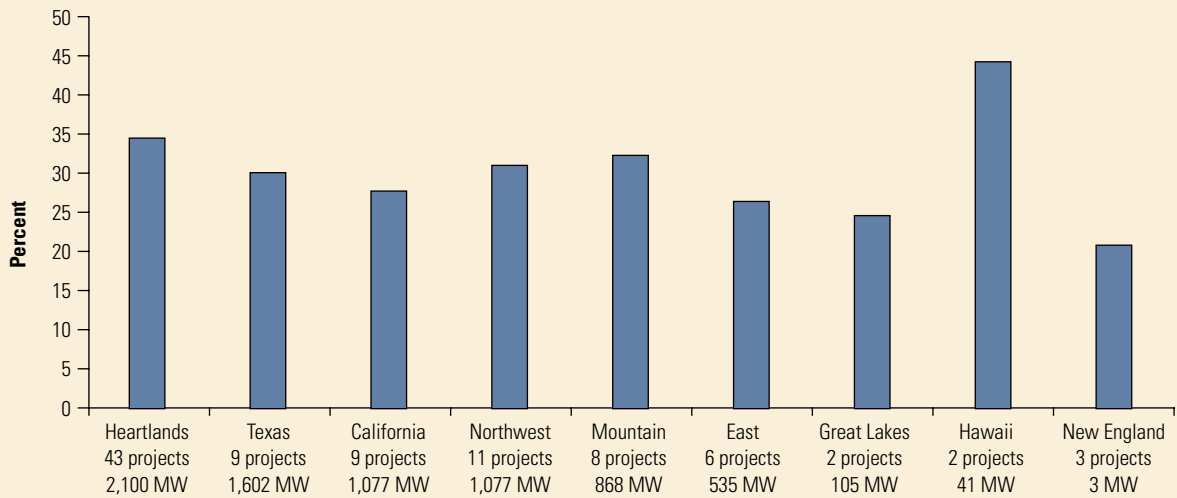
Certification has played a major role in the creation of reliable wind turbines in the West. The certification process is only helpful if it adds value through its technical input and can command the respect of the turbine manufacturers and designers. It must not be just a bureaucratic process; it must consist of a detailed and authoritative review of the design.

In order to ensure that proven turbines are available, a strong certification regime must be put in place. This regime must be based on substantial technical expertise. Any Chinese body providing such a service must be actively encouraged to cooperate fully with other similar international bodies. The Chinese certification bodies must be properly funded and encouraged to undertake detailed technical evaluations, help define applicable standards, and participate in international certification and standards cooperation.

I.3: Operational Monitoring

The wind industry in China is still relatively new and expanding very rapidly. Despite the presence of a large number of actual and potential manufacturers, there is little indigenous experience in design. The performance of turbines installed in China, both domestic and foreign, has been largely poor—the energy reproduced has been significantly less than that projected, as shown in Table B-4. For projects in the WPB areas, capacity factors in the region of 30–40 percent should be obtained, since the wind speeds are so high, as suggested above. This trend is a result of three separate issues: 1) poor calculation methodology and/or wind data used to make the original projections, 2) poor availability of the turbines due to operational shortcomings, and 3) poor-quality design and/or manufacture. Much can be learned from a detailed examination of these difficulties.

It is instructive to compare the values provided in Table B-4 for China with those for projects elsewhere in the world. Reliable published data are scarce but the U.S. Department of Energy does publish some useful results that are shown in Table B-5 and Figure B-24. It is clear that there is a considerable regional variation in capacity factor but, apart from some very early projects, the values are significantly higher than those reproduced in Table B-4 for China.

FIGURE B-24: CAPACITY-WEIGHTED CAPACITY FACTORS FOR U.S. WIND FARMS IN 2007

Source: U.S. Department of Energy—Energy Efficiency and Renewable Energy—Annual Report on U.S. Wind Power Installation, Cost and Performance Trends: 2007, Published May 2008.

TABLE B-4: ANNUAL FULL-LOAD HOURS OF SOME WIND FARMS

| Province | Number of wind farms | Annual full-load hours in 2007 | Capacity factor | Average power of wind turbine (kW) |
|----------------|----------------------|--------------------------------|-----------------|------------------------------------|
| Hebei | 4 | 2,373 | 0.27 | 885 |
| Inner Mongolia | 7 | 1,933 | 0.22 | 770 |
| Liaoning | 9 | 1,325 | 0.15 | 715 |
| Jilin | 4 | 1,931 | 0.22 | 798 |
| Shanghai | 2 | 1,651 | 0.19 | 1,356 |
| Zhejiang | 1 | 1,344 | 0.15 | 609 |
| Fujian | 5 | 2,000 | 0.23 | 986 |
| Shandong | 3 | 1,728 | 0.20 | 881 |
| Guangdong | 6 | 1,600 | 0.18 | 566 |
| Hainan | 1 | 1,417 | 0.16 | 483 |
| Gansu | 2 | 1,737 | 0.20 | 786 |
| Xinjiang | 4 | 2,401 | 0.27 | 654 |
| 12 provinces | 47 | 1,787 | 0.20 | 791 |

Source: "Booming Wind Power Market and Industry in China," Shi Pengfei, Chinese Wind Energy Association.

A detailed examination of a wide range of large operational wind farms should be undertaken and the results used to improve the operational procedures used for the wind farms as well as to identify the shortcomings of the turbine designs. International collaboration would be valuable in this work. The results should be disseminated to as wide a range of stakeholders as possible.

I.4: Development of Appropriate Turbine Supply Contracts

For projects of this size, careful thought must be given to the contractual conditions and the associated technical specifications. In the West a huge variety of contract conditions and specifications has been developed. Although some diversity is helpful since it allows developers to undertake projects to their own requirements, a higher degree of standardization would be helpful to give some commercial flexibility but within a standard form.

Low availability is likely to be a problem, at least with the early implementation of the projects. Hence, it is suggested that long-term availability warranties should be a standard part of the supply contract. These warranties should contain financial penalties for poor availability that adequately reimburse the project. A clear definition of availability should be provided that should be objective. Many warranty definitions are slanted in the manufacturer's favor. The warranties should be for a minimum period of five years and should also contain clauses that only relieve the project from these obligations after it has proven that it is capable of good, long-term availability.

TABLE B-5: CAPACITY-WEIGHTED CAPACITY FACTORS ACHIEVED BY U.S. WIND FARMS BY YEAR

| Capacity Factor | Heartlands (%) | Texas (%) | California (%) | Northwest (%) | Mountain (%) | East (%) | Great Lakes (%) | Hawaii (%) | New England (%) | |
|-----------------|----------------|-----------|----------------|---------------|--------------|----------|-----------------|------------|-----------------|----|
| Pre-1998 | 28.9 | 11.9 | 22.3 | | | | | | 19.8 | |
| 1998-99 | 30.2 | 28.2 | 29.8 | 32.1 | 34.4 | | 23.4 | | | |
| 2000-01 | 33.4 | 29.6 | 34.5 | 28.7 | 29.3 | 22.5 | 23.5 | | 27.0 | |
| 2002-03 | 34.4 | 33.5 | 32.6 | 30.5 | 30.3 | 28.5 | 21.2 | | | |
| 2004-05 | 36.8 | 34.5 | 37.5 | 34.0 | 38.9 | 26.7 | 31.0 | | | |
| 2006 | 40.8 | 30.4 | 36.9 | 31.3 | 34.7 | 29.4 | | 45.0 | 22.1 | |
| Sample | # | MW | # | MW | # | MW | # | MW | # | MW |
| Pre-1998 | 1 | 26 | 17 | 870 | | | | | 1 | 6 |
| 1998-99 | 8 | 470 | 5 | 190 | 3 | 68 | 3 | 22 | | |
| 2000-01 | 10 | 229 | 1 | 67 | 4 | 123 | 2 | 32 | 1 | 1 |
| 2002-03 | 20 | 628 | 4 | 287 | 3 | 510 | 1 | 50 | | |
| 2004-05 | 16 | 1,086 | 4 | 461 | 3 | 208 | 1 | 54 | | |
| 2006 | 7 | 386 | 3 | 944 | 2 | 150 | | | 2 | 41 |
| Total | 62 | 2,825 | 20 | 2,687 | 15 | 1,490 | 7 | 158 | 2 | 41 |

Source: U.S. Department of Energy—Energy Efficiency and Renewable Energy. Annual Report on U.S. Wind Power: Installation, Cost and Performance Trends: 2007, May 2008.

I.5: Making Data Available

In the West, progress has been hampered by the lack of freely available operational data and lack of attention to the data when they are available. The operational data are extremely valuable and can be used to improve the performance of the wind farm for which they are gathered and also to improve the behavior of future wind farms. Developers will not necessarily recognize this fact, so the projects should be structured so that they are required both to collect and to analyze these data.

As part of the contract, high-quality data collection systems should be specified and reporting obligations should be imposed. The general scientific data should be available for further analysis outside the commercial confines of the individual developer. Understanding the operation of the WPBs will be an essential ingredient for future optimization and therefore cost reduction.

Group J: Infrastructure and Support

J.1: Streamline Environmental Impact Assessment

The impact on the environment of such a concentrated wind farm scheme could be substantial, depending of course on where it is. Clearly, consideration of this matter will be part of the original site search and selection. Minimizing the aggregate environmental impact will be important, but at the same time recognition of the environmental benefit of benign generation on a large scale must be considered as a balance. An Environmental Impact Assessment will be required just as for any other large-scale developments and can follow the lines already established for normal-size wind farms.

In order to streamline the environmental assessment procedure it is suggested that a master plan for the production of such a study be provided. It can be based on the best practice guidelines that have been produced in Europe and can be suitably modified for application in China.

J.2: Training

There is no doubt that if 10 GW of wind energy is installed in a relatively concentrated way, that area will become an industrial center. Such activity will initially attract construction and manufacturing work. Later it will attract the support industry required for ongoing O&M, including

both direct operational crews and spare parts manufacture. Given this major concentration of wind energy endeavor, R&D activities may well follow. This plan will certainly have an effect on local industry and economic wealth if successful. It will be recognized as a center for wind energy in global terms. To the knowledge of Garrad Hassan and Partners Limited, there is no other equivalent center anywhere else. The WPBs will require a huge human resource. In the West there is a serious shortfall of trained personnel. There is no shortage of people to be trained, but the facilities to train them are lacking. The WPB will face exactly the same problem—only at a higher level.

China must make proper preparations to ensure that the trained personnel are available to support the WPBs and in time to be helpful. Training programs and other means of attracting the staff to the WPBs should be considered on an urgent basis. The training should be at all levels: from R&D through design and production to O&M. There are training programs that have been put in place by Western manufactures that could help significantly with this effort if they were made available. There are also specialist training schools for O&M activities that may be prepared to offer their services.

It is estimated that some substantial wind farms in the United States are losing 1–2 percent of the energy as a result of poor O&M practices, in particular through the use of inadequately trained personnel. The U.S. wind industry has been expanding very rapidly, and hence there is a close parallel to what might happen in China.

J.3: Creating Bankable Projects

It is not known whether it is expected or intended to attract Western finance to the WPBs. There is some merit in the argument that the bigger the project, the more debt that can be attracted. Some banks are not interested in lending on projects of less than US\$1 billion. The availability of debt for very large projects has not hitherto been considered to be a problem; the advent of the credit crunch may of course have a major effect on the availability of Western funds. The availability of Western debt for projects in China is a significant challenge, unless some substantial changes are made to typical wind farm deals.

If Western finance is required, it is suggested that the WPB projects be structured in such a way that allows the banks to assess their risk in a conventional fashion. They will have, at least, the following requirements:

- PPAs free from regulatory risk—no changes to commercial terms after initiation of project
- PPA with adequate term (say 20 years) with creditworthy offtaker
- All permits in place for the full length of the PPA
- Subprojects free from risk of interference from other subprojects
- Proven technology
- Full due diligence of insurance, technology and legal aspects of the subproject
- Creditworthy suppliers of all components
- Turbine supply and balance of plant contracts with adequate warranties
- O&M agreements with performance-related payment clauses
- Evidence of properly trained personnel
- Adequate spare parts holdings
- No currency risk
- Proper insurance
- Comprehensive construction and operation agreements; solid warranties from suppliers.

Introductory Guide to the Installation of Offshore Wind Farms

This annex provides an overview of major steps involved in the installation of an offshore wind farm. It includes an overview of foundation types, installation vessels, options for support structure installation, turbine installation, and electrical systems.

An offshore wind farm is made up of a number of wind turbines, each placed on a robust foundation, and connected by cables to the electrical grid. Installation of an offshore wind farm requires a suite of installation vessels and tools, with a custom-made vessel required for the support structure, the wind turbine, and the cables.

FIGURE B1.1: SIEMENS 3.6 MW WIND TURBINE AT BURBO BANK



Source: Siemens press photo.

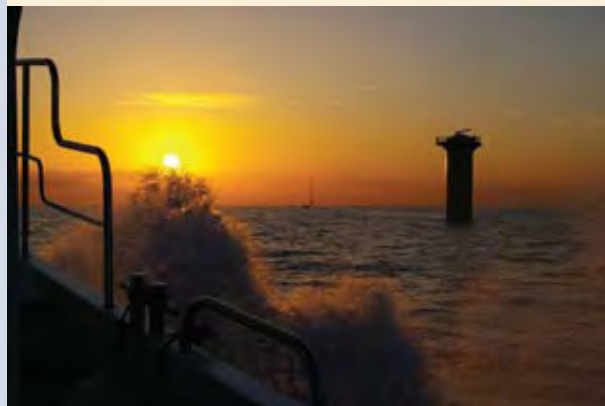
Currently, the largest offshore turbines (Figure B1.1) have rotors of more than 100 m in diameter, and the blade tip can reach up to 150 m above the surface of the water.

