China Suntien Green Energy Corporation

Technical Assessment – Final

30 September 2010
China Suntien Green Energy Corporation

Yuyan Square A, 9 Yuhua West Road, Shijiazhuang, P.R.C

Mott MacDonald, Victory House, Trafalgar Place, Brighton BN1 4FY, United Kingdom
T +44(0) 1273 365000 F +44(0) 1273 365100 W www.mottmac.com

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Content

Executive Summary

Introduction

Mott MacDonald Limited ("MM") has been appointed by China Suntien Green Energy Corporation Limited (the "Company") to provide technical assistance in connection with a potential listing of the Company on the Hong Kong Stock Exchange.

Mott MacDonald has carried out an independent technical appraisal of the Company's wind farm assets. Our review of wind farms includes wind resource assessment, power generation, availability, and operational and maintenance arrangements, wind turbine technologies, and grid connection arrangements as well as compliance with grid codes. The assessment covers the representative wind farms in the asset portfolio.

The main base of information from which the report was compiled comprises documents provided by the Company, discussions and meetings with relevant staff of the Company during the site visits between 19th and 22nd January 2010, and communication with the Company after visits. MM's professional judgement was exercised with regards to the validity and use of all information submitted from external sources. MM's knowledge of the Chinese power sector has been utilised throughout the assessment process.

There are a number of power plants involved in the asset portfolio, with these assets spreading across Hebei Province, China. These plants were designed by various Chinese design institutes based on the prevailing Chinese design standards and the turbines were supplied by well-known domestic and international manufacturers. For these reasons it was agreed that the report would be compiled with specific reference to representative power plants. These plants were selected to best encapsulate and represent the diversity of all power assets controlled by the Company. Particular attention was paid to the following factors when selecting the representative wind farms:

- **Wind farm status** — we reviewed the wind farms both in operation and currently under construction.
- **Turbine types** — Representative wind farms selected include turbines produced by both domestic and foreign manufacturers.
- **Installed capacity and company share** — Representative wind farms selected are those in which the Company is the controlling shareholder. The consolidated installed capacity of the projects selected represents 100% of the consolidated installed capacity of the Company as of 31 December 2009.

The process of technical appraisal was carried out in China and in the UK through a variety of procedures including, but not limited to: site visits, data collection, discussion, analysis and report production.

Wind Resource Assessment and Energy Yield

Wind resource assessments for each of the representative wind farms were reviewed and the Chinese standards of methodology, reporting, and data collection were compared to equivalent international standards. It was concluded that there was a consistent approach to the assessments largely adhering to standard international practice, although the Chinese standards lack some of the detail found in their international counterparts such as uncertainty analysis. However conservative estimation of energy yield was deemed to mitigate uncertainties.

We have reviewed the energy yield predictions for each of the visited sites and where possible compared the predicted generation with the reported production.

The energy yield assessment methodology used in each wind farm is consistent and is based on the Chinese standards, GB/T 18709-2002 and GB/T 18710-2002. These standards have been derived from western publications and are broadly consistent with wider international practice. Whilst they lack detail in some areas, they are generally more conservative. We are satisfied with the Chinese methodologies.

We are able to confirm that, for most of the wind farms reviewed, the availability was higher than the manufacturers' guarantee of 95% and the actual electricity generation was in line with the forecast made in the feasibility studies.

Turbine Technologies and Plant Operation

The Company uses many different models of wind turbine, supplied by both well-established international and domestic manufacturers. The wind turbine selection process is crucial for maximisation of electricity generation, hence an assessment of each of the key wind turbine manufacturers with installations on the representative sites was completed.

The assessments detailed the market share, utilisation of specific technologies, and historic track record of each manufacturer, in addition to focusing on the anti-corrosion features of the turbines and their suitability to harsh environmental conditions.

All wind farms we visited had the equipment supplied by well-known international or domestic manufacturers who employ proven technologies and have track records in the market. Mott MacDonald holds the view that the turbine technologies are in line with current industrial standards, all of the sites were considered to be built to a high standard, some exceeding our expectations.

All sites were regarded as having adequate operation and maintenance arrangements in place. Some wind farms that we assessed were still under construction. We observed the project management strategy to be consistent with that employed on other projects we have seen in China.

Grid Connection

The grid connection assessment has been conducted for all 11 wind farms within the portfolio of the Company. The purpose of this assessment is to determine:

- that all required equipment has been included (i.e. grid transformers, outgoing cable/overhead lines) and that it has been rated appropriately to export full generation from the wind farms;
- whether the reactive power compensation is sufficient to provide support for voltage control and power factor adjustment at the wind farm grid connection point; and
- the ability of the local network to dispatch the power generated from the wind farms and to mitigate any potential problems, i.e. voltage/frequency deviation, system overloading etc, whichever may be caused by the grid connection of the wind farm.

In general all wind farms are properly connected to the power grids, and there is no major constraint identified regarding the power output from the wind farms to the grid connection substations. All equipment, including switchgear and transformers are rated appropriately, and the reactive power compensation schemes are considered to be sufficient to provide necessary support to maintain voltage level and power factor correction.

Under certain scenarios of high power output we identified that grid restrictions could lead to generation curtailment (the local transmission corridor does not have sufficient capacity to evacuate maximum power from all connected wind farms) and that grid reinforcement would be required to resolve such problems. We were advised that grid reinforcements have been planned by the local grid company and in our opinion the major constraint regarding power output from the wind farms will be removed as soon as the reinforcements have been implemented.

Conclusions

From the high level assessment that we carried out we can confirm that the Company has employed qualified Chinese design institutes to carry out the energy yield assessment. The principles applied in the methodology are in line with international practice. The equipment we have seen was well maintained and in good order. In our opinion, the Company, with its technical skills and expertise, has strong capacity to develop, operate, maintain and manage its portfolio of wind farms in China.

1. Introduction

1.1 Independence of Mott MacDonald

This independent technical assessment report has been prepared by qualified staff at Mott MacDonald Limited ("MM"), the Technical Consultant appointed by China Suntien Green Energy Corporation Limited (the "Company") to provide technical assistance in connection with the potential listing of the Company on the Hong Kong Stock Exchange.

Mott MacDonald will be compensated with professional fees for the services and technical advice provided. However, none of the Mott MacDonald directors and staff who contributed to the report has any interest in:

- the Company; or
- the asset portfolio that was subject to the technical assessment.

Prior to issuing a final report, the Company and its advisers were provided with the draft of a technical report only for the purpose of confirming the accuracy of data used and factual material.

1.2 Mott MacDonald Qualification and Track Record

Mott MacDonald Limited is a world leading multi-disciplinary consultancy with expertise in energy, transport, water and the environment as well as in buildings, industry, communications, health and education.

Mott MacDonald is a wholly independent international company, headquartered in the UK, with turnover in excess of US$1.4 billion, over 14,500 staff and global experience spanning 120 countries. Our success in winning the Queen's Award for Export Achievement three times in 1996 and 1998, 2004 reflects the scale of our international business, which accounts for two thirds of our total earnings.

