Guidebook on Off-Shore Wind Farm Development in China

Edited by ZHANG Xiuzhi Richard BODDINGTON ZHU Rong Ian IRVINE

气象出版社
China Meteorological Press

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Energy and environmental concerns have become key issues for sustainable development and have drawn increasingly wide attention in society. Offshore wind provides a rich and stable source of renewable energy and many countries around the world have begun to focus on offshore wind development. This guidebook provides detailed information on offshore wind resource assessment，analysis of constraints that influence offshore wind development，potential offshore site selection，offshore wind farm design，energy yield prediction，financial feasibility and modelling，wind farm construction and operation & maintenance.

This book can be used as a guide for technical engineers，researchers and managers in the wind industry and as a reference for students and teachers of relevant professional institutions.

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DISCLAIMER

PREFACE ONE

It is with great pleasure that I introduce to you this final guidebook developed by the "Off—shore wind energy resources assessment and feasibility study of Off—shore wind farm development in China" project.

This project, implemented by European and Chinese partners in the framework of the EU-China Energy and Environment Programme, is a successful example of our cooperation in the field of renewable energy, which both the European Union and China consider as an increasingly important element of their energy mix.

In the EU, wind energy plays already an essential role in meeting the objectives of the EU Energy Policy, and while land-based installations will remain dominant in the immediate future, off-shore installations are becoming increasingly important, with more research funds and investments devoted to this component of the wind energy production. Also in China, land based wind energy capacity has been largely enhanced in the past years and the off-shore wind industry is rapidly emerging.

Exchanges of experiences, information, know—how and ideas are therefore key for both the EU and China in this field. The principal aim of this project has been to promote and strengthen these exchanges while delivering concrete and tangible results.

The guidebook you are about to read, presents you with a methodology for the identification of economic and reliable off-shore wind farms sites. It discusses advantages and constraints, and provides you with guidance on assessment methods. It is therefore a practical tool that gathers state-of-the-art experience from top class European and Chinese experts from the renewable energy sector.

This guidebook is also a further milestone in European Union cooperation with China for the development and enhancement of renewable energy options and I hope you and all stakeholders involved in this process will find it a useful and practical reference document in your work.

Johan Cauwenbergh
Minister Councillor

PREFACE TWO

The utilization of naturally renewable resources for the generation of energy is becoming increasingly common in many countries across the world. This is partly due to international conventions on climate change such as the Kyoto protocol and also as a natural response to the global economic threat of rising fossil fuel prices and their diminishing supply.

In the mid-latitudes the majority of development effort and research has been in the conversion of wind energy into electricity. So far the majority of wind farm developments have taken place on land (referred to as onshore wind). However the lure of higher wind resources and fewer planning and environmental issues is leading the development of the offshore wind industry.

The methodologies required for safe and economic siting and construction of developments on land are relatively well established, with significant amassed experience on the technical challenges that need to be overcome. Similarly, the roles and jurisdiction of regulatory bodies in the development of onshore wind farms are generally well defined. However the technical and regulatory expertise is not as well defined for offshore developments. This presents a new set of challenges for the development of the wind industry offshore.

Furthermore, the emerging offshore wind industry in China faces a unique combination of technical, social and economic challenges which require creative adaption of the experience gained from offshore wind farm development in Europe. In particular, the following factors differentiate Chinese offshore wind developments from developments in Europe:

- Greater prevalence of relevant extreme events, particularly typhoons.
- Relatively low wind speeds.
- Substantial upgrades to grid and balancing mechanisms required due to long coastline, stretching across: Fujian, Zhejiang, Shanghai, Jiangsu and Shandong provinces.
- Requirement to make substantial use of domestically manufactured turbines and components.
- Developing process of tariff determination.
- Centrally planned economy.

This guidebook presents a methodology to identify suitable locations for the construction of economic and reliable offshore wind farms. It discusses the key constraints and where to find information on these constraints. It also provides guidance on methods for assessing the technical and financial feasibility of potential offshore wind developments.

To demonstrate how these principles would be applied in practice, this guidebook makes use of a feasibility case study of a 100MW wind farm off the coast of Jiangsu province.