All offshore wind farm sites bring their own unique challenges. The conditions shown in Figure B1.2 may be ideal for offshore operations, but the capability must also be provided to operate in severe seas. Otherwise, weather downtime will be excessive, and the program will not be completed within a season.

The solutions need to be customized to site conditions, and different wind farm design choices require different foundation, installation, and electrical solutions.

The presence of a competent, highly skilled workforce is crucial for operating the specialist vessels in the

FIGURE B1.2: GUNFLEET SANDS, UNITED KINGDOM



Source: Andrew Henderson, Garrad Hassan.

challenging marine conditions that will invariably be faced offshore.

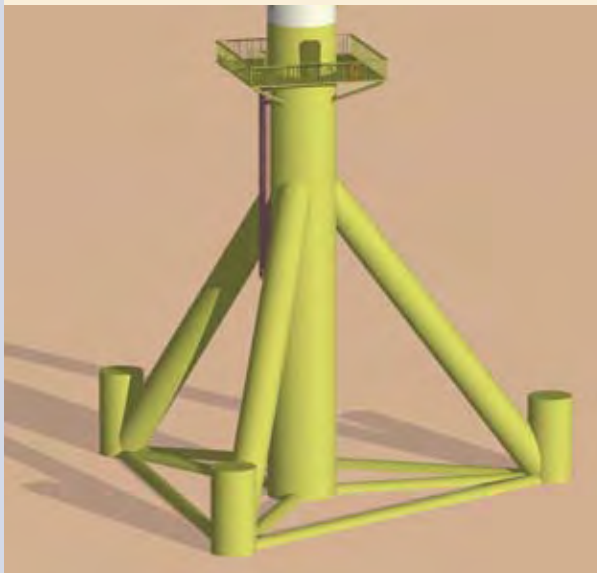
1. Foundation Types

The installation of an offshore wind farm requires very different types of foundation from those onshore. The most common type used to date has been steel tubes, called monopiles, which are driven into the ground with a pile driver.

The tube sizes needed to support a turbine in water depths of greater than 30 m become too large for the largest pile drivers in the world, and so tubular steel frameworks become the more economic option. These come in a number of forms, for example, a four-legged structure called a jacket, which is also commonly used for offshore oil rigs. Other forms of foundations that are being used or seriously considered include tripods (Figure B1.3) and quadropods, which have three or four legs, respectively, supporting a central tube, or a tripile foundation, which is a structure consisting of three separate piles with a connection piece located above the water.

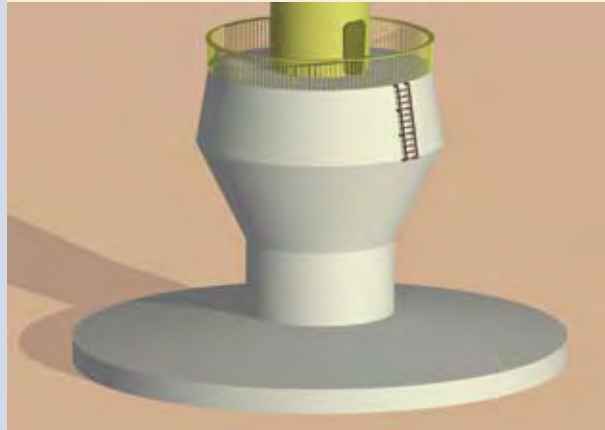
In certain situations, concrete structures called a “gravity base” (GB) (Figure B1.4) may be preferable for economic or practical reasons. They would generally not be piled into the seabed, but they are so heavy and have such a wide base that they can support all the loads of

FIGURE B1.3: TRIPOD SUPPORT STRUCTURE



Source: Andrew Henderson, Garrad Hassan.

FIGURE B1.4: GRAVITY BASE FOUNDATION



Source: Andrew Henderson, Garrad Hassan.

the turbine without the need for anything other than their self-weight. This approach naturally leads to very heavy structures, which require careful consideration with respect to transport and installation. To reduce the weight, they can be of a hollow design, and thus may be able to float. They would later be filled with ballast when they are in place.

The main disadvantage of GB structures is that they require a lot of seabed preparation, offshore ballasting, and sometimes backfilling around the base. Foundation contractors prefer to keep offshore operations to a minimum in the onerous conditions found at most offshore wind farm sites. Hence, to date, most offshore wind GB structures have been built in the calmer Baltic Sea, the exception being the Thornton Bank project off the Belgian coast.

2. Installation Vessels

The favored installation vessel for both foundations and the wind turbines themselves is the jack-up crane-barge (Figure B1.5). This is a crane on a boat, which can jack itself out of the water. Effectively, the crane is on a stable platform, and the challenges of the excessive movement when floating on a rough sea are avoided.

Specialist wind farm installation vessels are also available, which are ships designed to include cranes, as well as jacking legs. They are self-propelled and can sail quickly between port and the offshore wind farm carrying foundations or turbines (Figure B1.6).

FIGURE B1.5: JACK-UP CRANE-BARGE: SEA JACK

Source: A2Sea.

FIGURE B1.6: SPECIALIST WIND FARM INSTALLATION VESSEL: THE RESOLUTION

Source: MPI Offshore Limited.

When very heavy lifts are needed, such as some offshore substations, shear leg crane-barges are required. The crane is firmly attached to the structure of the barge and cannot rotate; it can only be raised or lowered. Although there is a loss of flexibility, there is a greatly increased load-carrying capability. This type of vessel can lift many thousand tons.

Finally, there is a group of vessels that will have been designed for a particular specialist project, and once that task has been completed can be modified to undertake other tasks, such as installing offshore wind farms. An example that is being used regularly for offshore wind farms is the Svanen. It can lift 8,700 t and was designed to install the Oresund Bridge connecting Denmark and Sweden. It has been found to be suitable to install both piled and gravity foundations, and has worked on a number of wind farm foundations around the UK and Dutch coasts.

FIGURE B1.7: SPECIALIST INSTALLATION VESSEL: THE SVANEN

Source: Ballast Nedam Offshore.

Figure B1.7 shows the Svanen working on a monopile installation with a red L-shaped pile-lifting tool, a piling hammer to its right, and a yellow transition piece. Svanen means swan in Dutch, an apparent reference to the shape of the vessel.

In addition to the installation vessels, there will be a large fleet of support vessels called the *spread*, for personnel transport, surveying, and transportation (Figure B1.8). For example, it may be uneconomic to use the large installation vessels for transporting foundations and turbines from the mobilization port to the wind farm site. In that case, feeder barges are towed to the site using tugs, and sometimes jack-up barges are used, since this allows the

FIGURE B1.8: TRANSPORTATION BARGE TOWED BY A TUG AT GUNFLEET SANDS

Source: Chris Garrett, Garrad Hassan.

cargo to be lifted from a fixed platform, and the site can operate in a wider range of sea conditions than if heavy loads are lifted from a floating craft.

3. Support Structure Installation

The monopiles are lifted into a frame on the installation vessel called a piling gate (Figure B1.9) and supported while the crane lifts the hammer on top. To avoid injury to dolphins, seals, and whales, an underwater loudspeaker system may be used to drive sea creatures away before piling starts.

Hydraulic impact hammers (Figure B1.10) have been preferred and are capable of driving piles of up to 6 or 7 m in diameter.

If the ground conditions are particularly hard and the pile cannot be driven to its design depth, a drill will be used to remove some material before further attempts are made to drive the pile (Figure B1.11). This is called “drive-drill” installation. Great care must be taken with disposal of any cuttings from the center of the pile, since disposal of the “up-rising” can cause a plume of contaminated water.

A number of pieces of secondary structures are required on each foundation, for example, boat fenders, electrical cable guides (called *J tubes*), access ladders, walkways, davits, navigation lights, transformers, and other sensitive equipment. These structures would impede pile driving and could be damaged in the process. The solution is to fit a transition piece over the pile with all of these items prefitted and tested. This approach also allows final adjustment for verticality of the pile, using jacks, before it is grouted firmly. When the grout has been allowed to cure, the foundation is ready to receive the turbine tower.

FIGURE B1.9: MONOPILE INSTALLATION



Source: Chris Leach, Noble Denton.

FIGURE B1.10: PILING HAMMER (LEFT) AND ANVIL/ADAPTOR PIECE (RIGHT)



Source: Chris Garrett, Garrad Hassan.

FIGURE B1.11: REVERSE CIRCULAR DRILL



Source: Chris Garrett, Garrad Hassan.

FIGURE B1.12: HEAVY LIFTING CRANE HANDLING GRAVITY BASE STRUCTURE



Source: This image is used with the permission of Scaldis Salvage and Marine Contractors NV.

GB support structures are installed using very different vessels, either a shear-leg barge or a specialist vessel, such as Eide 5, shown in Figure B1.12. The crane picks the GB off the barge and lowers the structure onto the carefully prepared seabed.

4. Turbine Installation

The requirements of the crane for the installation of the turbines are somewhat different from those for the foundations; hence, different vessels may be used. In particular, the nacelles and blades need to be lifted to a great height above the water—beyond the normal capability of conventional offshore crane vessels (Figure B1.13). Many jack-up installation vessels have long legs, but it takes a long time to jack up and it fatigues the expensive legs, so the better option is to use a crane with a lower lift capacity than the piling crane, possibly with an extended boom, called a fly jib, to further increase lift height and reach.

Towers are in one or two sections. The main turbine unit is called the nacelle, which contains the gearbox and generator, the rotor hub, and the three blades, meaning that a large number of lifts may be required. Some of these components will be preassembled onshore in order to reduce the activity offshore. For example, two blades may be attached to the nacelle, after which this partly assembled turbine is raised in what is known as a “bunny ears” lift, with the final blade being attached last. Figure B1.14 shows a single blade being lifted.

FIGURE B1.13: INSTALLATION OF WIND TURBINE AT BURBO BANK, UNITED KINGDOM



Source: Siemens Press Photo.

FIGURE B1.14: INSTALLATION OF WIND TURBINE AT BURBO BANK



Source: Siemens Press Photo.

5. Electrical System

If the wind farm is very large or far from the electrical grid, an offshore substation may be needed to transform the voltage from the wind turbine level (typically 33 kV) to a level suitable for long-distance transmission. This would typically be around 132 kV, so that the electrical losses in the long export cable can be reduced.

HVDC connections are under serious consideration for some European projects.

Offshore cables must be robust; hence, they are expensive specialist components. An AC connection consists of three conductors (for the three-phase electricity generated), together with a fiberoptic cable for the computer data communications and steel wire armoring for protection.

All cables are buried under the seabed to ensure their protection, as well as safety, to mariners and fishermen. This can be undertaken with specialist plows that are towed across the seabed. They bury the cable and refill the trench as they proceed (Figure B1.15).

FIGURE B1.15: CABLE LAYING



Source: Image courtesy of IHC Engineering Business Ltd.

Turbines are usually connected in strings of 6 to 10 and are limited by the maximum capacity of the medium-voltage, interturbine array cables. The strings are then connected to an offshore substation (Figure B1.16). For smaller projects, they are connected directly to land. From the substation, an HV high-capacity cable will deliver the power to shore.

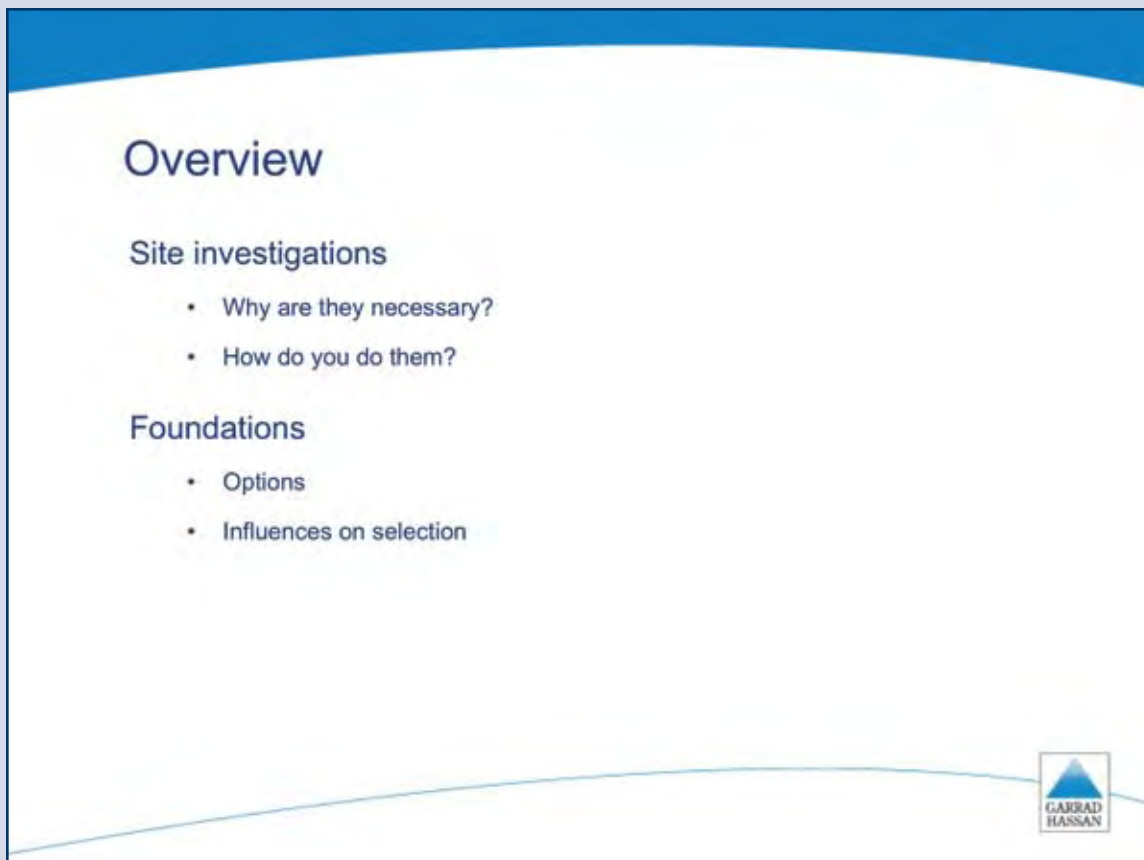
When the cable arrives on land, it often has to be buried for several kilometers in order to reach the nearest point at which it can connect to the electricity grid.