Mott MacDonald operates from offices in centres throughout the UK and in countries across Europe, Asia and the Pacific, the Middle East, Africa and the America. This wide geographical network means we can bring our skills and resources closer to our clients wherever they or their projects are based.

Mott MacDonald is committed to Quality Assurance and is accredited to ISO 9001 and ISO 14001.

Our experience in the energy sector is second to none amongst the world's major engineering consultants. We have played a leading role in the electricity sector restructuring in Hong Kong, Ukraine, Malaysia, Indonesia, Thailand, Philippines, Pakistan, Northern Ireland, Ireland, Singapore, Iran and Qatar where we advised the respective governments on the financial/technical options best suited to the country in question, as well as regulatory, efficiency and contractual issues. We have been involved in regulatory reviews of electricity utilities, which have been corporatised or privatised and have advised various major investors on prospective power plant and distribution company acquisitions. Additionally we are involved with the development of privately funded power projects throughout the world as independent advisers to both owners and lenders.

Mott MacDonald is experienced in all types of power generation and transmission technologies and works in partnership with its clients, ensuring through total commitment that MM adds maximum value to every project. We have engineered over 200 GW of power plants worldwide. Our strength lies in a rich diversity of expertise which covers the complete spectrum of disciplines and skills. We have extensive experience with the technical and power network aspects of wind power (both onshore and offshore). Roles have included providing consultancy services to financiers, potential investors, project developers, owners and contractors as well as governments, local authorities and regulatory bodies. We have undertaken a wide range of roles in project development, appraisal and implementation and are able to bring the full range of resources to our assignments in both the onshore and offshore sectors.

We have undertaken over 70 projects in China totalling over 32 GW including wind, hydro, biomass, waste-to-energy, gas and coal power plants. Selected projects are provided below.

- China Longyuan HK IPO, Morgan Stanley — Appointed as independent technical consultant to assess an asset portfolio totalling capacity over 3GW. Comprehensive technical report on the assets' conditions and verified information included in the company prospectus to potential shareholders.
- Baicheng Wind farm, HSBC — Acting as the Lender's technical adviser, we undertook a comprehensive review on renewable market and policies in China, energy yield, turbine technology, civil, grid connection, carbon credits, financial model and environmental issues.
- Portfolio of Wind farms, Dragon Power/Citi Bank — Technical adviser to assess a portfolio of wind farms totalling 357 MW in PRC for potential acquisition.
- Dafengba Wind farm, Hong Kong Electric International — Acted as technical adviser to conduct a due diligence for this 47.6 MW wind farm located in Yunnan Province.
- Rudong Wind farm, Rabobank International — Technical adviser to conduct a due diligence for procurement of certified emission reductions (CERs) under clean development mechanism (CDM) from 100 MW Rudong wind farm.
- Inner Mongolia Wind farms, Honiton Energy — Owner's engineer on geological investigation, transportation, grid connection, turbine, electrical equipment procurement and site supervision for wind farms in Bailingmiao and Xiwu.
- Project Taishan IPO, JP Morgan/Dragon Power — Acted as the technical consultant to undertake a due diligence on the National Bio Engineering biomass power plants for listing on the Hong Kong Stock Exchange. Work includes fuel market review, straw burning technology assessment and benchmarking of construction and operation.
- Suhrak Due Diligence, KEPCO — Asset Appraisal, — Acted as the technical adviser undertaking asset appraisal, electricity market review and contract review. The Suhrak asset portfolio includes eleven operational, three under-construction and nine planned power plants as well as nine coal mines in a Chinese province

1.3 Core Team Members

Mott MacDonald has selected a core team of specialists to complete the technical appraisal for the Company's generation assets. The core team members and their roles are presented below.

Dr. Aijuan Wang: Project Director

Dr Wang holds BSc, MSc and PhD qualifications and is a Chartered Engineer with over 20 years of technical and commercial experience in the energy sector. Aijuan has extensive work experience in China in the areas of project development, commercial contract negotiation, generation and transmission asset expansion and strategy. Aijuan Wang worked in Ministry of Energy of PRC and China Longyuan in the 1990s.

Since joining Mott MacDonald in 1998, Aijuan has undertaken, managed and directed a number of due diligence assignments for banks and investors/developers and is familiar with the business environment and regulations in China. In addition, Aijuan has extensive experience in working with financial institutions and merchant banks to provide technical and commercial advice on transactions of M&A, project finance and IPO. Team Leader of Technical Consultant for China Longyuan Hong Kong IPO.

Other experience includes power sector restructuring and privatisation, implementation of competitive electricity market, project business case justification and market study, corporate development strategies, and technical performance audit for utilities, regulators and governmental organisations. Aijuan is of Chinese origin and speaks Mandarin Chinese.

Duncan Broom: Project Manager

Duncan Broom holds a BEng Hons, Electrical and Electronic Engineering, (Power Systems) from the University of Wales, Cardiff, (1989) and is a Chartered Electrical Engineer with over 20 years experience in design engineering and project management, predominantly in the electrical transmission and distribution sector. Since joining Mott MacDonald in 2008, Duncan has successfully led several major multi-disciplinary engineering projects and has also been a contributor to due diligence reports for a number of Chinese wind farm projects.

Previous roles have included head of electrical engineering for one of the two London Underground rail system infrastructure companies and design manager for a number of HV substation and Static Var Compensator projects. Technical experience covers design in all areas of transmission and distribution systems including system studies and power systems protection.

Duncan's recent China related experience includes input into a number of due diligence projects including China Longyuan IPO, where he was responsible for carrying out professional review of the overall report and checking the input from each of the disciplines.

Senior Consultants:

In conducting this independent technical assessment, Mott MacDonald assembled a team of qualified consultants and engineers who have been involved in providing advisory services for transactions of this type and have gained experience in Chinese projects and elsewhere in the world. These core team members are presented in Table 1.1, below:

Table 1.1: Core Team Members

Roles and Responsibilities	Staff Name
Project Director	Aijuan Wang
Project Manager/Electrical Power Engineer	Duncan Broom
Wind Energy Yield	David Mudie
Wind Farm Operation	Cyril Pacot
Grid Connection Specialist	Roddy Wilson
Wind Turbine Design	Babak Badrzadeh
Power System Analysis	Jingwei Lu
Electrical Engineer	Douglas Ramsay
Project Coordination	Jinyu Yang

2. Methodologies

2.1 Objectives of Technical Appraisal

Established in 1988, HeBei Construction & Investment Group Co., Ltd. (HECIC) is a stated-owned investment company specialising in infrastructure, particularly energy and transport investments and development of key industries.

HECIC New-Energy Co., Ltd. (HECICNE) was established in July 2006 as a wholly-owned subsidiary of HECIC. HECICNE is principally engaged in the investment, development and operation of wind farms as well as other renewable energy sources including solar power.