Shi Pengfei

Vice President, Chinese Wind Energy Association (CWEA)

GLOSSARY

AC	Alternating Current
ADP	Acoustic Doppler (Current) Profiler
AEP	Annual Energy Production
BM	Build Margin
BoP	Balance of Plant
Capex	Capital Expenditure
CDM	Clean Development Mechanism
CER	Certified Emission Reduction
CFD	Computational Fluid Dynamics
CMA	China Meteorological Administration
CO_2E	Carbon Dioxide Equivalent
COD	Commercial Operation Date
CWERA	Centre for Wind & Solar Energy Resources Assessment
dB	Decibels
DOE	Designated Operational Entity
DSCR	Debt Service Coverage Ratio
EIA	Environmental Impact Assessment
EBP	Environmental Bureau of Protection
EPC	Engineer Procure and Construct
EY	Energy Yield
Galion	Galion Lidar device
GEBCO	General Bathymetric Chart of the Ocean
GIS	Geographic Information System
GPS	Global Positioning System
HVDC	High Voltage Direct Current
IEA	International Energy Agency
IEC	International Electrotechnical Commission (IEC)
IRR	Internal Rate of Return
JuB	Jack up Barge
km	kilometre
kV	kilovolt
Lidar	Light Detection and Ranging
LV	Low Voltage
m/s	Metres per second
MCP	Measure Correlate Predict
Met mast	Meteorological Mast
MV	Medium Voltage

MW	Megawatt
NCEP/NCAR	National Centres for Environmental Prediction/National Centre for Atmospheric Research
NDRC	National Development and Reform Commission
NPV	Net Present Value
NWW3	National Oceanic & Atmospheric Administration Third Generation Wave Watch Model
OHL	Overhead line
O & M	Operation and Maintenance
OM	Operating Margin
Opex	Operational expenditure
PLA	Peoples Liberation Army
PPA	Power Purchase Agreement
PV	Photovoltaic
RD	Rotor Diameter
RMB	Renminbi
SCADA	System Control and Data Acquisition
UNFCCC	United Nations Framework Convention on Climate Change
VOS	Voluntary Observing Ships Scheme
WACC	Weighted Average Cost of Capital
WAsP	Wind Atlas Analysis and Application Program
WMO	World Meteorological Organisation

Contents

INTRODUCTION

Project Background and Objectives

This guidebook is the final deliverable of a year-long EU-aid funded project, aimed at transferring knowledge from the European offshore wind generation industry to the emerging Chinese offshore wind industry.

The project has the following objectives:

- Assessment of the offshore wind energy resource covering the coastline from the province of Fujian to Shandong.
- Training of local professionals in wind energy resource assessment through the transfer of international methodologies during the term of the project.
- Provision of a feasibility study for a 100MW offshore wind farm located in Jiangsu Province.
- Characterisation of the steps involved in the development of a Chinese offshore wind farm. This description will range from resource assessment and site selection through to technical specifications and grid connection.

The following results are expected from the study:

(1) Wind resource assessment of the offshore wind resource along the Chinese coastline from Fujian Province to Shandong Province.

(2) A wind resource assessment map of the Chinese coastline from Fujian Province to Shandong Province.

(3) Transfer of international resource assessment methodologies to Chinese resource assessment experts via training modules.

(4) Assessment of potential sites for offshore wind farm development along the coastline from Fujian to Shandong.

(5) Feasibility study for a 100MW offshore wind farm located in the Jiangsu (previously Shanghai) area.

(6) Guidebook on offshore wind farm development and supporting training course.

This guidebook is based on the findings of the study and presents a concise method for the site selection and feasibility assessment of offshore wind development locations across China. Elements from our experience in this project will be used to provide examples and illustrate points.

Guidebook Structure

Throughout the guidebook, generic information on each topic is given in the main text of the report, along with sources of further information. This generic information is then supported by two types of information boxes:

- Supplementary Reading—These boxes provide additional information which adds depth and detail to the body of the main report.
- Jiangsu Case Study—These boxes provide details of how the general principles outlined in the main body of the report were applied in the example feasibility study that was undertaken for a wind farm off the coast of Jiangsu Province.

The following topics will be covered in detail by this guidebook:

- Wind resources
- Site identification and constraint mapping
- Consultation and approval
- Scoring and ranking
- Consideration of site characterization issues

- Wind farm design including wind turbine selection and layout design
- Environmental assessment
- Full energy yield prediction
- Construction including discussion of relevant issues such as grid connection and foundation type.
- Operation and maintenance considerations
- Economic benefits and financial model
- Financing considerations and risk mitigation

The book is divided into 13 chapters.

Chapter 1 Introduces assessment methods and results of offshore wind energy resources, completed by ZHANG Xiuzhi, ZHU Rong, HE Xiaofeng, XU Jingwei, SHEN Yanbo, and LIU Yanxiang;

Chapter 2 discusses climate revision for the wind energy resources, completed by ZHANG Xiuzhi, YOU Lijun, JIANG Ying;

Chapters 3-5 describe constraints which have impacts on wind power development, methods of making constraints map, rating methods of all constraints and determination of the potential wind farm site;

Chapter 6 describes the meteorological, oceanographic and geological observations for the potential wind farm;

Chapters 7-11 introduce the design of an offshore wind farm, expected energy yield output, construction, operation and maintenance;

Chapters 12 and 13 give an introduction of financial model and financing of offshore wind farm project.