FIGURE B1.16: SUBSTATION AT BARROW OFFSHORE WIND FARM



Source: Centrica Energy.

Summary of Seabed Conditions and Foundation Options



The need for site investigations

Foundation design

- Foundations may constitute up to 20–30% project cost
- Bathymetry
- Foundation design—geotechnical/geophysical conditions
- Hydrodynamic loading of structures (met ocean)

Environmental impact assessment

- Physical
 - Baseline data
- Biological
- Socioeconomic/cultural



“No construction project is risk free. Risk can be managed, minimised, shared, transferred or accepted. It cannot be ignored.” M Latham (1994)

Well-planned site investigations, carried out early in the project timescale are essential to ensure that the potential risks associated with the occurrence of unexpected physical site conditions are minimised.



Geotechnical / geophysical investigations

Phased approach

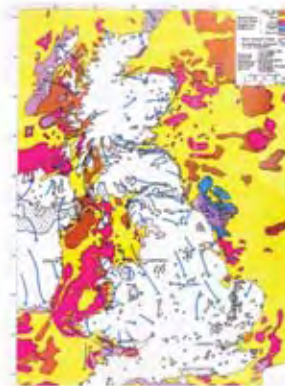
- Desktop studies
- Preliminary geophysical survey
- Preliminary project layout
- SI planning
- Onsite investigation
- Laboratory testing



Geotechnical / geophysical investigations

Desktop studies

- Sources of existing information
 - Geological maps
 - British Geological Survey
 - Previous works
 - Construction works
 - Cable/pipeline laying
 - Oil/gas exploration
 - UK Hydrographic Office
 - Aerial photography
 - Local knowledge
- Collate and compare all existing information
 - Define the current state of knowledge
 - Highlight what is not known about the site



Geotechnical / geophysical investigations

Preliminary project layout (based on desktop studies)

- Physical constraints
 - Historical comparison of bed levels—time history
 - Water depths
 - Grid connection
 - Ecological constraints
- Preliminary site layout
 - Site area
 - Possible turbine layout
 - Likely cable route



Geotechnical / geophysical investigations

SI planning

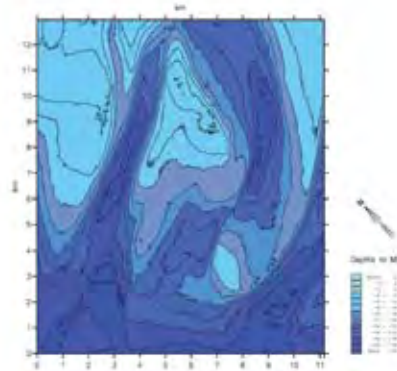
- Risk vs. cost
 - Initially sufficient information for preliminary design
 - Adequate coverage
 - Reliability of data—borehole vs. seismic
- Weather/accessibility—summer preferable
- Program
- Contractor availability / vessel choice
- Range of investigations
 - Based on results of desktop study
 - Geotechnical/geophysical
 - Metocean



Geotechnical / geophysical investigations

Onsite investigations—bathymetry

- Sonar survey
 - Cover turbine area and surrounding sea
 - Closely spaced orthogonal survey runs on main area - 100 to 150 m
 - Surveying can be more widely spaced on more remote areas
 - Large areas covered at minimal cost
 - "Fills in" areas between boreholes
 - Should be planned to coincide with borehole locations
- Linked into coastal processes study



Geotechnical / geophysical investigations

Onsite investigations—geophysical

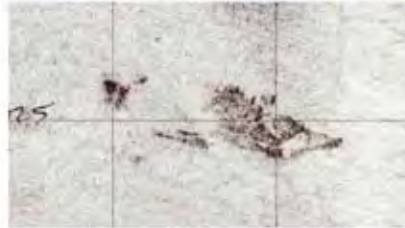
- Sub-bottom profiler
 - Towed array with DGPS positioning
 - Provides information on sub-bed stratigraphy
 - Results based on interpretation of seismic profile
 - Large areas covered at minimal cost
 - "Fills in" areas between boreholes
 - Should be planned to coincide with borehole locations



Geotechnical / geophysical investigations

Onsite investigations—geophysical

- Side scan sonar
 - Towed array with DGPS positioning
 - Provides information on bed profile
 - Identifies size and direction of sand waves
 - Used by archaeologists to identify wrecks / anomalies



Geotechnical / geophysical investigations

Onsite investigations—geophysical

- Magnetometer
 - Towed array with DGPS positioning
 - Provides information on metallic anomalies
 - Used by archaeologists to identify wrecks/anomalies



Geotechnical / geophysical investigations

Onsite investigations—geotechnical

- Boreholes
 - Shell and auger / rotary drilling
 - Grid pattern modified as required by local features—number of holes will depend on the purpose of the investigation and the stage of the project.
 - Depths typically 30–40 m
 - Drilled from jack-up platform
 - Flexibility through prompt reporting
 - Range of sampling/testing
 - Description/logging
 - Undisturbed and disturbed sampling
 - Cone penetration testing
 - Rock coring



Offshore foundations

- Types
- Influences on selection and design



Offshore foundations to date

| Location | Date of commissioning | Distance from shore (km) | No of turbines | Turbine type & rating | Water depth (m) | Foundation type |
|-----------------------|-----------------------|--------------------------|----------------|-----------------------|-----------------|------------------|
| Vindby, Denmark | 1991 | 1.5 > 3.0 | 11 | Bonus 450 kW | 2.5 > 5 | Concrete gravity |
| Lely, Netherlands | 1994 | 1 | 4 | Nedlwind 500kW | | Steel monopile |
| Tund Knob | 1995 | 6 | 10 | Vestas 500kW | 3 > 5 | Concrete gravity |
| Dronien, Netherlands | 1997 | 0.4 | 28 | Nordlank 600kW | 5 | Steel monopile |
| Bockstigen, Sweden | 1998 | 4 | 5 | Wind World 500kW | 6 | Steel monopile |
| Ugrundan, Sweden | 2000 | 8 > 12.5 | 7 | Enron Wind 1500kW | 7.2 > 10 | Steel monopile |
| Blyth, UK | 2000 | 0.5 | 2 | Vestas 1800 & 2000kW | 7.5 | Steel monopile |
| Middlegrundan, Sweden | 2000 | 2 | 20 | Bonus 2000kW | 2 > 5 | Concrete gravity |
| Ytre Stengrund Sweden | 2001 | 6 | 5 | Neg Micon 2000kW | 9 | Steel monopile |
| Horns Rev, Denmark | 2001 | 17 | 80 | Vestas 2000kW | 6.5 > 13.5 | Steel monopile |
| North Hoyle, UK | 2003 | 7 > 8 | 30 | Vestas 2000kW | 10 > 15 | Steel monopile |
| Nysted, DK | 2004 | 12 | 72 | Bonus 2.3MW | 10 | Concrete gravity |
| Arklow Bank, Ireland | 2004 | 14 | 7 | GE 3.6 MW | 5 > 8.5 | Steel monopile |
| Sorby Sands, UK | 2004 | 2.5 | 30 | Vestas 2MW | 4 > 12 | Steel monopile |
| Kentish Flats | 2005 | 12 | 30 | Vestas 3MW | 5 | Steel monopile |
| Barrow | 2006 | 5 | 30 | Vestas 3MW | 20 | Steel monopile |
| OWEZ | 2006 | 10-18 | 36 | Vestas V90 | 22 | Steel monopile |
| Beatrice | 2007 | 25 | 2 | REpower 5M | 45 | Quadropod |
| Burbo | 2007 | 6 | 25 | Siemens 3.6 | 8 | Steel monopile |



Foundation types

Monopile

Gravity

Multi-pile

Suction

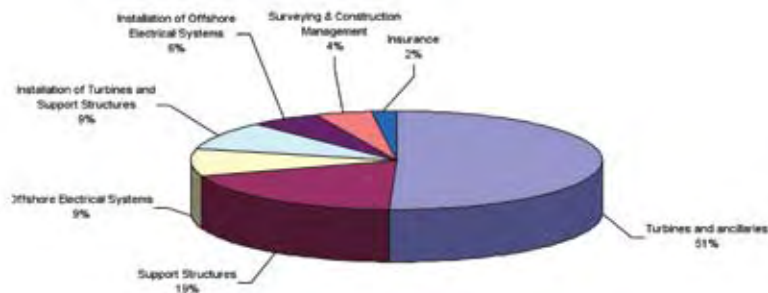
Floating



Why are foundations important?

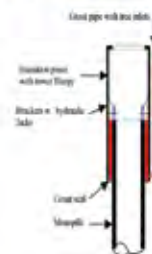
Large proportion of capital costs

Major risk for cost and program



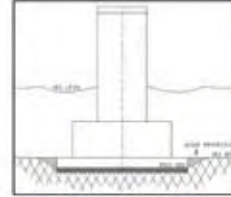
Foundation types—monopile

- Steel tube
- Typically 4.5–5 m dia
- Thickness 30–60 mm
- Driven/drilled
- Transition piece grouted to top of pile



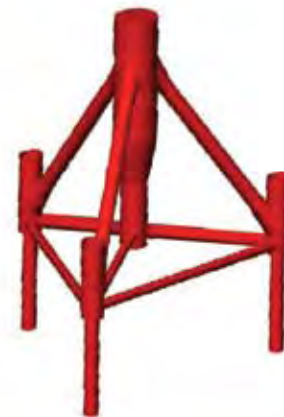
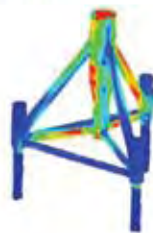
Foundation types—gravity

- Steel or concrete
- Relies on weight of structure to resist overturning
- Ballast may be required
- Seabed preparation essential
- Can be susceptible to scour
- Better suited to shallower sites



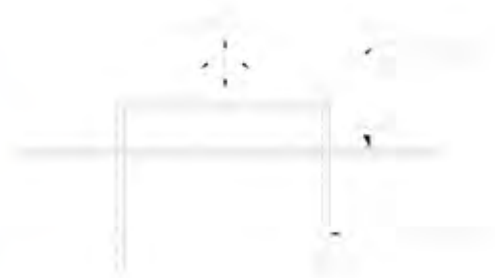
Foundation types—multi-pile

- Small diameter steel piles
- Tubular steel superstructure
- Grouted or swaged pile connections
- Suitable for deeper water
- No installations to date



Foundation types—suction

- Steel skirt caisson structure
- Penetrates into seabed under self-weight
- Trapped water pumped out to produce suction effect
- In use as mooring anchors for offshore installations
- Feasibility stage at present for turbine foundations