In February 2010, China Suntien Green Energy Corporation Limited. (the "Company") was established as a separate holding company for the proposed listing of HECIC's clean energy assets. HECIC is currently controls 100% stake of the Company and is expected to maintain a controlling interest after the proposed listing. HECICNE is now a wholly-owned subsidiary of the Company.

MM's role is to assess the conditions of wind asset portfolio and confirm adequacy of the technologies used, plant performance and comment on capacity of the power transmission and distribution systems.

Hence, our review has been focussed on the following aspects:

- Wind resource assessment
- Wind turbine technology
- Generation, availability and maintenance
- Grid connection and grid code compliance

This report has been compiled based upon:

- Documents provided by the Company, discussions and meetings with relevant staff of the Company and manufacturers
- Site visits to the representative power plants
- Relevant data and information from the public domain, together with our general knowledge in this field and specifically of the Chinese power sector

During the course of producing this report, we have predominantly relied on the information made available to us, including the response to our questionnaire, although we have used our professional judgement in analysing the data. Our analysis and report production were undertaken in our UK offices.

In the following sections of this report, we will address the key issues identified above, present our findings obtained during this technical due diligence exercise, and make our recommendations and conclusions.

2.2 Asset Overview

MM understands that at the end of December 2009, the Company had 15 wind farms, including those in operation and under construction controlled by its subsidiaries. With one exception in Shanxi Province, all of the other wind farms are located in Hebei Province. Nine wind farms were in operation at the end of December 2009, with consolidated installed capacity of 406.7 MW.

Wind turbine technologies adopted by the Company are from recognised international suppliers including: GE, Vestas, Gamesa and Chinese turbine manufactures such as Goldwind, Sinovel and Dongfang Turbine Company. The size of a single machine varies from 750 kW to 1.5 MW.

2.3 Selection of the Representative Wind Farms

The MM team agreed with the Company to select representative power plants, as shown in Table 2.1.

When selecting the 11 representative wind farms, the following factors were considered:

- Wind farm status
  The aim of reviewing all of the operating wind farms is to provide sufficient information to assess the conditions, turbine technologies, plant performance, O&M arrangements, and capacity of grid connection. We also review some of the wind farms which were under construction to assess the capability of project planning, turbine technologies and capacity of grid connection.

- Turbine types
  The second key factor considered in selecting projects was the types of turbine used in the asset portfolio. As mentioned earlier in this report, the Company has installed several types of turbines purchased from international brands and domestic manufacturers. We consider the turbine models in the projects to be representative of the predominant technologies adopted by the Company. The turbine manufacturers and ratings are detailed in Table 2.1.

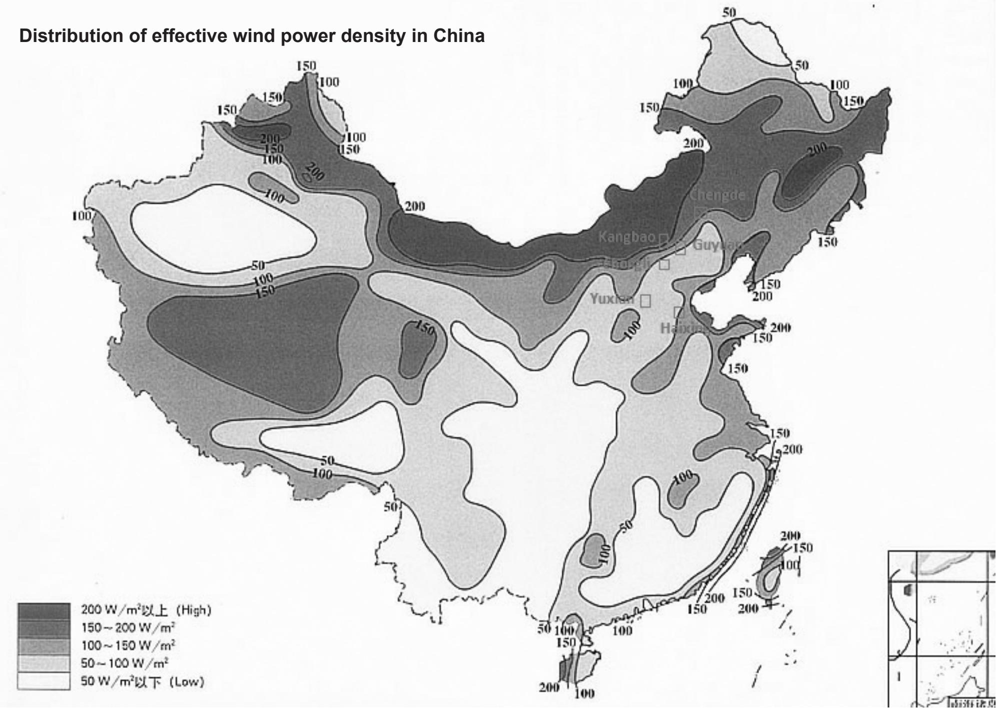
- Installed capacity and company share
  The third key factor in the selection was the project size, both as a whole and also the size of the Company's share in the project. In other words, our focus is on wind farms with larger installed capacity, and those which the Company can exercise control.

Table 2.1: Representative Wind Farms

	Project Name	Location	Shares controlled by the Company	COD	Installed capacity (MW)	WTG capacity (kW)	Units	WTG manufacturer
1	Kangbao Wind Farm Phase 1	Zhangjiakou	100%	Nov-06	30.0	750	40	Goldwind
2	Kangbao Wind Farm Phase 2	Zhangjiakou	100%	Jan-10	49.5	1,500	33	GE
3	Guyuan Wind Farm Phase 1	Zhangjiakou	100%	Oct-07	30.6	850	36	Gamesa
4	Guyuan Wind Farm Phase 2	Zhangjiakou	75%	Jan-10	49.5	1,500	33	GE
5	Dongxinying Wind Farm	Zhangjiakou	100%	4Q 2010	199.5	1,500	133	Dongfang Turbine Company
6	Haixing Wind Farm	Cangzhou	70%	Sep-08	49.5	1,500	33	Dongfang Turbine Company
7	Chongli Wind Farm Phase 1	Zhangjiakou	50%	Nov-08	49.3	850	58	Gamesa
8	Chongli Wind Farm Phase 2	Zhangjiakou	51%	Mar-09 (29 units) Jun-09 (29 units)	49.3	850	58	Vestas
9	Yuxian Wind Farm Phase 1	Zhangjiakou	55.9%	Jan-09	49.5	1,500	33	Dongfang Turbine Company
10	Yuxian Wind Farm Phase 2	Zhangjiakou	55.9%	Nov-09	49.5	1,500	33	Dongfang Turbine Company
11	Chengde Weichang Yudaokou Wind Farm	Chengde	100%	4Q 2010	150.0	1,500	100	Sinovel

Figure 2.1 shows the wind resources distribution in China and the location of the selected wind farms.