The above chapters 5 – 13 are completed by Richard Boddington, Ian Irvine and team members of SgurrEnergy. ZHANG Xiuzhi is the chief editor of the book. XUE XiaoPing, GAO JianYun, CHEN Shengjun, ZHOU Weidong and CHEN Yan supported work relating to provincial wind resource analysis. CHU Dan, CHEN Yanyan, BAI Luolin, WANG Yun, WU Di, CHANG Hao from SgurrEnergy undertook the translation work of Chapter 4 to 13.

The Development Process

The development process of an offshore wind farm is shown in Intro Figure 0.1 Offshore Wind Development Process below:

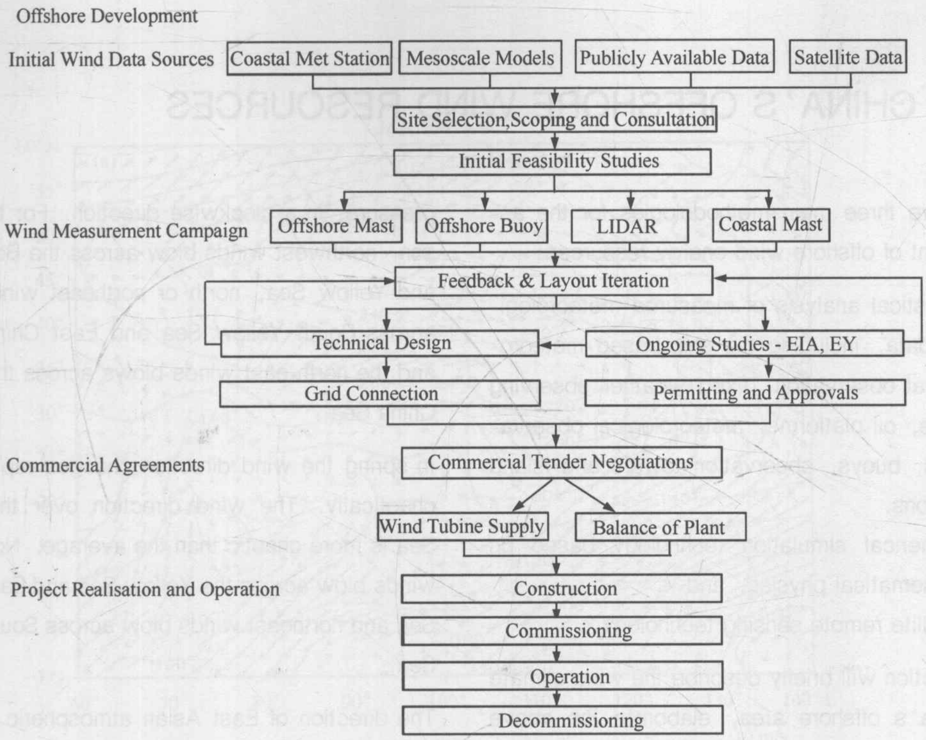

Figure 0. 1 Offshore Wind Development Process

1 CHINA'S OFFSHORE WIND RESOURCES

There are three main methodologies for the assessment of offshore wind energy resources:

- Statistical analysis of measured meteorological data, including the ship-based meteorological observation, fixed weather observing ships, oil platforms, meteorological observations, buoys, observation towers and island stations.
- Numerical simulation technology based on mathematical physics, and
- Satellite remote sensing technology.

This section will briefly describe the wind climate of China's offshore area, elaborate the above three methodologies in detail and present the results of the wind energy resource assessment.

1.1 Prevailing Winds of China's Offshore Area

The Chinese mainland is located to the west of Pacific Ocean, and to the east of the Qinghai-Tibet Plateau. Its unique topographical features and land-sea thermal distribution make China's offshore area subject to a monsoon climate. The prevailing wind direction over the year varies with the season.

In winter the East Asian continent is controlled by a powerful high-pressure (see Figure 1.1), whose center is located in northern Mongolia; therefore it is called the Mongolian cold high pressure. The corresponding low pressure is above the east of Japan near the Aleutian Islands, so it is called Aleutian low pressure. Cold and dry air is driven southward by the north-west flow between the Mongolia high and the Aleutian low pressure, in a clockwise direction. For this reason, northwest winds blow across the Bohai Sea and Yellow Sea, north or northeast winds blow across South Yellow Sea and East China Sea, and the north-east winds blows across the South China Sea.