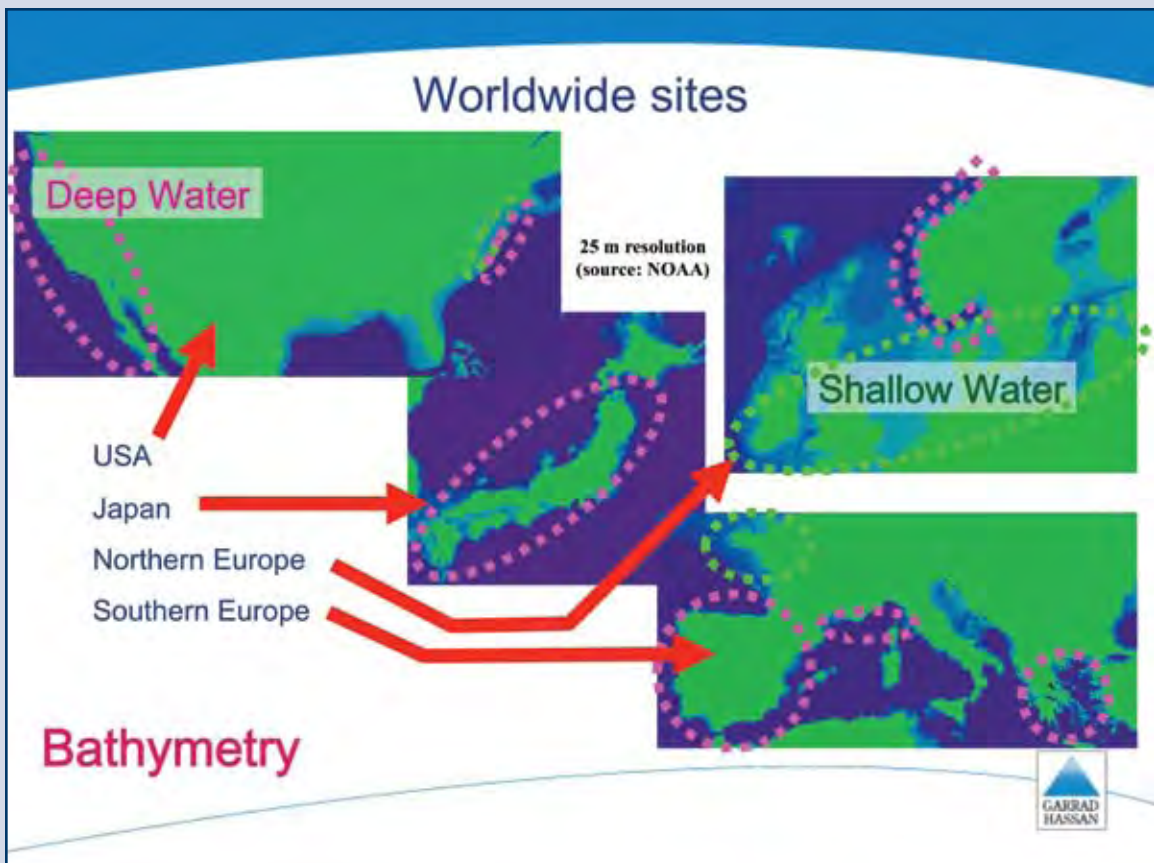
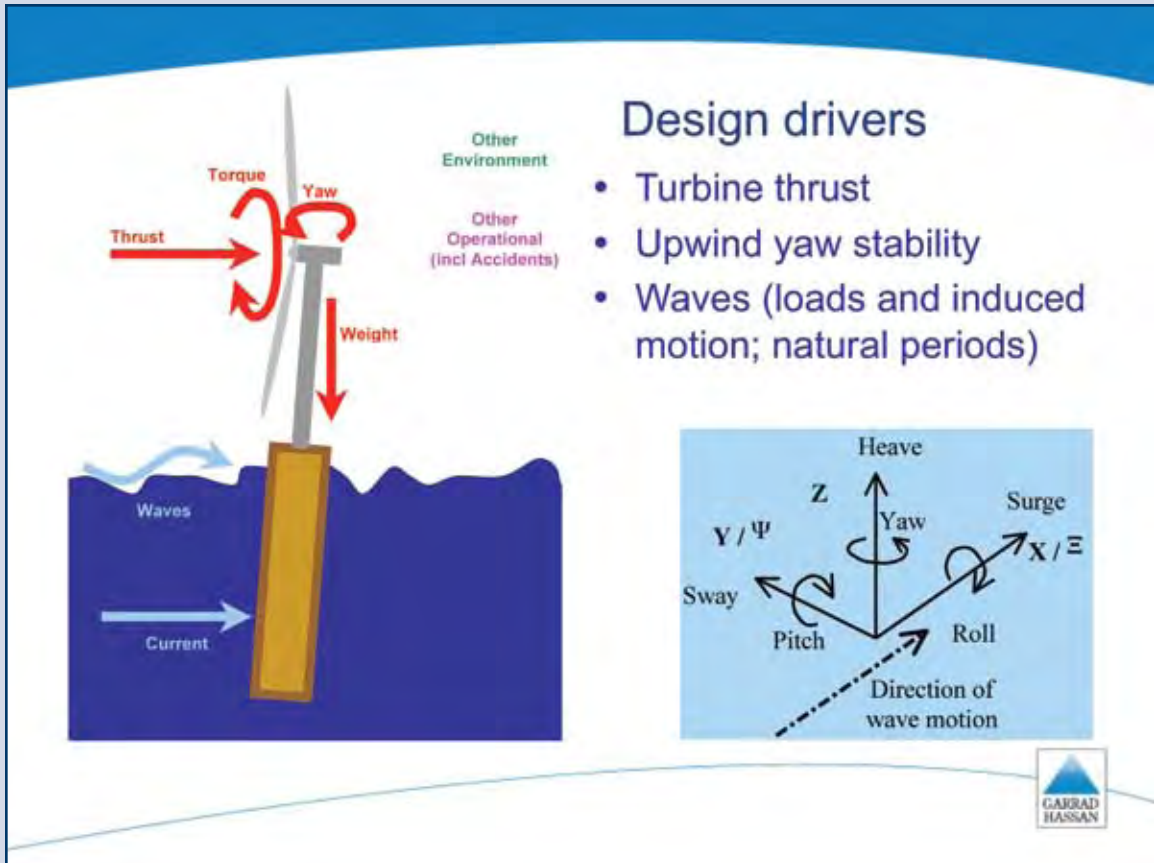


Floating foundations

Benefits:

- Expands potential to new sites and countries
 - Norway, USA, Spain, Japan...
- Wide choice of concepts
 - Evidence: see variety of proposals
- Similar cost as bottom-mounted
 - Once concepts are proven
- Greater flexibility of construction and installation procedures
- Easier removal / decommissioning





Floating Foundations: 3 Classes of Concept

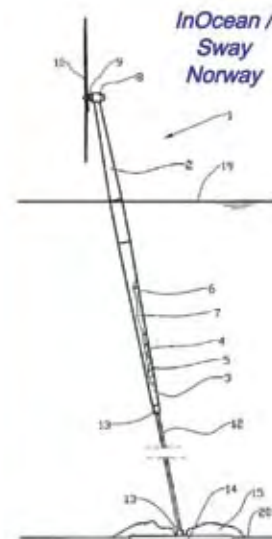
Achieving stability

- i. Hydrostatic (water-piercing area)
- ii. Mass (pendulum effect)
- iii. Moorings (tensioned)



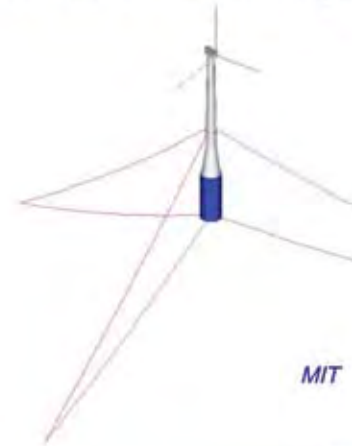
Candidate Concepts: TLP

- Low motion
- Cost of moorings
- Difficulty of installation / removal



Candidate Concepts: Spar Buoy

- Large mean and dynamic motion response (c.f. other concepts)
- Shorter buoy would require a heave-suppression disc or firmer moorings



Candidate Concepts: Tri-Floater

- Damping plates needed to increase natural periods (and hence reduce motion response)
- Shallow waters (< 50 m)
- c.f. TLP: less risky but more expensive
- Turbine at corner
→ Heavier structure
- 4-floater
→ Heavier structure



Foundation Types—Influences on Choice

- Water depth
- Soil and bed conditions
- Environmental loading
- Construction methodology
- Cost



Influences—Water Depth

- Increased overturning with increased depth
- Larger structures required to support same turbine
- More difficult working environment



Influences—Soil and Bed Conditions

- Stratigraphy
- Soil strength
- Level of rock head
- Bed mobility
 - Overall bed movement
 - Local scour



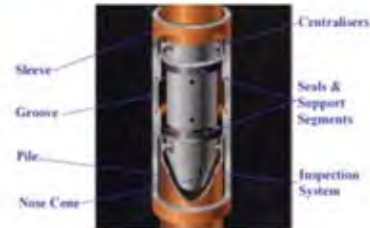
Influences—Environmental Loading

- Wind loading from turbine
- Wave height and period
- Breaking wave conditions
- Current speed
- Ice
- Marine growth



Influences—Construction Methodology

- Fabrication/shoreside facilities
- Available installation equipment
- Transport of foundations
 - Size
 - Weight
- Foundation connections
 - Speed of installation
 - Temporary propping required?
 - Attendance required?



Hydra-Lok® Swaged Connection



Influences—Installation

- Available equipment/resources
 - Jack-up/floating barge
 - Piling equipment
 - Cable laying
- Local logistical restrictions
 - Harbor/shoreside facilities
 - Water depth/tidal restrictions
- Conditions of statutory consents
- Weather



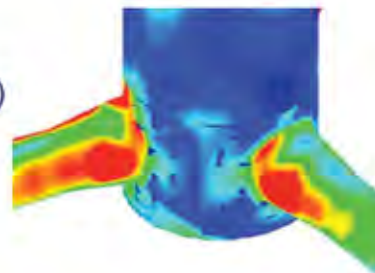
Influences—Cost

- Fabrication
 - Raw material cost
 - Location—at port if possible
 - Transport—overall size/weight
 - Form of fabrication
- Installation
 - Attendance required
 - Transport from port
 - Time on site/potential for delay
 - Tolerance
 - Weather windows
- Decommissioning
- Risk



Foundation Types—Detailed Design Considerations

- Combined wind and wave loading
- Dynamic loading
- Fatigue (FE analysis)
- Interaction with turbine (natural freq.)
- Access
- Cable connections - J tubes
- Corrosion protection
- Scour protection
- Constructability
- Cost
- Decommissioning



Overview

Site investigations

- Why are they necessary?
- How do you do them?

Foundations

- Options
- Influences on selection



Source: Garrad Hassan and Partners Limited Roadmap.

Part C

Messages from the Workshop on Offshore and Intertidal Wind Power Development in China

Technical Notes on Resource Assessment, Construction, and Grid Integration

This section comprises three technical notes summarizing the messages emerging from the Workshop on Offshore Wind and Coastal Wind Base Development held in Beijing on January 15, 2009. Each section covers one of the three major topics discussed during parallel sessions of the workshop, namely:

1. Wind resource assessment and site screening.
2. Offshore wind farm construction technology.
3. Grid integration.

The notes provide a summary of the discussions that took place during each session, focusing on the key concerns raised, and possible solutions. Although not an exhaustive list of all possible issues and solutions, the notes are intended to give the readers a sense of what issues were raised in the workshop, and what is being done in China and internationally to address the issues raised. These are followed by further technical guidance specific to those issues.

Additional information and comprehensive discussion of issues not covered in these notes are available in Part B, Implementation Guidance for Offshore and Large-Scale Onshore Wind Power Development in China.

Session on Wind Resource Assessment and Site Screening: Overview of Workshop Presentations

Coastal and Offshore Wind Resource Assessment in China.

Yang Zhenbin from the Chinese Academy of Meteorological Sciences presented information on the ongoing nation-wide wind resource assessment effort. He also discussed the results of a numerical simulation his agency undertook to model wind resources in Jiangsu coastal and offshore areas. Song Lili, of the China Meteorological Administration (CMA), presented typhoon scale wind speed observation data and analyses on the risk and frequency of typhoons for southeast China. Zhang Xiuzhi, of the CMA, informed participants about the coastal wind resource assessment effort and feasibility study for a 100 MW offshore wind farm project off the coast of Jiangsu, both supported by the EU-China Energy and Environment Program.

Offshore Wind Resource Assessment and Site Selection: The case of Jiangsu Dongtai project.

Gao Hui, Chief Engineer, Guohua Energy Investment Company, presented the company's experience with wind resource assessment and site selection for wind power projects in Jiangsu Dongtai. Results from a wind resource measurement effort in Jiangsu were also discussed.

Offshore Wind Resource Assessment and Site Selection: The Case of Fujian Province.

Richard Boddington, from Sgurr Energy, discussed the example of an offshore wind farm in Nanri Island and presented the step-by-step best practice methodology that was developed for offshore wind resource assessment and site selection.

Key Messages, Issues, and Solutions

The following subsection presents some perspectives, issues, and solutions discussed during the workshop with respect to wind resource assessment and site screening.

Quality and sharing of offshore wind resource data

It was noted that at present there is a huge variation in terms of the means, tools, and quality of data collected on offshore wind resources and ocean conditions; data across multiple sources are not comparable.

- Participants expressed concern over the apparent fragmentation of offshore wind resource measurement, data collection, and analysis efforts and responsibilities. It was noted that this situation results in redundancy of efforts and a waste of money and resources.

- Discussions at the workshop indicated that there is limited, if any, cooperation or data sharing between the different entities that are in possession of information, including private entities, government agencies, and research institutes.
- At present, in addition to the CMA's efforts to undertake wind resource assessments of specific areas, the State Oceanic Administration, provincial fishery administrations, other provincial agencies, wind power developers, oil platform owners, and so forth gather data on wind resource and ocean conditions in offshore areas. (Examples of activities focusing on wind resource assessment are presented in Box C-1.)
- It was pointed out that the existing national technical specifications for wind resource measurement and assessments (GB/T 18709-2002 and GB/T 18110-2002) are considered to be rather general and insufficient for practical operation. At present, there are no national specifications for assessment of offshore wind resources. CMA plans to develop new technical specifications for that purpose.
- Participants discussed the most efficient way to encourage private developers to contribute their data to a possible public database for China's offshore wind resources. One of the possible options identified was the use of an incentive structure. Developers noted that, in the absence of such an incentive, there would be no reason to share data collected.

Proposed solutions

Participants concurred that the concerns identified could be addressed by:

- Establishing a national offshore wind resources observation network and an offshore wind resource database for integrating data gathered by various entities, under the leadership of NDRC or NEA
- Formulating standards specific to the measurement of offshore wind energy resources and evaluation of ocean conditions, such as sea level and wave height, including meteorological mast specifications that clearly lay out particular differences between on- and offshore requirements
- Developing guidelines for site selection for offshore wind farms.

Specific characteristics of the wind regime in coastal areas in southeast China

- During the session, typhoons were identified as one of the biggest barriers to coastal and offshore wind farm development in the coastal and offshore areas. An analysis of the 50-year, three-second gusts along

BOX C-1: WIND RESOURCE ASSESSMENT EFFORTS IN CHINA

The following is a summary of examples of recent and ongoing activities in support of wind resource assessment in China. In addition to the activities outlined here, there are various efforts by universities, research institutes, provincial meteorological bureaus, and wind farm developers to assess wind resources in various parts of the country. The efforts are undertaken at multiple levels, from very broad resource mapping to site-specific measurements and assessments tailored to the development of individual wind farms.