Figure 2.1: Wind Resources Distribution in China and Project Locations



Source: Chinese Academy of Meteorological Sciences

2.4 Process of the Technical Due Diligence

Following selection of the 11 representative wind farms, our appraisal started with issuing the Company with a detailed questionnaire addressing all issues relating to the scope of the technical assessment. Issues addressed included wind energy yield, wind turbine type, operational records, maintenance arrangements, construction arrangements, turbine supply agreement and grid connection.

During January 2010 engineers from the UK offices conducted a document review in the UK. Initially we reviewed feasibility studies and grid connection study reports.

In parallel with this review, site visits were carried out in January 2010. Geographically the representative wind farms were all in Hebei province, China. Our engineers, consisting of wind energy and power network specialists, were divided into two groups. These groups were then sent to Zhangjiakou, Chengde and Cangzhou. The site visits allowed MM to assess the assets first hand and to meet with the site operational and maintenance staff to discuss technical issues in more detail.

We undertook an analysis of the data collected and of the information obtained. Where gaps were identified upon our return from the site visits our engineers requested further information from the Company. Our report was produced in our UK offices.

The key process of the technical due diligence is summarised below.

Table 2.2: Process of Technical Appraisal

Procedure	Location
Questionnaire preparation	UK
Document review	UK
Site visit, data collection and discussions	China
Analysis of data	UK
Report production	UK

3. Technical Appraisal of Wind Farms

3.1 Wind Resources Assessment

This section contains the findings from our review of the wind resource and energy yield assessments contained within the feasibility studies for each project. Our review focuses on the adopted methodology and assumptions and does not include remodelling or recalculation of the energy yields. In addition we have reviewed the applicable Chinese standards, which set out recommended practice, in order to comment on the approach compared to wider international practice.

The wind resource assessments form a key component of the feasibility reports produced during the development stage of the wind farms, and can provide a useful insight into the expected generation, particularly where limited production data is available.

Although the wind resource assessments in the reviewed wind farms have been carried out by a number of different Chinese design institutes, the methodology and reporting of results is common to all studies and is based on the Chinese standards GB/T 18709-2002 — Methodology of Wind Energy Resource Measurement for Wind Farm (風電場風資源測量辦法) and GB/T 18710-2002 — Methodology of Wind Resource Assessment for Wind Farm. The former standard covers data collection and reporting, while the latter outlines the procedures for long-term correction, data screening, data processing and reporting.

With regard to data collection, GB/T 18709-2002 is largely consistent with international convention and includes guidance on measurement parameters, calibration and mast specification and set-up. Although the standard covers key principles, it lacks some of the details that can be found in other international equivalents such as IEC 61400-12-1. For example, the Chinese standard provides guidance on meteorological mast configuration and sensor placement, but it does not specify details on sensor alignment and mitigating influence from tower shading. It is noted that, often, fewer masts are used in Chinese measurement campaigns compared to the European practice. This can adversely affect the confidence in a prediction, particularly in complex terrain. It is noted that in several of the feasibility studies, the mast height is reported to be shorter than the wind turbine hub heights. This deviates from GB/T 18709-2002, which states that the mast height should be no lower than the proposed hub height. This is not a major concern as it is common industry practice to use shorter masts in simple terrain environments, although it demonstrates a degree of non-compliance with the prevailing standards.

GB/T 18710-2002 is the Chinese standard for wind resource assessment and outlines the methodology for processing the wind data and reporting results. The standard covers reference data requirements and long-term correction as well as data screening, formulae for extracting relevant parameters (wind shear, turbulence intensity) and reporting of results. GB/T 18710-2002 references a number of documents including NREL/SR-440-22223 — Wind Resource Assessment Handbook. This is an American publication issued by the National Renewable Energy Laboratory of the U.S. Department of Energy and provides a good overview of the well established measurement based wind resource assessment method or MCP (Measure Correlate Predict). Much of the Chinese standard is derived directly from this document and hence the approach to wind resource assessment in China is largely consistent with international practice.

The MCP method requires that at least 12 months of quality wind speed and direction data is collected from the proposed site. This is then correlated with data from a nearby reference meteorological station with a reliable historical record. A relationship between the site and reference data is then established and the long-term wind conditions at the site can then be calculated by extrapolating over the historical record. GB/T 18710-2002 provides some good advice on implementing this method, including how to select and assess the integrity of reference meteorological data, but lacks detail in methods of correlation. A common observation in many of the wind resource assessments reviewed is that the MCP techniques adopted are relatively simple, often based on a simple comparison of historic annual wind speeds. This is largely due to the quality and consistency of the reference data records available resulting in potential uncertainty in the energy yield predictions. In several of the feasibility studies reviewed, where doubts in the integrity of the reference data was encountered and the MCP process resulted in an increase in long-term wind speed, then the MCP process was abandoned and the 12 months site data was used as the basis for the energy calculations. This shows evidence of diligence and conservatism in approach.

The culmination of GB/T 18710-2002, in terms of energy yield, is the reporting of average annual wind speed, wind direction and power density (W/m2), and diurnal and seasonal profiling. In order to calculate the energy yield from a proposed wind farm it is necessary to calculate the wind speed distributions at each wind turbine location and to integrate these over the power curve for the chosen wind turbine. The wake losses must then be modelled, and other losses, such as electrical efficiency and availability, must be considered, in order to arrive at a Net Energy Yield.

In the feasibility studies reviewed, the wind speed distributions at each wind turbine have been modelled by WasP, which is a software package developed by Danish wind institution RISO. WasP is an industry standard tool for evaluating variation in wind flow from topographic and ground cover variation in non-complex environments. From our review of the sites visited, this method is appropriate.

In our experience, it is common for some modifications to the wind farm layout to be required between the production of the wind resource assessment and construction. In some of the feasibility studies reviewed it was noted that, either, the turbine model, hub height or layout were not consistent with the constructed layout. In our opinion, this is not a significant issue, as the key assessment is measured energy yield once the asset is in operation.

The power curves used in some feasibility studies were not listed numerically and the origins were not stated. To appreciate the accuracy of a wind resource assessment it is necessary to understand whether the power curve is theoretical or derived from measurement, and whether it is guaranteed by the manufacturer. By way of conservatism, the energy yield predictions in the feasibility studies have generally been reduced by 5% to account for any shortfall from the power curve. We consider this provides some comfort and compensation for the lack of detailed information on the power curves.

Air density has a significant impact on the amount of energy that can be extracted from the wind. This is of particular relevance due to the high altitude of many of the sites visited. The correction method applied by the Chinese design institutes uses a scaling factor derived from the ratio of site average air density to standard air density. In our opinion, this method may not accurately capture the impact of air density on a wind turbine power curve and can result in a significant over calculation of the energy lost due to air density in high altitude sites. This means that the power generation may be higher than anticipated and as such these calculations can be considered to be conservative.