In spring the wind direction changes rapidly and chaotically. The wind direction over the Bohai Sea is more chaotic than the average. Northwest winds blow across the Yellow Sea and East China Sea and northeast winds blow across South China Sea.

The direction of East Asian atmospheric circulation in summer is opposite to that in winter. Mongolia high and the Aleutian low pressure become unclear. The major weather systems controlling the China offshore area are the Western Pacific subtropical high and the southwest monsoon, so southwest winds blow across this area.

The Western Pacific subtropical high pressure weakens southward rapidly in autumn. The Mongolia cold high and Aleutian low pressure systems re-emerge again and atmospheric circulation changes from the summer to winter. Southwest wind blows across this area during this season.

There usually exist tropical cyclone activities over China's coastal waters during summer half year (May-September). The summer mean circulation is replaced by the tropical cyclone circulation during this period. Figure 1.2 shows strong typhoon "Damrey" in 2005 and super typhoon "Wipha" in 2007, reflecting the distribution of tropical cyclones in the South China Sea and East China Sea.

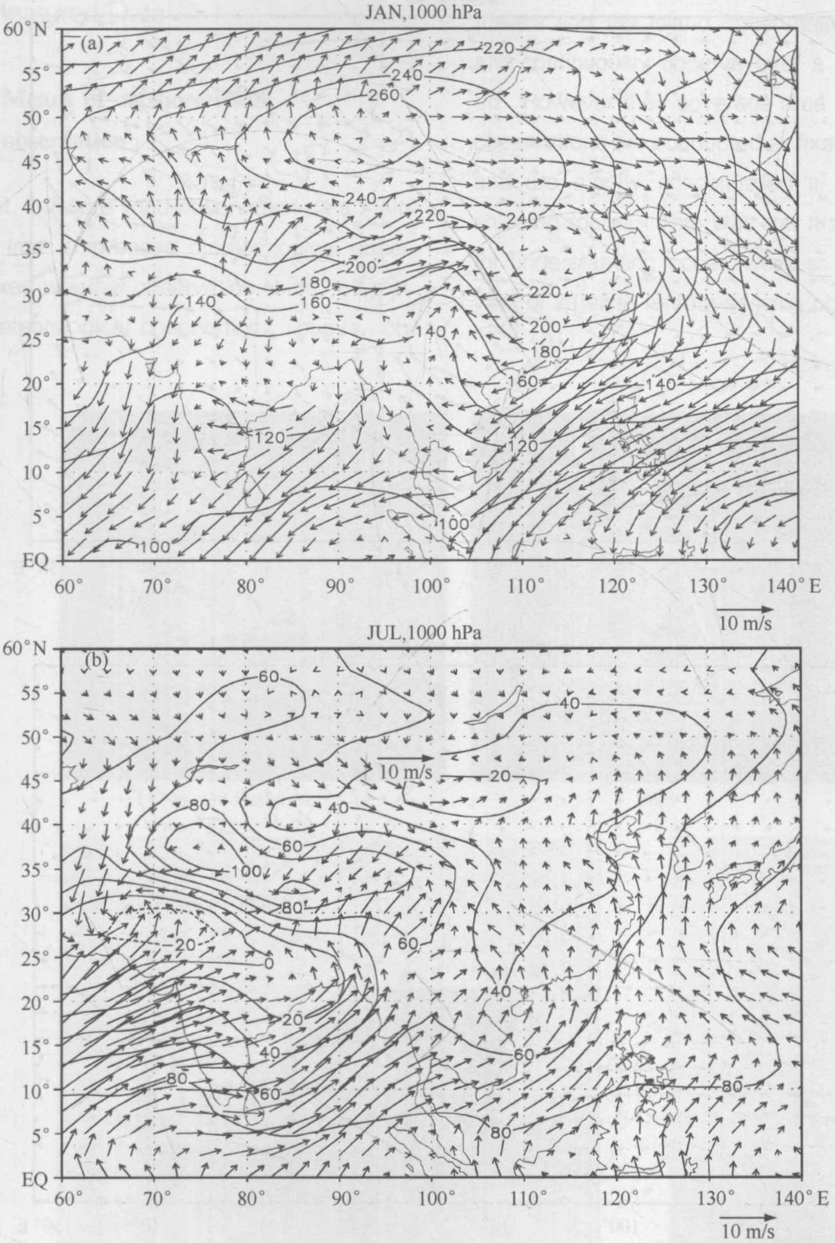

Figure 1. 1 Average air pressure and wind over East Asia at 1000 hPa