- **UNEP/NREL/GEFWind Energy Resource Atlas of Southeast China.** Between 1996 and 1999, the U.S. Environmental Protection Agency (EPA), and the U.S. Department of Energy (DOE) sponsored a wind resource assessment effort for specific regions of southeast China. The U.S. National Renewable Energy Laboratory (NREL) and the American Wind Energy Association, which administered the activity on behalf of the EPA, lead the technical analysis and mapping activities. Data for the activity were collected with the assistance of the China Hydropower Planning General Institute (CHPGI) of the State Power Corporation. High-resolution wind resource maps were developed using a GIS-based program developed at NREL.
- **Wind resource mapping of onshore areas by CMA.** Between 2005 and 2007, CMA carried out an onshore wind resource extrapolation, based wind data collected on 10m height in 2,500 climate stations in 31 provinces. This activity resulted in the creation of a general wind energy resource map of China. Under the project, a preliminary wind resource database was set up, and national “technical specifications” for wind resource measurement and assessments were formulated (GB/T 18709-2002 and GB/T 18110-2002).
- **New CMA activity for expanded measurement network, meso-scale modeling, and mapping.** In 2007 the CMA, with support from MOF and NDRC, launched a meso-scale modeling and wind mapping effort based on data from a country-wide wind resource observation network. The network comprises all of CMA’s climate stations and 400 masts to be built, with heights of 70 m, 100 m, and 120 m. The 400 new meteorological masts would be set up in areas with a minimum annual average wind power density 150 W/m², measured at 10 m. The number and heights of masts to be set up in the coastal areas of Fujian, Jiangsu, and Zhejiang Provinces, as part of this activity, are as follows:
 - Fujian: 15 70 m masts and 3 100 m masts
 - Jiangsu: 12 70 m masts and 2 100 m masts
 - Zhejiang: 9 70 m masts, 2 100 m masts, and 1 120 m masts.

The **World Bank/GEF China Renewable Energy Scale-Up Program** supports a series of provincial and site-specific wind resource measurement and assessment activities in Fujian, Inner Mongolia, Jiangsu, and Zhejiang.

Under the **EU-China Energy Environment Programme**, the Center for Wind and Solar Energy Resource Assessment (CWERA), of the National Climate Center under CMA, will be developing meso-scale models covering a 10,000 km stretch of coastline from Fujian to Shandong. This will be combined with satellite derived wind data and local wind measurements to produce a high-resolution wind map of an area 10 km inland and 30 km offshore from the coastline.

As part of the **Sino-Danish Wind Development Programme**, CMA will work with Risoe to undertake meso-scale modeling and high-resolution wind mapping of Northeast China (Heilongjiang, Jilin and Liaoning).

the Chinese coast was presented by the CMA. In this analysis on the risk and frequency of typhoons, it was found that only the east coast of Hainan Island and a few isolated parts of the coast of Fujian Province experienced wind speed values in excess of 70 m/s, which is equivalent to IEC Class I turbines.

According to the analyses, there has been very limited occurrence of typhoons north of the Yangtze River, making the area suitable for offshore wind power development. Nevertheless, it was stressed that this analysis is not comprehensive, and further studies and measurements are required.

- Fast-changing, twisted wind shear profiles combined with sudden changes in wind direction and flow inclination common in typhoon situations will create additional loading on the turbines; therefore, some areas that exhibit 50-year gusts of less than 70 m/s may still be unsuitable even for Class I turbines. In fact, in the areas in question, although average wind speeds are within IEC design classes, there have been cases where the extreme wind speeds during typhoons led to turbine damages in wind farms.
- A recommendation was made to install 100m and 120m masts in these areas to measure the shear across the rotor disc.
- In the case of coastal Jiangsu, findings from a recent measurements carried out by an investor indicated that offshore wind speeds in Jiangsu are 1.3 to 1.5 times faster than onshore. Moreover, it was noted that wind speeds appeared to increase the most within 20 km of the coastline, and more or less stabilized beyond 20 km from the coast.

Large Wind Farm Wakes

It was stressed that additional high wake effects not modeled by traditional wake modeling software packages have been noted in large offshore projects in Europe. It was noted that this effect is currently not well understood and R&D is ongoing.

Conclusions

The most prominent conclusion that emerged from the session was the importance of the availability and quality of wind resource data. It is evident that it will be useful to create a mechanism for data sharing, whereby the owners of the data will be compensated for their contribution, after which the data will be accessible to all interested parties. This may form a good basis for a high-level study on the wind power potential for the coastal areas. Establishment of an offshore database of measurements spread along the coast of China will provide a strong resource for calibrating a meso-scale wind map.

An important aspect will be to identify the most appropriate way to give private developers an incentive to contribute their data to this platform. Of the options discussed during the session, creation of an incentive for data sharing could be explored further. However, it is essential that any development priority given to a private party be accompanied by an obligation to make data available and proceed with development within an agreed-upon

time frame; and the developers should be made aware that they risk losing that priority in case they fail to meet either of the commitments.

Government guidance for offshore resource measurement standards would be useful. The measurement standards for offshore wind energy resources and ocean conditions, which session participants requested the government to develop, should provide guidance on the scope and means of measurements.¹¹ The establishment of standards for measurement by the government could also help reduce the cost of offshore measurement masts for investors, by identifying items that absolutely need to be measured.

It was evident from the session that step-by-step guidance on site selection for offshore wind farm development is of interest for the parties involved. In addition to the “roadmap” prepared by Garrad Hassan and Partners Limited, international examples of required steps in offshore wind farm site selection and development are available and could be a useful input to the preparation of such guidance.

Further Considerations

In addition to the recommendations made during the workshop, some lessons from international experience are important for wind resource assessment and site selection. Though not fully covered during the workshop, the consideration of these aspects will be useful as China moves forward and decision makers identify solutions to issues encountered. These are discussed below.

Data collection and monitoring are vital for the accurate assessment of wind resources at a site and determination of energy production from a possible wind farm. A robust on-site monitoring campaign with well-instrumented hub height masts remains of paramount importance for an accurate energy assessment of a specific wind farm to be undertaken.

- The choice of mast type, height and setup, and measurement equipment, and selection of the number and location of meteorological masts, are essential components for enabling detailed and accurate assessment of the wind and energy resource of

11. For instance, these standards could require involved parties to record wind speeds at heights of 10 meters, 40 meters, 80 meters, and 100 meters.

the site. Conducting measurements at hub height is strongly advisable, given the small relative extra cost of choosing a tall mast, compared to the overall cost of installing a mast offshore.

- Satellite data, combined with meso-scale modeling, can give a sense of relative wind speeds, though not as accurate as actual measurements and monitoring at a site.
- In addition, wind flow modeling over larger distances, up to 10 km between mast and turbine locations, is acceptable for sites that are far offshore.¹²
- Light detection and ranging (LIDAR) remote sensing systems, as discussed during the workshop, do present some clear advantages over traditional cup anemometers mounted on a measurement mast, such as ease of relocation, ability to measure at a large number of heights, and, in the case of some new systems under development, the ability to map a number of potential turbine locations from the same position due to a moveable beam.¹³ However, current disadvantages of LIDAR systems include high costs, high power requirements, difficulty in remote locations, lack of validation data for most options on the market, and security issues. Even the most established LIDAR systems available at present have been validated only in certain operational conditions. At present, devices whereby a number of turbine locations can be monitored from a single stationary point, or motion-sensitive devices for allowing the LIDAR systems to be floated offshore, are far from providing a realistic commercial alternative to standard wind monitoring methodologies. Nevertheless, LIDAR will play a very important role in the future wind measurements globally and will be particularly powerful when used in combination with conventional anemometry masts.

Continued monitoring after wind farm construction is critical. There is need for reliable long-term meteorological masts in wake-free locations to be left in place close to wind farms, subsequent to their construction and commissioning in order to allow a consistent source of reference data to be available for postconstruction operational energy analyses to be undertaken.

12. The definitive standard for the mounting of anemometry and wind vanes on wind measurement masts is currently provided in the relevant IEC Standards. (IEC 61400-12-1, “Wind turbines—Part 12-1: Power Performance Measurements of Electricity Producing Wind Turbines, Annex G,” 2005).

13. In addition, LIDAR systems can monitor only one location at any given time. Additional calibrations are being actively pursued.

It is important to undertake specific work to understand the average and extreme wind characteristics in likely sites, particularly in southeastern coastal regions where typhoons have been observed. Standard storm extreme design load cases for wind turbines assume that the turbine yaw system will be in operation. This means that a turbine will, at least to some extent, track changes in wind direction, and that the spectral, temporal, and spatial characteristics of turbulence are assumed to be the same as for normal operating conditions. For typhoons, it is likely that changes in wind direction occur rapidly enough for the yaw system to be “caught out.” Therefore, extreme conditions for all wind directions (and possibly coherent changes in direction) should be considered. It is also possible that the spectral, spatial, and temporal characteristics of typhoon winds are different from those assumed for normal operating conditions. As a result, although analyses indicate a low incidence of 50-year extreme wind speeds along the coast of China in excess of 70 m per second, specific work should be undertaken to understand the wind characteristics in detail (both mean and extreme) in the likely wind farm sites.

Underprediction of wake effects by models needs to be recognized and should be carefully considered. Validation of wake loss models against actual production from large offshore projects indicates that wake loss models are underpredicting the actual wake impacts under some scenarios; and the reasons for this deviation are the subject of significant ongoing debate. With regard to onshore wind farms, it is difficult to differentiate wind speed changes due to wake effects from those due to terrain effects. Therefore, the quality of the datasets available for validation of wake effects for large onshore is lower. It is likely that the mechanisms that are causing underprediction of wake effects for large offshore wind farms will also be experienced for large onshore wind farms, at least to a certain degree. This effect is more likely to occur where the surface roughness and ambient turbulence are both low, as is the case for many large planned onshore developments within northern China. Additional wake effects are generally observed for turbines with at least five rows of upwind turbines. Since many planned developments in China are an order of magnitude larger than even the wind farms used as the basis for these investigations, the potential for increased wake effects is likely to be high and should be carefully considered when reviewing the predicted energy yield of large wind farms.

Session on Offshore Wind Farm Construction

The topics discussed during the session included international experience with offshore wind farm construction and installation, offshore wind turbine foundation design and certification, an overview of the proposed methodology for the construction of an intertidal wind farm in Jiangsu Province, and Longyuan Electric Power Group's strategy for coastal offshore wind farm development.

Review of internationally adopted construction methods.

Andrew Garrad, from Garrad Hassan and Partners Limited, provided a detailed overview of construction and installation methods for offshore wind farms. The presentation covered information on options for equipment transport and logistics, support structure setup, wind turbine assembly, subsea cable installation, substation setup, and vessels.

Offshore wind turbine foundation design and design certification. Zhang Yu from the China General Certification Center made a presentation on internationally used offshore wind turbine foundation design approaches, followed by a discussion of the certification processes.

Proposed construction approach of an intertidal wind farm.

Wang Xinming from SANY Heavy Industry Co. presented the company's approach for the construction of an envisaged intertidal wind farm in Jiangsu Province. His presentation included an analysis of geographic conditions, construction challenges and possible solutions.

A developer's perspective on intertidal wind power development.

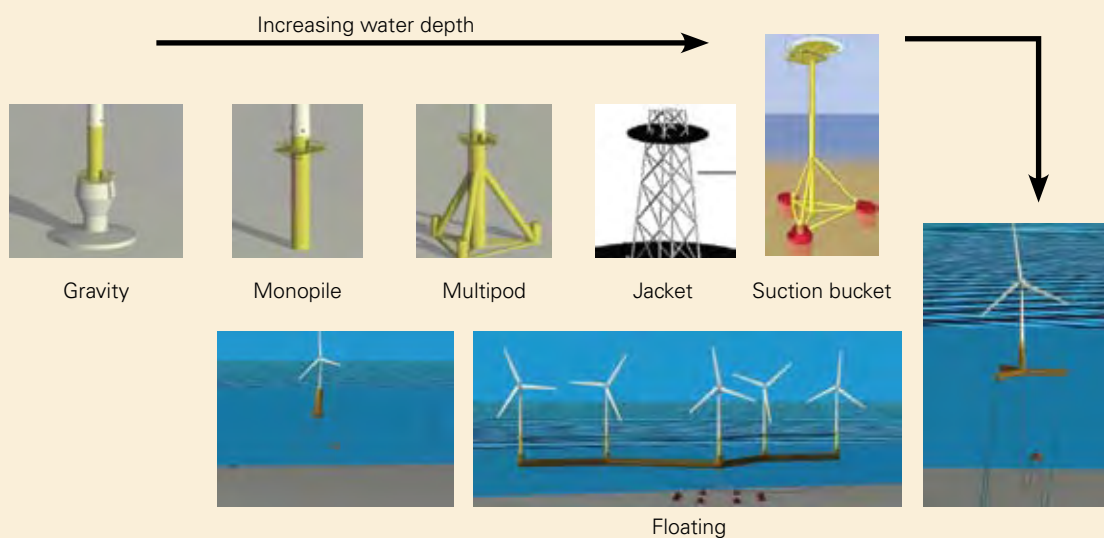
Longyuan Power Corporation's representative presented the company's plans for intertidal and offshore wind farm development.

Key Messages, Issues, and Solutions

The presentation by Garrad Hassan and Partners Limited provided a technical overview of the various options for offshore wind farm construction methods. The key messages from Mr. Garrad's presentation on options for offshore wind farm construction methods are summarized below:

- The choice of offshore foundation is determined by seabed conditions and water depth. (Various foundation options are illustrated in Figure C1.1.)