Wake modelling has been carried out using WasP software, which is an acceptable method. The wake model parameters have not been provided in the feasibility studies, however the results appear to be in line with our expectations. In many of the sites visited, the wind farms have been developed in stages, or have other wind farms constructed adjacent to the site. It is understood that the influences of neighbouring wind farms and of subsequent phases have not always been captured in the feasibility study wind resource assessments. However, it has been determined that sufficient space exists to site the different phases.

Estimated losses have been factored to account for electrical efficiency, availability, and grid downtime etc. The losses applied to each project vary significantly; this can be attributed to regional climate variations and the engagement of different institutes to conduct the studies. The loss evaluations are generous, resulting in project efficiencies (excluding wake effect) of approximately 70% on average (in Europe a figure of 90% is typical). This suggests a good deal of conservatism in the energy yield prediction.

The Chinese standards do not prescribe any evaluation of uncertainty in the measurement of wind speed and direction. Consequently, uncertainty analyses are not provided in the feasibility studies and only central estimates are presented. Uncertainty analyses are important for making commercial decisions about wind farm performance as they describe the confidence, and hence degree of risk associated with a prediction. Adherence to published industry standards does not immunise an energy yield assessment from uncertainty as sources of error are endemic in the process and are not necessarily consistent from site to site. The lack of the requirement for uncertainty analysis is, in our opinion, an omission in the Chinese approach. Likewise inter-annual variability has not been considered in the feasibility studies. Inter-annual variability accounts for the fact that wind speed varies year on year, however the variation reduces as the averaging period increases. It is therefore easier to predict the annual production, averaged over 10 years than it is to predict the production during a particular year. We are able to confirm a long-term prediction was carried out in the feasibility studies, although in the case of some of the wind farms there was either a lack of long-term correlated or reliable reference data or the on-site mast data was measured in low wind speed years. In these cases conservative estimations were made in the long-term prediction.

From the pool of studies reviewed we can conclude that there is a consistent approach to wind resource assessment and the adopted methodology is largely consistent with standard international practice. The Chinese standards have been derived from well known western publications; but they do not contain the same level of detail as other international equivalents. The most notable omission from the Chinese approach is the lack of uncertainty analysis. This said, there is evidence of conservatism in the process and in the assumptions made. In particular the losses applied to calculate the net yields are, in general, extremely generous compared to those typically included in other areas of the world.

The conservative estimations of project efficiency can be considered to compensate for the areas of doubt within the analysis (such as the lack of uncertainty analyses) and provide comfort in the predictions. This is backed up by the production data supplied for the operational wind farms.

3.2 Key Wind Turbines Involved

Many different wind turbine models, supplied by both international and domestic manufacturers are used in the wind farms reviewed by Mott MacDonald, as shown in Table 3.1. The wind turbine selection process is crucial for maximisation of electricity generation, as factors such as suitability to site conditions, energy yield, market availability, price, and technology can cause significant impacts on the operation and economics of a wind farm.

The representative wind farms include wind turbines produced by well-established domestic and foreign manufacturers. All the wind turbine models reviewed have a modern design in line with current technology standards with a rated power ranging from 750 to 1,500 kW. All installed wind turbine models have been selected according to the specific site conditions, designed to sustain extreme wind speed and the very low temperatures which can occur in the northern regions of China. Therefore, extra care has been taken in the analysis of low temperature and anticorrosion features for the wind turbines located in harsh environments such as shore areas or cold, steep regions.

In our high level review we have analysed the various wind turbine models in order to identify potential technology risks which could prevent the wind turbines from operating in accordance with the developer's expectations. Whilst operational experience reduces the possibility of failure, independent analysis and certification of the design can give additional confidence. However the key safeguard is the manufacturers' warranty and the inclusion of liquidated damages for under performance.

The Chinese wind turbine supply chain is in constant growth, producing an output that meets 90% of the country's demand for 600 kW and 750 kW turbines and about 70% for bigger wind turbines[1]. However the domestic market for high precision and high technology components such as gearboxes, bearings, and control systems is still not independent and relies on foreign imports.

When we assess wind turbine generator (WTG) technologies, it is essential to review a type certification for the mitigation of design-related risks. The type certificate is issued to the wind turbine manufacturer following a thorough design review with respect to the relevant codes and standards. The testing of the prototype wind turbine and the evaluation of the implementation of design-related requirements in Implementation in Production and Erection (IPE) forms an integral part of the certification process, which is carried out through inspections at the manufacturer or respective sub-supplier.

The quality of wind turbine technology is a key element for performance of a wind farm, for the maximisation of the electricity production, and for other aspects such as the electrical system and equipment, and the Operational

[1] BTM Consult ApS — March 2008

and Maintenance (O&M) arrangements in place. Power generation and maintenance plans are also reviewed in this report. We are generally satisfied with the selection of wind turbines and the contractual arrangements in place for O&M, warranty and liquidated damages, which are in line with the current market practice.

Table 3.1: WTGs Installed in Representative Wind Farms

Ref	Wind farm	Capacity (MW)	COD	Manufacturer	WTG Model	Rated Power (kW)	WTG No.
1	Kangbao Wind Farm Phase 1	30.0	Nov-06	Goldwind	S50	750	40
2	Kangbao Wind Farm Phase 2	49.5	Jan-10	GE	GE 1.5sle (77m rotor diameter)	1,500	33
3	Guyuan Wind Farm Phase 1	30.6	Oct-07	Gamesa	G52	850	36
4	Guyuan Wind Farm Phase 2	49.5	Jan-10	GE	GE 1.5sle (77m rotor diameter)	1,500	33
5	Dongxinying Wind Farm	199.5	4Q 2010	Dongfang Turbine Company	FD77B	1,500	133
6	Haixing Wind Farm	49.5	Sep-08	Dongfang Turbine Company	FD77A	1,500	33
7	Chongli Wind Farm Phase 1	49.3	Nov-08	Gamesa	G52	850	58
8	Chongli Wind Farm Phase 2	49.3	Mar-09 (29 units) Jun-09 (29 units)	Vestas	V52	850	58
9	Yuxian Wind Farm Phase 1	49.3	Jan-09	Dongfang Turbine Company	FD70B	1,500	33
10	Yuxian Wind Farm Phase 2	49.5	Nov4-09	Dongfang Turbine Company	FD70B / FD77B	1,500	33
11	Chengde Weichang Yudaokou Wind Farm	150.0	4Q 2010*	Sinovel	SL1500/77	1,500	100

3.2.1 GE

GE Energy (GE) is part of General Electric group, the world's largest power equipment manufacturer. GE is one of the world's largest wind turbine suppliers with over 10,000 worldwide wind turbine installations comprising more than 15,000 MW of power capacity, with knowledge and expertise spanning more than two decades. GE is well-established in the Chinese market, having manufacturing and assembly facilities located in Shenyang, a research centre in Shanghai, and several O&M centres that are spread across the country. GE's 1.5 MW wind turbine has an impressive track record with over 8,500 units in operation worldwide.

The GE 1.5sle wind turbines have an active yaw and pitch regulated with power/torque control capability and an asynchronous generator. They use a bedplate drive train design where all nacelle components are joined on a common structure, providing exceptional durability. The generator and gearbox are supported by elastomeric elements to minimise noise emissions and the slip coupling is designed to reduce gearbox load.

Since the commencement of production of the 1.5 MW wind turbines in 2002, GE has invested $750 million in improving the reliability and performance of this wind turbine model, and we have no concerns over the quality of this product. Details are given in Table 3.2.

Table 3.2: Technical Summary of GE 1.5sle

Hub Height	80 m
Rotor Diameter	77 m
Rated Power	1,500 kW
IEC Classification	IIA
Certification	Germanischer Lloyd IIA
Cut-in Wind Speed	3.5 m/s
Nominal Wind Speed	14 m/s
Cut-out Wind Speed	25 m/s
Generator	Asynchronous, doubly fed induction
Gearbox	Combined spur / Planetary gear
Gearbox Ratio	1:98
Power Regulation and Control	Variable via microprocessor, active blade pitch control

3.2.2 Vestas

With a 20% market share, Vestas is currently the world's leading supplier of wind turbines and has 39,000 wind turbines installed worldwide. Vestas entered the Chinese market 20 years ago and has supplied more than 1,500 turbines in 13 provinces in China with a total installed capacity of over 1,350 MW. Vestas is currently the leading foreign supplier in China. It has a head office in Beijing, a procurement office in Shanghai, and factories in Tianjin, Xuzhou and Hohhot with more than 80% of components produced in China.

The Vestas V52 wind turbines are pitch regulated, three-bladed, horizontal axis, variable speed upwind turbine for medium and high winds utilising Vestas' OptiSpeed control system. There are over 2,100 V52 turbines installed worldwide. The impressive operational experience and the excellent track record give confidence in the quality of the technology.

The OptiSpeed system employed in this wind turbine is a variable speed technology that allows the rotor speed to vary within a range of approximately 60% in relation to nominal rpm, which allows the rotor speed to vary by as much as 30% above and below synchronous speed, hence increasing productivity. Each turbine has a service crane that can lift up to 800 kg, used for lifting equipment and material needed to service the turbine. Additional sub-components can be lifted and fitted to the crane and support structures enabling the lifting capacity of the crane to increase to 6,400 kg. This additional lifting capacity allows components up to the weight of a generator to be removed without having to employ an external crane.

Overall, we consider Vestas to be a high quality, low risk supplier, widely accepted by the market and the certification provided for the projects gives us considerable confidence in the quality of the Chinese supply chain. Key parameters of the Vestas V52 are given in Table 3.3.

Table 3.3: Technical Summary of Vestas V52

Hub Height	55 m
Rotor Diameter	52 m
Rated Power	850 kW
IEC Classification	IA/IIA
Certification	Germanischer Lloyd IIA /DIBt II
Cut-in Wind Speed	4 m/s
Nominal Wind Speed	16 m/s
Cut-out Wind Speed	25 m/s
Generator	Asynchronous with OptiSpeed
Gearbox	Planet/Parallel axles
Gearbox Ratio	1:64.6
Power Regulation and Control	Variable via microprocessor, active blade pitch control

3.2.3 Gamesa

Gamesa is a leading wind turbine manufacturer in Spain, as well as one of the major international suppliers. In 2008 it was ranked the third largest wind turbine supplier in the world with more than 13,000 MW of installed capacity and a global market share of more than 15.4%[2]. Gamesa has installed thousands of wind turbines in China to date with a total installed capacity of 1,700 MW and has gained a relatively large market share.

Gamesa has extensive capabilities in designing wind turbines, as well as having the largest integrated production capacity in China, comprising the manufacturing of blades, root joints, blade moulds, gearboxes, generators, converters, towers, and assembly lines for wind turbines. Gamesa's domestic manufacturing facilities are located in Tianjin, where the company currently has four manufacturing plants which employ 1,000 people. Gamesa's presence in China dates to 2000.

The G52 wind turbine is a standard Gamesa product. Currently over 5,800 Gamesa G5X-850 kW wind turbines have been installed worldwide. We consider the G5X-850kW to be a well-established and mature wind turbine developed based on a Vestas' licensed design. The design of the G52 is similar to the Vestas V52 model which is recognised as a robust product. This also reflects the common ties of the two companies. Gamesa's G52 technology incorporates features including a doubly fed induction asynchronous generator and variable speed generator as summarised in Table 3.4.

Table 3.4: Technical Summary of G52

Hub Height	55/65m
Rotor Diameter	52 m
Rated Power	850 kW
IEC Classification	IA
Certification	TÜV Nord IA (2007)
Cut-in Wind Speed	4 m/s
Nominal Wind Speed	15 m/s
Cut-out Wind Speed	25 m/s
Generator	Doubly fed asynchronous
Gearbox	1 planetary stage / 2 helical stages
Gearbox Ratio	1:61.74
Power Regulation and Control	Pitch and variable speed technology

[2] BTM Consult ApS — March 2009

3.2.4 Goldwind

Goldwind is the oldest, largest, and most experienced wind turbine manufacturer in China. Founded in 1998, Goldwind started its business by procuring know-how from German wind turbine manufacturers. It first licensed REpower's 48-kW to 750-kW turbine technology in 2002 and then acquired a license in 2003 from Vensys Energiesysteme GmbH for its Vensys 62 1.2 MW turbine, and subsequently for the low wind speed version 64m — 1.5 MW model.

Goldwind has been enjoying an annual market share growth of 100% between 2000 and 2007, and 1,132 MW[3] of new installed capacity was implemented in 2008 alone. It has become the second largest WTG supplier in China with a market share of 18% by the end of 2008[4]. Goldwind currently offers WTG products ranging from 600 kW to 1,500 kW. Further to the acquisition of a 70% stake in Vensys, Goldwind started to develop 2.5 MW and 3 MW turbines. The manufacturer has built three factories in Hebei, Zhejiang, and Guangdong province and two production bases in Beijing and Baotou (Inner Mongolia), establishing a large production capacity in China.

The early Goldwind model S50 (summarised in Table 3.5) is based on REpower's 750kW wind turbine technology. Licensed by the German manufacturer, this technology has been replaced gradually by bigger, MW-sized wind turbines in the European market. Although the technology is relatively old, with stall blades that do not allow speed control and thus power control, we consider that the technology is mature and proven and this model to be reliable.

Table 3.5: Technical Summary of Goldwind S50

Hub Height	50 m
Rotor Diameter	50 m
Rated Power	750 kW
IEC Classification	IA
Certification	Germanischer Lloyd IA
Cut-in Wind Speed	3.5 m/s
Nominal Wind Speed	15 m/s
Cut-out Wind Speed	25 m/s
Generator	Squirrel-Cage induction generator
Gearbox	2 stages with 1 planetary gear and 1 helical gear
Gearbox Ratio	1:70.022
Power Regulation and Control	Stall regulation system, no speed control

3.2.5 Sinovel

Sinovel is a major Chinese wind turbine manufacturer and one of the world's top ten suppliers, achieving an installed wind turbine capacity of 1,403 MW in 2008 alone[5]. It has become the largest WTG supplier in China with a market share of 22% by the end of 2008[6]. Currently Sinovel has a factory in Dalian and is in the process of establishing its manufacturing facilities in Baotou (Inner Mongolia), Yancheng (Jiangsu Province) and Jiuquan (Gansu Province).