FIGURE C1-1: FOUNDATION OPTIONS



- Offshore foundation is determined by the seabed condition and the water depth.
- Currently gravity and monopile are the most frequently used options.

Source: Presentation by Garrad Hassan and Partners Limited.

- Choice of method for transporting components and equipment depends on the physical dimensions of tower/nacelle/blade and the closeness of fabrication to port.
- The installation sequence begins with the foundation, followed by the transition piece, the two sections of the tower, and nacelle and blade assembly.
- Installation of subsea cable and substation is also part of offshore wind farm construction.
- Vessels and other construction equipment are critical.

The presentation by the China General Certification Center also provided an overview of foundation options, outlined aspects of foundation design, and emphasized the role certification can play in the process. Mr. Zhang pointed out that:

- The selection of wind turbine should be taken into account during foundation design.
- Foundation design certification (including site assessment, load assessment, structure strength assessment, load reassessment, anticorrosion design, and anti-erosion design) can help ensure the quality of foundation design and reduce the investment risk.
- Proper attention needs to be paid to O&M procedures to be adopted after construction.

Current thinking in terms of intertidal wind farm construction methods

- Wang Xinming, from SANY Heavy Industry Company, presented the company's design for construction of the construction of an intertidal wind farm. His presentation included an analysis of geographic conditions, construction challenges, and possible solutions.
- During the presentation by SANY, transportation and storage of materials, vessels, and components; installation of foundation and wind turbine; and anticorrosion of materials were identified as primary technical difficulties of intertidal wind farm construction.
- In view of the features of the tidal range, the intertidal zone was classified into two parts:
 1. "Area I" is characterized by high tide water levels of between 0.5 and 2.5 m—where the length of time without water is long enough to enable the use of amphibian equipment as the preferred option.
 2. "Area II" is characterized by high tide water levels of 2.5 to 7.0 m, and the period of time where the seabed is submerged under water is long; therefore, offshore equipment is preferable.

- The company identified the following as workable options for intertidal wind farm construction: amphibian multipod rail vehicle, flexible crawling crane, aerial floating pile driver, and small removable platform.
- The presentation was based on the use of a 1.5 MW turbine. The envisaged foundations include multiple piles with a concrete cap. Foundation is designed as multipod, PHC tube pile is used to match the wind turbines.
- The central component of the design is a large vehicle with four independent crawlers with a maximum weight of 200 tons. On the crawler vehicle is mounted an extendable crane that can lift the various wind turbine components and the pile driver. Concrete for the foundation is pumped from the shore. The turbines are delivered to the specific locations in separate lots: one assembled three-bladed rotor, the tower divided into three sections, and the assembled nacelle. The crawler-mounted crane can lift these elements individually.
- It was clear that much work had been done on the subject and the process can be considered to be well advanced and at the end of the outlined design stage.

Longyuan's plans for intertidal wind farm development

Longyuan Power Corporation, a major wind farm developer and a subsidiary of the State Power Corporation, outlined the challenges of offshore wind farm development from a developer's perspective. These included high construction cost and risk, higher requirement for wind turbine, the limited number of mature Chinese-made wind turbines, and increased difficulty of O&M.

As part of a discussion of the company's development plan and current work, it was pointed out that the State Power Corporation views intertidal development as a starting point for offshore development and plans to go to offshore after the intertidal scale-up development. This choice appears to stem from the belief that this approach would enable the company to reduce risks to some extent and to establish a foundation for offshore wind farm development. However, Longyuan representatives acknowledge the fact that there are no mature examples of intertidal wind farm development.

The State Power Corporation plans an intertidal wind farm demonstration project in Jiangsu. So far, the company has completed wind resource measurement, environmental assessments, wind farm development planning, intertidal construction method research, and verification of key technical parameters for construction. It was also

noted that the company drafted “Engineering Specifications for Offshore Wind Farm Construction.”

Conclusions and Further Considerations

Currently, intertidal wind farm development is the focus of attention. Presentations by Chinese speakers in the session on offshore wind farm construction technology focused primarily on intertidal development, rather than “true offshore” development.

Intertidal development should be encouraged since the potential for wind energy in these areas is huge, provided that a reliable economic means of construction can be developed. There is no useful precedent for this type of development elsewhere in the world. During this session, there was no presentation from the only active offshore project, that is, the Shanghai Donghai bridge project. It would be useful if the lessons learned from the Shanghai Donghai project’s experience were shared by the interested parties.

There needs to be further preparatory work to gather data about site conditions, in order to identify the most appropriate construction techniques. Site conditions remain a matter of the utmost importance if developments are to take place in a sensible fashion. To date there is little, if any,

information about either the wind or the soil conditions offshore. There is consensus that the soils data within the intertidal region vary considerably. Therefore, it seems entirely plausible that adequate strength is available in some locations. There should be a central mechanism for gathering these data as described in the “roadmap.” It appears that the development of technical guidance and standards for offshore wind farm construction will be appreciated by the parties involved.

Development of vessels and other equipment to respond to the particular conditions of intertidal areas is crucial. The outline design that was presented for the intertidal developments is of considerable interest. Although it was not possible to gain a real insight into the work, due to limited time during the session, it was clear that work done is rather advanced and has been professionally conducted. The conclusion that the crawler vehicles can be used was somewhat surprising; however, this reluctance about the validity of that method is based on the very limited soils data that were publicly available. Work on these technologies should be started as soon as possible. In view of possible challenges, government support will be necessary to mitigate the risks associated with the process and share the costs of preliminary development efforts.

Session on Grid Integration

Presentations during the session on grid integration covered a range of subjects, including technical issues, challenges, and solutions for grid integration of wind farms, as well as overview of international experience and preliminary plans for grid integration of large wind farms in China.

Challenges and solutions for grid integration of wind power in China. Wang Weisheng, of China Electric Power Research Institute (CEPRI) under the State Grid Corporation, outlined the issues for grid integration of wind power in China from the perspective of the transmission system, conventional power producers, wind turbine manufacturers, and wind farm developers. Dr. Wang also presented a range of technical and policy solutions to resolve possible issues.

Preliminary plans for grid integration of large wind farms in China: The case of Northwest Wind Power Base. Yi Linong, of the Northwest Grid Company, presented technical issues, possible solutions, and overall plans for wind power integration in northwest China, where large projects are concentrated in certain areas and necessitate power transfer over long distances (greater than 1,000 km).

Preliminary plans for grid integration of large wind farms in China: The case of Jiangsu coastal WPB. Zhang Pu Zhuan, the Deputy Director of the Planning Department of the State Grid, reaffirmed State Grid Company's commitment to addressing the challenges associated with grid integration of large wind farms. Wang Ya Li, Senior Engineer in the Planning Department, provided a review of State Grid Company's work on grid integration of wind power and presented a study on preliminary plans for the grid integration of the 10 GW WPB in the coastal area of Jiangsu Province.

European experience in grid integration of wind power. Paul Gardner, of Garrad Hassan and Partners Limited, presented the European experience with grid connection and integration of offshore wind farms. In his presentation, Mr. Gardner discussed technical aspects of grid connection of offshore wind farms, as well as issues, costs, and risks associated with the operation of a system with large amounts of wind power penetration.

Learning from international experience: The case of grid integration of wind power in Alberta, Canada. Hu Ming, of the Alberta Electric System Operator (AESO) in Canada, presented AESO's experience with preparing for grid integration of wind power. Mr. Hu discussed the scope and findings of studies on the possible effects of increasing

wind power penetration in southern Alberta. He presented detailed methodologies to assess and analyze the operational impacts of wind power variability and uncertainty and related mitigation measures.

Key Messages, Issues, and Solutions

From the session, it was evident that sector participants and decision makers were aware of the range of technical issues associated with grid connection and integration of large wind power capacity. The issues identified included: achieving transmission planning to match the pace of wind farm development; optimal solutions for connecting wind farms to the grid; the availability of balancing services to addressing variability and limited predictability of wind power; and reactive power control.

The general conclusion was that the technical issues that were identified during the workshop are generally the same issues found on other national electricity systems with high wind penetration, and technical solutions are available for the anticipated issues. In other words, none of these issues is insurmountable. It is worth noting that, as technical issues become more complex, solutions become more expensive (Box C–2).

BOX C–2: SOLUTIONS FOR GRID INTEGRATION OF WIND FARMS

Possible solutions to ensure increased wind power penetration have been widely recorded in recent publications. Options for addressing wind power impacts on the grid, arising from its variability and limited predictability, include:

- Transmission network upgrades to accommodate the incremental output and assist with issues such as voltage control
- Satisfactory reactive power control achieved with conventional solutions
- Balancing provided by other generators
- Geographic aggregation of wind farms, that is, spreading wind farms widely across the available area in order to reduce the variability of the total output power
- Improved control of wind farms both on local and system levels
- Introduction of specific grid code requirements for wind farms, such as low voltage ride through
- Forecasting, monitoring, and communication technologies.

Source: European Wind Energy Association, "Wind Energy: the Facts."

The following subsection presents some of the perspectives and solutions discussed during the workshop with respect to grid connection and grid integration of wind power.

Power transmission planning

- The problem of achieving transmission planning and constructing the reinforcements within the same timeframe as wind farm development was recognized by multiple parties.
- State Grid Company representatives reaffirmed the company's commitment to undertake the preparatory work to ensure that the transmission system meets the needs of large-scale wind power development. The company plans to make major network extensions and reinforcements where necessary, and intends to strengthen its network development planning activities to keep up with the rate of wind power development.
- The large WPBs are concentrated in areas that are rather far from load centers, necessitating the transmission of a large volume of output over long distances and at high voltages. Work is under way for the development of a substantial 750 kV line from the western China to the load centers on the east coast. Although the 750 kV line is not being built specifically for transmission of wind power, it is expected to be useful in transmitting the output of the large WPBs from the northwest.

Optimal solutions for connection of wind farms

- State Grid Company plans to connect different wind farms to different voltage levels, according to their scale.
- For example, in the case of the coastal WPB in Jiangsu Province, the dispersed onshore wind farms built earlier can integrate into local 220 kV networks, while a portion of the offshore farms to be developed can be connected to the 220 kV network; the rest can be connected to the "super grid" at a voltage above 500 kV.
- State Grid Company also investigates the feasibility and potential benefits of "bundling" wind power generation with other conventional power generation, in order to improve the capacity factor of long-distance transmission.

Addressing the variability and limited predictability of wind power

- The parties understand that the uncertainty of wind power leads to difficulty in predicting the power output of wind farms.

- The provision of balancing power was reported as a possible problem in the presentation by the Alberta Electricity System Operator. The experience in Alberta showed that the standard accuracy metrics used to describe forecast performance may not be applicable or meaningful to system operations. Errors in short-term forecasts could have a large effect on system balancing costs, as the uncertainty also impacts the ability to forecast the system balancing requirements and identify adequate resources to provide balancing. These characteristics indicate that there may be need for changes to existing operating policies and procedures and the way real-time operating decisions are made. AESO developed a simulation model to assess the impacts of large wind capacity on the operation of its power system and evaluate various mitigation measures such as wind power forecasting, use of more flexible generation resources, greater use of ancillary services, and wind power management.
- In the case of the Northwest Grid Company, particular concerns reported were: 1) output power fluctuations, in a setting where balancing was likely to be difficult due to limited availability of balancing capacity from existing conventional generation, and 2) reactive power control. Northwest Grid Company is considering hydropower generation in the area as a way to address the balancing concerns. The company intends to put in place a system for obtaining real-time data from wind farms, and integrate that information with forecasting and operational decision-making tools.
- In the case of the European experience in offshore wind power grid integration, the principal technical solutions included transmission reinforcement and curtailment of wind generation at critical periods. Some countries, such as Denmark, chose to address the issue by selling surplus wind power output to other countries and purchasing power in times of shortage. On isolated systems, it may be satisfactory to reduce the wind generation output during critical periods.

Conclusions and Further Considerations

It appears that the right issues are being addressed, and that there is reasonable knowledge of experience abroad. It is clear that the potential technical problems of grid integration of proposed wind developments have been acknowledged. The following paragraphs provide key conclusions and additional technical guidance on a select set of issues that will be important going forward.

It will be important to give further thought to the optimization of the size of wind farm connections. For onshore WPBs, there may be scope for economic optimization of the network reinforcements. For example, further study may show that it is not essential to provide network capacity equivalent to the full output of the wind farm, in light of the fact that the wind farms will rarely achieve full output. Rated power is achieved at relatively high wind speeds that do not occur frequently. For example, 1,000 MW of wind generation nameplate capacity is likely to get a 1,000 MW connection, which may never be used to full capacity. One important factor is that, at present in Europe, offshore projects are developed in isolation from other projects, and hence it is difficult to achieve optimized network connections. For example, it is difficult to arrange for one submarine cable to serve two separate projects. This may be easier in China. There was a general anticipation that the offshore grid would be centrally provided.

Further study will be necessary to identify the best connection methods. The best connection methods for offshore wind farms and intertidal wind have not been established. European practice will be relevant, but local factors (such as availability of suitable vessels, project size, and location offshore) will be important. For the intertidal wind farm concept, grid connection should be easier than for offshore installations, but there is no equivalent experience elsewhere from which to learn. With respect to offshore wind farms, there are advantages in avoiding offshore substations for wind farms closer to the shore, particularly for those that are smaller in size, although offshore substations may still be necessary for large offshore projects. Transmission cable to shore is one of the major risk and cost item for an offshore wind project. The layout and construction are influenced mainly by seabed conditions, especially the nearest hundreds of meters to shore. Burial of the transmission cable under the seabed appears to be the best protection.

In thinking about system operation with high wind penetration, the recognition of the uncertainty of short-term forecasts is critical. Forecasting of wind power output variability is critical to wind power integration, particularly for large wind farms. For instance, the studies presented by Mr. Hu showed that, in the case of the Alberta power system, which has a high load factor and relatively little flexible generation, the rate-of-change of power output from wind generation could become a problem at high levels of wind power penetration. It was also found that the uncertainty in short-term forecasts could have a big impact on the efficiency of potential mitigation

measures, as more potential mitigation measures are needed to cover both magnitude forecast error and time forecast error. One implication of the variability and forecast uncertainty is that existing operating practices may need to be changed.

Early experience with short-term forecasting (STF) is essential for China and should be initiated immediately in pilot projects. Experience in Spain, the United Kingdom, Texas, Denmark and Germany has shown that useful short-term forecasts can be obtained. It appears sensible to extend the work on options for providing system balancing to be studied in the context of different locations in China. This could include analyses of the effect of forecasting uncertainty. It is important to define the best approach to assess the impact of STF on system dispatch in China and developing local capacity in this field. The experience by AESO during its STF pilot study indicates that “learning by doing” is the best and most efficient way to build capacity in this field. It is therefore recommended to initiate the work on STF as soon as possible. There are well-established companies that provide STF services internationally. Using one of these services, instead of designing and developing from scratch, is likely to save China some valuable time.

It will be critical to put in place a mechanism by which knowledge of costs of various measures is fed back into decision making. Going forward, while making decisions about project size and location, it will be important to take into account the financial costs of transmission reinforcement and other issues, such as reactive power compensation equipment, balancing services provided by hydro and thermal power generation, and losses. In the case of Alberta, AESO set up a wind power integration market and operation framework to clarify the responsibility and cost allocation among related parties

Further information exchange, specifically on system operation experience, will be beneficial. Information exchange and cooperation between policy makers, research institutes, and those who actually operate the power systems are critical in ensuring the success of wind power development program. The setting up of a continuous platform for information exchange would provide the opportunity to review the success of the current strategies.

Arrangements for covering the additional cost of increased wind power penetration will need to be identified. Responsibilities for costs and construction of grid upgrades and other measures taken to accommodate new wind power capacity should be clear.

Further Reading

Wind Resource Assessment Handbook, National Renewable Energy Laboratory.

The American Wind Energy Association's "10 Steps in Building a Wind Farm." http://www.awea.org/pubs/factsheets/10stwf_fs.pdf.

"Fujian Offshore Wind Resource Assessment and Site Selection Methodology." Presented during the workshop by Sgurr Energy, available at www.cresp.org.cn.

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**World Bank Presentation
at the Workshop**

The World Bank



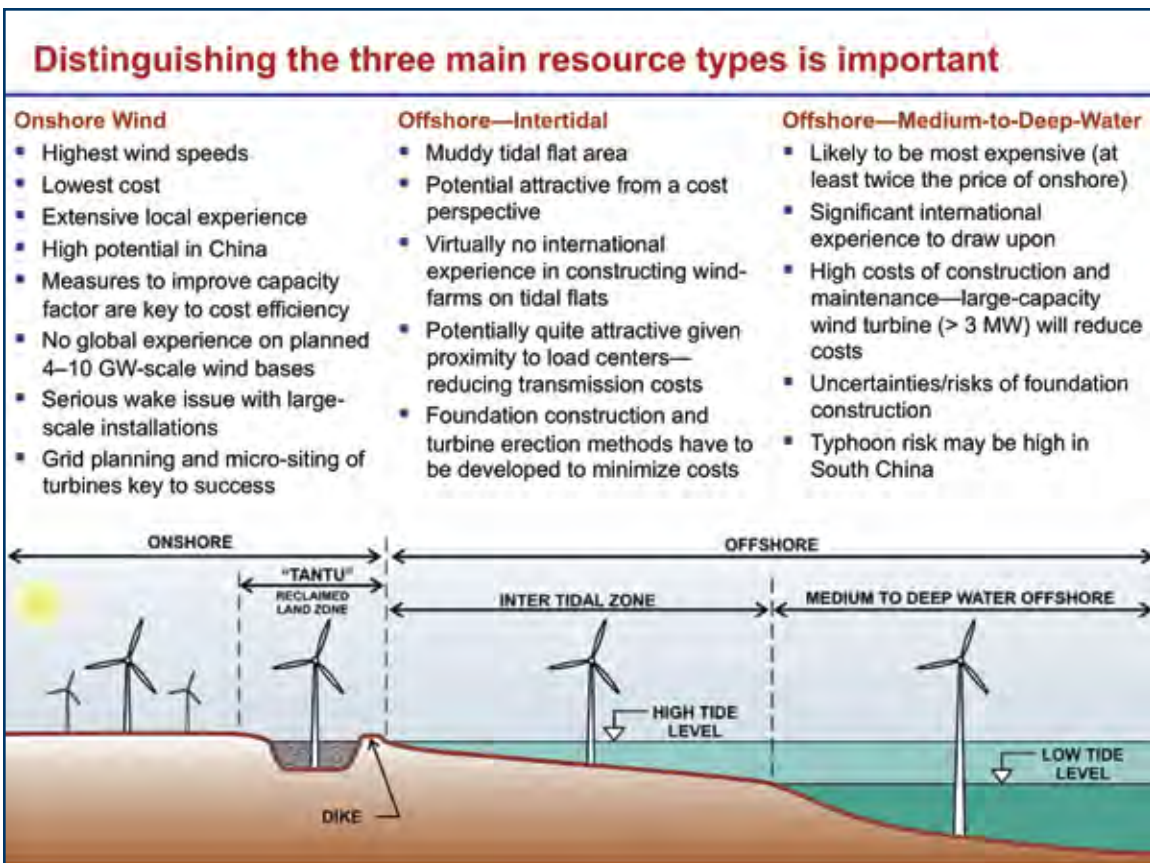
Strategic Implementation Perspectives

Developing Offshore Wind Farms and Large-Scale Wind Bases in China

Beijing
January 15, 2009

Presentation outline

1. **China's Wind Development Strategy and Challenges**
2. **The Four Pillars of Efficient Wind Power Scale-Up**
3. **Implementation Suggestions**
4. **World Bank Support for Demonstration Projects**



Wind power development—a global comparison

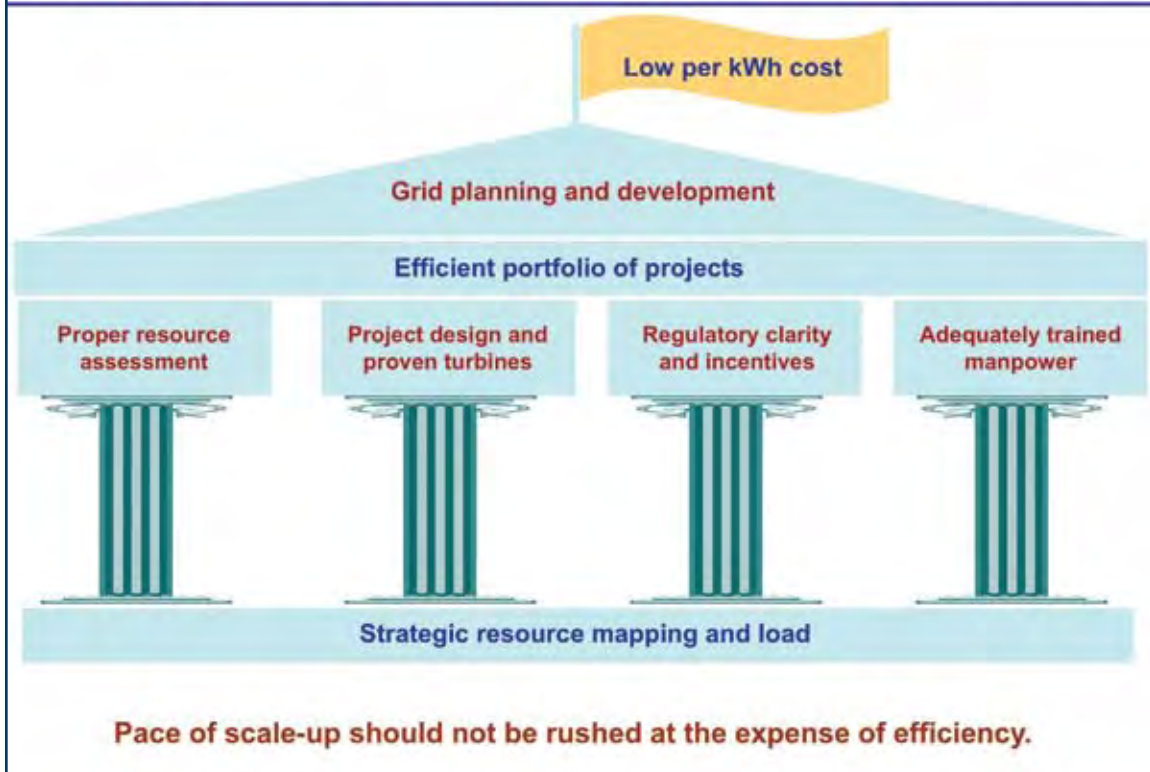
| | Installed (End 2007) | Average capacity factor (2006/07) | Annual average growth (2005–07) | Forecast GW 2012 |
|----------|-------------------------|---|---------------------------------------|---------------------|
| China | 5.91 | 20% | 97% | 42.41 |
| Canada | 1.85 | 28% | 56% | 10.05 |
| Denmark | 3.13 | 23% | | |
| France | 2.45 | 22% | 85.7% | 12.45 |
| Germany | 22.25 | 18% | 10.2% | 32.35 |
| India | 7.85 | 23% | 37.8% | 22.85 |
| Italy | 2.73 | 20% | 29.2% | 9.13 |
| Portugal | 2.15 | 26% | 54.3% | 6.95 |
| Spain | 15.15 | 24% | 21.2% | 26.65 |
| UK | 2.39 | 28% | 39.1% | 11.79 |
| USA | 16.82 | 30% | 35.7% | 60.32 |

- Second largest installed global wind power capacity by 2012; highest past and planned global growth rate in capacity addition
- Lower capacity factor in China; generally believed to stem from inadequate site investigation studies and wind farm operation practices
- A 1% improvement in capacity factor from current 20% national average leads to 5% increase in electricity output, savings of ~ 5%+ of investment cost for same output; lower wind power prices.

Elements of GoC strategy (2005–08) and achievements

| Key elements of strategy | Achievements |
|---|--|
| Effective utilization of wind resources | <ul style="list-style-type: none"> ▪ Rapid growth in installed capacity base: ~ 6 GW by end 2007. ▪ Major GW-scale projects initiated in record time (e.g., Jianquan) ▪ National program for resource assessment and mapping ▪ Offshore measurements initiated |
| Domestic technology development | <ul style="list-style-type: none"> ▪ 5 large-scale domestic firms manufacturing IEC certified turbines ▪ 5 foreign-owned JV firms manufacturing in China ▪ 10+ domestic firms with prototype testing under way ▪ Domestic manufacturers market share 45% (cumulative up to 2007) |
| Incentive mechanisms | <ul style="list-style-type: none"> ▪ Mandated Market Share (MMS) Obligation on “non-hydro” energy sector firms—to invest in renewables ▪ Concession bidding programs to select investors for projects above 100 MW. |

The four pillars for efficient wind power scale-up



Pillar 1: Proper resource assessment

- **Systematic site-specific wind data collection is vital** for the scale and pace of wind power development in China
 - Engineering problems can be corrected through additional expenditure—**POOR RESOURCE ASSESSMENTS AND ESTIMATES CANNOT!**
- **Wind speed matters greatly**—its importance cannot be overemphasized
 - A turbine produces twice the energy at 9.0 m/s as at 6.5 m/s.
- **Good assessments are cheap**—insignificant when compared to the benefits
 - One measurement mast costs merely 10–15 % of a 2 MW turbine!
- **A disciplined national measurement program is required:**
 - Government should support comprehensive wind database development backed by a credible protocol and measurement verification (use available meteorological data, but check with certified equipment).
 - Extrapolations of existing data from meteorological data, offshore platforms, etc., is a good start—use this to identify locations for detailed site specific measurements.
 - Assemble data in a national GIS system.

Pillar 2: Project design and proven turbines

- **Utilizing proven and certified turbines is essential**—particularly for offshore applications.
 - Dealing with even minor problems offshore can be expensive.
 - Use of unproven turbines has derailed offshore programs.
- **Detailed layout planning** with wind tunnel studies important to maximize the output of wind farms.
- **Getting Chinese turbines to rise to the scale-up challenge.**
 - China's wind manufacturing industry is not fully mature yet... some competitive pressure will be extremely beneficial.
 - Encourage technical innovation... R&D is essential! Leapfrog to the cutting edge; do not wait for Western development. Cost per turbine: design \$5 million and prototype \$15 million. Scientific investigation of the behavior of prototypes is necessary.
 - Develop turbine specifications based on Chinese wind regime. This could reduce cost of development.
 - Upgrade and/or design new turbines to make them more grid friendly (turbines should be able to control power factor and provide fault-ride-through capability).
 - Provide government support to develop domestic turbines with a capacity of more than 4 MW for eventual offshore deployment.

Layout design—minimizing losses due to “wake effects”

- **Power output can drop by 30–50%** from first row of wind turbines to subsequent rows.
- Potential for wake effect losses is **greater in simple or low roughness areas** (sea, rolling hills, or plateaus as found in NW China).