[3] BTM Consult ApS — March 2009

[4] Global and China Wind Power Industry Report, 2008-2009

[5] BTM Consult ApS — March 2009

[6] Global and China Wind Power Industry Report, 2008-2009

Sinovel SL1500/77 is a turbine product developed jointly with German manufacturer Führlander which owns independent intellectual property rights. Details are given in Table 3.6

Table 3.6: Technical Summary of SL1500/77

Hub Height	60 m
Rotor Diameter	77.4 m
Rated Power	1,500 kW
IEC Classification	IIIA
Certification	Germanischer Lloyd IIIA
Cut-in Wind Speed	3 m/s
Nominal Wind Speed	11 m/s
Cut-out Wind Speed	20 m/s
Generator	Doubly fed asynchronous
Gearbox	Two planetary stages + One spur gear stage
Gearbox Ratio	1:100.4
Power Regulation and Control	Electromechanical blade pitch

The SL1500/77 is a three-blade, horizontal shaft, wind turbine with a doubly fed generator, active pitch, and active yaw system with variable speed. The applicable low temperature version of SL1500 has an operating temperature ranging from -30°C to +45°C and survival temperature is from -45°C to +45°C. Structural components, rotating equipment, electric components and control system, and heating and sealing parts are all designed to sustain in cold climate conditions. In order to meet the harsh operating environment of China's windiest regions, Sinovel has gained experience in manufacturing built-to-resist wind turbines.

Sinovel's manufacturing process and quality control has obtained GL, CGC, ISO 9001 and ISO 14000 certifications and has some independent quality inspections of the quality system.

As discussed above, Sinovel developed its turbine technology jointly with the German manufacturer. We therefore expect limited technology risk. We consider Sinovel's design and manufacturing processes in-line with general industry trends.

3.2.6 Dongfang Steam Turbine Works (Dongfang Turbine Company)

Dongfang Steam Turbine Works (DFSTW) was founded in 1966 and is today one of the largest industrial enterprises in China engaged in research, design and manufacture of large-size steam and gas turbines for power plants. It is located in the suburbs of Deyang City, Sichuan Province, China. At present, DFSTW has an annual production capacity for conventional turbines of 14,000 MW in total. Through 38 years of development, DFSTW has built up production capability for manufacturing steam turbines from 0.75 MW to 1,000 MW as well as heavy duty gas turbines.

Recently, DFSTW established a production line in Tianjin for its 1.5 MW wind power turbines, FD70B and FD77B under its wholly owned company, DEC Tianjin Wind Power Technologies ("DEC Tianjin"). DEC Tianjin has a license from the established German company REpower to manufacture the latter's models in China. REpower has produced many hundreds of turbines with a similar design and this technology has gradually been replaced by bigger, MW-sized wind turbines in the European market. Although the technology is relatively old, we consider that the technology is mature and proven and this model to be reliable.

DEC Tianjin plans to produce 300 sets of 1.5 MW and 100 sets of 2.5 MW wind turbines in 2010. DEC Tianjin has a long-term aim to increase the productivity to realize an annual output target of 600 sets of 1.5 MW wind power turbines and 200 sets of 2.5 MW.

The technical summary of DEC Tianjin's turbines is provided in Table 3.7.

Table 3.7: Technical Summary of FD77A, FD70B/FD77B

	FD77A	FD77B	FD70B
Hub Height	61.5 m	61.5 m	65.0 m
Rotor Diameter	77 m	77 m	70 m
Rated Power	1,500 kW	1,500 kW	1,500 kW
IEC Classification		IIA	IIA
Certification		Germanischer Lloyd IIA	Germanischer Lloyd IIA
Cut-in Wind Speed	3 m/s	3 m/s	3.5 m/s
Nominal Wind Speed	12.5 m/s	12.0 m/s	13.0 m/s
Cut-out Wind Speed	20 m/s	20 m/s	25 m/s
Generator	Doubly-Fed asynchronous generator	Doubly-Fed asynchronous generator	Doubly-Fed asynchronous generator
Gearbox	3 stages with combined planetary and spur gear	3 stages with combined planetary and spur gear	3 stages with combined planetary and spur gear
Gearbox Ratio	1:104	1:104	1:94.7
Power Regulation and Control	Electrical blade pitch	Electrical blade pitch	Electrical blade pitch

3.3 Plant Performance — Availability and Generation

With the exception of Chengde Weichang Yudaokou wind farm, Mott MacDonald has visited all representative wind farms and held discussions with the technical staff in the local project teams in order to inspect the assets, gain a better understanding of the operational practice used and the management organisation in place, as well as to collect operational data of the plants.

In this sub-section, we summarise our findings in relation to the performance of the wind farms such as the availability of the wind turbines and actual electricity generated arrangements. Our assessments and findings are presented below on an individual wind farm basis.

3.3.1 Kangbao Wind Farm Phase 1

Kangbao wind farm is located in Zhangjiakou, Hebei province, China, and approximately 10 km away from the town of Kangbao. The wind farm consists of two phases controlled and operated by the Company. Phase I has a rated power of 30 MW and comprises 40 Goldwind S50 750 kW wind turbines. Phase I was commissioned in November 2006.

3.3.1.1 Generation and Availability

The wind farm is constructed on Bashang Plateau, which is a low mountain and hill region. The terrain of Phase I is relative high and simple, varying in altitude from 1,463 m to 1,694 m. It does not present any concerns regarding shading, channelling or excessive gradient which could cause adverse wind conditions. The climate is cold, with an annual mean ambient temperature of 1.7°C and this could be expected to influence performance in terms of blade icing. From an operational perspective, the site does not present any concerns.

A control building for both Phase I and Phase II is located close to the wind farm step-up substation. The control building includes the control centre, offices, spare parts store, accommodation and other site facilities. There are two areas for reactive power equipment.

The Company employs one site manager, six operational personnel and eight maintenance personnel in the site office for the entire wind farm operation and maintenance. The building and facilities are of a high standard and appear well maintained.

Site roads are good and should not present access problem for heavy plant in snow and ice. When MM team visited the site in January, we were able to visit the control building, site facilities and wind turbines.

Currently 40 Goldwind S50 wind turbines are operating at Phase I of Kangbao wind farm. Some technical maintenance issues were reported during our site visit. It was reported that hydraulic oil leakage occurred twice a month after the commissioning date. The problem was resolved by keeping topping up hydraulic oil by the maintenance staff. It is known that some wind turbines required their hubs to be replaced, resulting in reduced availability in April and May 2008 and a low average availability in 2008.