Photo from www.uni-fly.dk

Pillar 3: Regulatory clarity and incentives

- **Regulatory clarity very important to scale up offshore**, given the higher financial risks faced by developers.
 - Higher level of incentives and government support are required at early stage of development.
 - Regulation change and weak government support can damage the confidence of investors.
- **An offshore specific regulatory framework would be important to develop.**
 - Fitting offshore wind program within existing legislation has not been successful.
 - Consider a single “one-stop-shop” authority to issue permits and provide licenses.
- **For additional incentives, consider...**
 - Grid connection free of charge for all offshore demonstration projects.
 - Allow return on investments commensurate with the risks of offshore projects.
- **No major regulatory issues for onshore wind base scale-up...**
 - ... it may be timely to evaluate and fine-tune the concession system based on the experience of the past three years.

Pillar 4: Adequately trained manpower

- **Poor O&M reduces wind resource utilization**—owing to reduced availability of turbines.
 - Lack of qualified personnel leads to the poor O&M practices.
 - GHP estimates that 2% of energy is lost in U.S. wind farms because of lack of well-trained staff and poor O&M practices.
- **China’s “wind power manpower” needs are very, very large**—to build, operate, and maintain wind farms at the scale and pace planned, China needs to...
 - Undertake a strategic assessment of manpower skills and prepare capacity building and training program to upgrade skills
 - Review O&M practices in existing farms and prepare and implement programs to improve O&M procedures and practices.
- **Leverage available skills by using technology and management systems wisely.**
 - Use SCADA systems and turbine condition monitoring systems to support predictive maintenance.
 - Centralized operations for several wind farms.

Grid planning and development is critical

- **Grid connection issues have delayed projects—increasing commercial risks for developers.**
 - This has been the case in many countries.
 - Problem is unclear technical requirements and responsibilities for network financing and construction.
- **A new grid code on wind power development is necessary, which should...**
 - ...be prepared by State Grid Corporation in consultation with industry—clarify the technical connection requirements for onshore and offshore wind farms.
- **Grid connection and stability issues for GW-level scale wind bases have no precedent globally. China is bound to take the lead on this issue.**
 - Comprehensive connection studies involving all stakeholders necessary—with special attention to the optimum connection size and connection circuit layout.
 - Initiate short-term operational forecasting studies. International experience has been good in planning wind farm operational integration.
- **For offshore wind farms, consideration should be given to...**
 - Giving grid connections free of charge to approved demonstration projects—at wind farm voltage.
 - Building an offshore wind energy grid by a new agency (or alternatively extend existing grid corporations' responsibilities to offshore).

Large wind bases—toward successful scale-up

Build upon the large amount of onshore experience in China—recognizing the specific technical risks

| | |
|---|---|
| Strategic review of site layout design philosophy | <ul style="list-style-type: none"> ▪ Optimal dispersion study essential to determine... <ul style="list-style-type: none"> ▪ Wind tunnel assessment to evaluate turbine concentration in order to minimize wake losses inherent to large sites |
| Electrical integration studies and grid code | <ul style="list-style-type: none"> ▪ Grid connection and integration studies: <ul style="list-style-type: none"> ▪ Optimization of connection capacity based on expected continuous output. ▪ System reliability issues—loss of generation; operational regime, etc. ▪ WT generator technology—power factor control, grid fault management capability ▪ Grid code definition based on above assessments |
| Wind resource assessment and site selection | <ul style="list-style-type: none"> ▪ Reference database and systematic refinement/verification of available data and measurement: <ul style="list-style-type: none"> ▪ Compare historical meteorological data with data from new measurement masts ▪ Potential sites with adequate number of measurement masts—at least 12–24 months of data to be collected and analyzed ▪ Wake modeling studies to be undertaken |
| Turbine choice—research and development | <ul style="list-style-type: none"> ▪ Establish requirements on minimum certification and performance standards for “commercially proven” turbines to be used: <ul style="list-style-type: none"> ▪ Chinese wind class definition and adoption ▪ Improve testing and certification capacity to cope with Chinese wind class definition |

Going to medium-to-deep offshore—managing the risk

Costs and risks are highest here—careful planning and piloting will reap huge gains for China

Task A.

Preparatory work

- **Legal regime and institutional arrangements:** Identify current responsibilities/functions of institutions involved in regulating offshore activities; work toward developing a legal and institutional framework that can improve coordination for offshore wind.
- **Grid development and integration:** Define appropriate HV connection points and circuits. Responsibilities and schedule for completion. Offshore grid code—as extension of existing codes/regulations.
- **Database and site identification:** Create master geographical information system (GIS) that will assemble data on wind speed, undersea/bathymetric data, wave height, etc. Initiate wind speed measurements and computational models using standardized (national) approach; consult with industry. Insist on at least 12 months of meteorological data at site prior to preparation of feasibility study.
- **Determine government support for 2- to 3-year program:** Develop prefeasibility level cost estimates for select projects (Task B) and determine level of government support and incentives.

Task B.

Project demonstration and knowledge building

- **Pilot projects (immediate development):** Select 2–4 potential sites with at least 12+ months of wind measurements to begin pilot projects. Objective is to gain knowledge and experience on foundation/WT installation on scale, but use proven turbines. Number of turbines ~10; capacity ~ 30–50 MW. Government support may be higher for these projects.
- **Plan commercial-scale demonstration projects (Initiate in 2nd year):** These projects should be more carefully designed and planned with more focus on detailed wind measurement, and WT array layout. Select 2 projects with high potential to support. Choose turbines that have been proven onshore.

Piloting intertidal offshore—pioneering uncharted territory

Costs are expected to be lower than medium-to-deep offshore—however, China will be a pioneer.

Approach similar to the initiation of offshore—key issues include:

- **Geotechnical foundation data needs to be systematically collected and assessed, since foundation construction on muddy tidal flats and turbine erection can be very expensive:**
 - **Evaluating the choice of foundation type in conjunction with the most efficient construction approach.** Do you build an access road and use onshore construction methods—or dredge a channel for floating platform access?
- **Initiate pilot/demonstration projects:**
 - **Identify 2–3 intertidal wind farm sites** based on adequate geotechnical studies and at site-specific measurements for at least 12–24 months.
 - **Develop the site efficiently in 100 MW scale** with qualified project developers with agreed incentive package.

Learning through offshore demonstration projects

- **Aim of initial demonstration**—gain experience in offshore specific techniques and approach NOT to demonstrate turbine technology.
 - Use proven turbines if Chinese manufacturers do not meet specified technical requirements.
 - Focus on rapid learning of techniques in construction/erection, maintenance practices, and cabling.
 - Obtain information to improve design methodology.

- **Aim of commercial-scale demonstration**—to build “industrial capabilities” to implement large-scale projects and operate them efficiently.
 - Focus on committed and qualified wind developers with proven track record.
 - Develop prototype vessels for construction and installation of offshore wind turbines.
 - Develop supporting industry for foundation construction.
 - Maintenance practices and the development of vessels necessary for regular and reliable access.

The strategic outcomes desired

| Key elements of strategy | Desired outcomes |
|--|---|
| Effective utilization of wind resources | <ul style="list-style-type: none"> ▪ Improving wind farm capacity factors and availability ▪ Ensuring coordinated grid development plans and system operation ▪ Adequate resource assessment to achieve effective and optimum utilization |
| Domestic technology development | <ul style="list-style-type: none"> ▪ Globally competitive industry quality and reliability across the entire spectrum of hardware and components ▪ China-specific turbine designs—suited to Chinese wind regime ▪ Credible certification system ▪ Bring China to technological cutting edge—innovation versus Imitation |
| Incentive mechanisms | <ul style="list-style-type: none"> ▪ Incentivize generation output (kWh) ▪ Developing government support and incentives for R&D and risky demonstration projects—particularly offshore. |

Closing Address at the Offshore Wind and Coastal Large Wind Power Base Development Workshop

Shi Lishan, Deputy Director General, NEA

January 15, 2009

Ladies and Gentlemen:

After one day of plenary presentations and sessions, the Offshore Wind and Coastal Large Wind Power Base Development Workshop has completed its agenda and achieved expected results. This is a successful, practical, and efficient workshop. From international keynote speakers and session exchanges, we have gained better knowledge on offshore wind power histories, technology development status and development trends, challenges, and experiences and lessons. This will help us for better planning and project development in China. In particular, the NDRC vice chairman Zhang Guobao's presence and his important address proposed clear information on offshore development in China. Based on the presentations and discussions, I would like to make the following closing remarks.

Fully aware of importance and challenges of offshore wind

Energy is one of the most important necessities for economic development. It is estimated that since industrialization, the growth rate of energy consumptions is faster than that of population. So far, about 16 billion tons of coal-equivalent energy is consumed in the world each year, but only about 15 percent of the population enjoys the results of industrialization. Along with an increase in the speed of the pace of industrialization in developing countries, global energy consumption will continue to grow. In particular, excessive consumption of fossil fuel

has resulted in serious climate change problems. Facing the energy and environmental challenges becomes a task of all human societies. Currently, fast-growing renewable energy utilizations can be a common interest for coping with energy shortage and pollution. As one of the most matured renewable energy technologies, wind power is considered a promising solution by all countries. So far, the installed wind power capacity in the world has been more than 120 GW, which has played a significant role in world power supplies. Offshore wind, because of its sustainable resources and higher working hours and less environmental effect, will have great potential. China must pay more attention to offshore wind development in the future energy strategies.

However, compared with onshore wind technologies, offshore wind has more complicated working conditions and tougher technical requirement and is more difficult to install. All these will bring new challenges in turbine manufacturing, project construction, operation, and management. Offshore wind is not just a copy of onshore technologies. We must fully be aware of challenges by examining international experiences and learning lessons in offshore project development. Based on offshore project characteristics in China, R&D should be strengthened, particularly in manufacturing, foundation design and instruction, turbine transportation and installation, power grid connection, and management techniques. All these are new to offshore wind. Therefore, pilot and demonstration can be necessary to promote offshore in China in an active and planned approach.

Pay more attention to offshore planning

Offshore project planning and preparation can be more challenging than onshore wind because of many complicated variables such as coastal land uses for harbor, navigation channel, tantu farming, and inning land. There are also environmental protection issues to be considered.¹⁴ Hence, offshore planning must have a methodology and procedure. Otherwise, the plans may be very diverse. In addition, offshore development involves many administrative departments, which requires good coordination. The discussed guidelines for offshore base planning today have identified planning activity principles, working methods, affecting factors, authorities, and responsibilities. It can be a basis for regulating offshore planning activities. Based on the discussions during the workshop, it will be further improved and published in the form of workshop conclusions.

After this workshop, I would suggest that the coastal provincial government carry out studies on offshore planning by fully considering local resource characteristics. Only through thorough studies can a good plan be worked out. In 2003, for example, when we started to assess wind resources, a number of provinces, including Guizhou and Yunnan, said they did not have enough wind resources and were reluctant to conduct wind assessment activities. However, after a certain period of hard work, they changed their minds and now wind farms are working well in these provinces. I do hope through this workshop that relevant provincial authorities will see the importance and act immediately in making work plans for promoting offshore wind projects.

Offshore wind project management regulations must be formulated and implemented

Today, we proposed a draft of management regulations on wind farm project land use and environmental management. Our purpose is to provide a flexible and transparent management environment for wind power development. Since offshore is a very new sector, strong support will be necessary. During the discussions, some practical suggestions were proposed by administrative bodies according to current legal and regulation frameworks. At the same time, I feel that the support to the new renewable energy sector should be more flexible. Currently, a scientific outlook for development program is in practice in China. The critical points of the program are to explore new ideas, reform, and innovation. Therefore, while we are following the renewable energy laws

and regulations in our management, innovative administration will be more important, so that some constraints should be removed for a innovative approach for offshore development in China. We must study and work out a better offshore program.

In order to implement the government support to renewable energy technologies, in particular offshore, for a better investment channel, a regulated and coordinated management, and a favorable offshore wind environment, a system of offshore management regulations must be formulated and implemented by and for relevant authorities. To be effective and efficient, I would like to suggest that the China Hydropower Engineering Consulting Group Co can work out a draft document for management regulations based on the workshop conclusions. After broad consultation, a final proposal will be submitted.

Promptly start several demonstration projects

Favorable wind resource development conditions can be seen at Jiangsu coastal tantu and ocean areas with great potential for power generation and with ready grid and large-scale wind energy infrastructures. In recent years, China's wind power development projects have gained rich experience. Onshore and offshore wind power at Jiangsu coastal tantu areas have achieved significant progress, which also established good conditions for deeper-water projects. In particular, the Shanghai Donghai Bridge started the 100 MW offshore wind project. Three-megawatt offshore wind turbines have been successfully tested by Dalian Sinovel. These successful projects will contribute to the scale-up of offshore development in China. In addition, offshore wind resource assessment facilities have been established, and site investigation and project plans have been conducted by some major renewable energy companies in Jiangsu in the past years. It is imperative, therefore, to start several common, recognized demonstration projects at some selected sites.

Ladies and gentlemen, offshore wind is a new area of development for China. We have very limited experience in either technologies or solutions of many problems. Ocean resources cannot only be used for offshore wind, but for many other purposes, such as land resources, transportation, harbors, and fisheries. Today's workshop has been important for learning about international best practice in offshore development and discussing China's

14. *Tantu* is a reclaimed land zone.

strategies for offshore wind power. It has been a valuable face-to-face exchange. I believe it is good for everybody. I hope that after the workshop, central and local government agencies will study offshore wind development in long-term and strategic provisions. Let us work together to make China's offshore wind development successful.

Finally, representing the National Energy Administration, I would like to take this opportunity to thank international experts and experts from the World Bank, all workshop participants, and workshop organizers. My best wishes to you all for a happy Chinese New Year!



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