The wind farm is currently maintained by on-site maintenance personnel. A service and maintenance agreement with Goldwind lasted 2.5 years and expired in May 2009. It included an availability warranty of 95% (excluding scheduled maintenance, outage due to operational fault, and outage out of manufacturers' control such as grid downtime and severe weather conditions) with liquidated damages payable for shortfall. The liquidated damages are equivalent to the cost of wind turbines and are no greater than 15% of the total contract fee. In the service agreement, training of the Company's personnel includes a four-week on-site training for one person and four-week in-factory training for four people. The on-site staff are carrying out operation and maintenance work for Phase I wind farm. Six-month scheduled maintenance is arranged according to Goldwind maintenance guidelines. Commonly used spares were retained on site and major components could be sourced at relatively short notice. Kangbao has been set a target availability of 95%, which is expected to be exceeded.

Operational data, including monthly production and availability, has been supplied for Phase I from 2007 to 2009, as shown in Table 3.8. The type of WTGs installed has been changed from those in the feasibility study. It was originally envisaged to install 35×850 kW WTGs with hub height of 65 m and an energy yield calculation was undertaken on this basis in the feasibility study. We were informed that the change was due to unavailability of the originally specified WTGs. Although MM has no concerns over the suitability of the Goldwind S50-750 kW wind turbines, it is advisable, as per the international best practice, to undertake a detailed study including micro-siting as part of the decision making process to change to 40×750 kW WTGs with hub height of 50 m.

The predicted annual net energy yield calculated in the feasibility study is 65.0 GWh/year; actual reported production and availability during 2007 and 2008 is shown in Table 3.8 and is discussed below. This data shows the actual annual net energy yield is approximately 10% lower than the predicted value. Energy yield increased in 2009, as explained below, and we would expect future years to be more in line with expectations.

We have analysed the Phase I monthly production records for 2007 to 2009. As mentioned previously, the wind farm experienced low availability during two months of 2008 due to the hub replacement, resulting in a total availability of 92.9% and a capacity factor of 21.6%, slightly lower than the predicted figure. However, the average availability recovered and exceeded the guaranteed level of 95% again in 2009. With relatively higher wind speeds, the capacity factor in 2009 significantly increased.

At the date of inspection, some WTGs were stopped from 6 am to 5 pm due to grid dispatch centre order. We were informed that the local grid company would sometimes restrict the output of the wind farm during windy seasons. If there is no restriction from the grid company, the production can be expected to be higher during an average year.

Table 3.8: Operational Data of Phase I of Kangbao Wolongtushan Wind Farm

	Average availability	Total on-grid generation (MWh)	Utilisation hours	Capacity factor	Average wind speed at 70 m (m/s)
2009	98.5%	68,019	2,267	25.9%*	7.86 (Jan – Sept)
2008	92.9%	56,702	1,890	21.6%	7.73
2007	98.4%	59,500	1,983	22.6%	7.22

* includes a small portion of production from Phase II in Oct and Nov 2009 (Phase II commissioning test period)

3.3.1.2 Internal Connection and Substations

The wind farm has 40 Goldwind 750 kW WTG units installed. Each turbine is connected to a WTG step-up transformer via XLPE cross-bonded underground cables. These cables are rated appropriately in order to carry maximum output from each individual turbine.

These turbines are divided into two groups with 23 units and 17 units respectively, and each group is connected to its own 35 kV collection trunk line circuit. Both circuits consist of overhead line connection only, and are rated appropriately to carry the maximum output from the wind turbines.

A 110 kV step-up substation has been built for the wind farm. Single bus bar arrangement has been applied to both the 110 kV and the 35 kV bus bars. Both 35 kV collection lines are connected to the 35 kV bus bar at the substation, and then stepped up to 110 kV via one 50 MVA, 121/36.5 kV transformer. The transformer is equipped with an on-load tap changer which is able to control voltage between 110% and 90% at the HV winding. This transformer is rated sufficiently and has sufficient capability to maintain the voltage level at the wind farm step-up substation.

Appropriate protection schemes have been applied to the wind farm, including unit protection and overcurrent protection, which seem to be the common practice for most Chinese wind farms. All circuit breakers are rated appropriately to break fault current at different locations. Lightning protection equipments have been installed to prevent lightning impact on the wind farm equipment. No significant issue has been raised regarding the equipment condition.

3.3.2 Kangbao Wind Farm Phase 2

Phase II of Kangbao wind farm is located in Zhangjiakou, Hebei province, China, and is approximately 10 km away from the town of Kangbao. The rated capacity of the wind farm is 49.5 MW and it comprises 33 GE SCWE 1,500 kW SLE wind turbines. At the date of inspection, Phase II wind farm has been in commissioning test period from November 2009 and entered commercial operation in January 2010.

3.3.2.1 Generation and Availability

The wind farm is constructed on Bashang Plateau, which is a low mountain and hill region. The terrain of Phase II is relatively high and simple, varying in altitude from 1,446 m to 1,574 m. It does not present any concerns regarding shading, channelling or excessive gradient which could cause adverse wind conditions. The climate is very cold, resulting in long periods of subzero temperatures. These factors can be expected to influence performance in terms of blade icing. From an operational perspective this wind farm does not present any concerns.

A control building for both Phase I and Phase II is located close to the wind farm step-up substation. The control building includes the control centre, offices, spare parts store, accommodation and other site facilities. There are two areas for reactive power equipments. Phase II wind farm will be operated and maintained by the same O&M team as Phase I. The building and facilities are of a high standard and appear well maintained.

Site roads are good and should not present access problem in snow and ice. When MM team visited the site in January, we were able to visit the control building, site facilities and wind turbines.

Presently 33 GE1.5sle wind turbines are being tested by GE technicians at Phase II of Kangbao wind farm. A service and maintenance agreement with GE will last for one year from commissioning and includes an availability warranty of 95% (excluding scheduled maintenance and outages outside of manufacturer's control, such as adverse weather conditions) with liquidated damages payable for shortfall. The liquidated damages are equivalent to the loss in revenue. After one year, servicing and maintenance will be carried out by the Company. We were informed that two people from the Company had received training in Germany and would pass on their knowledge to the on-site O&M team.

Since the Phase II wind farm is currently in its commissioning test period, operational data, including monthly production and availability, is only available for December 2009 and January 2010, as shown in Table 3.9. Operational data during the commissioning period is heavily influenced by commissioning activities and standard teething issues and may not be a good indicator of future performance.

The predicted annual net energy yield calculated in the feasibility study for the investigated 1,500kW wind turbines, with a hub height of 80m, is 118.4 GWh/year. The generous loss assumptions in this assessment are expected to provide some comfort against the shortcomings of the wind resource analysis. Although there was not sufficient production data to verify the prediction when our assessment was undertaken, the two-month operational data provided is in line with expectations.

At the date of inspection, some WTGs were stopped from 6 am to 5 pm due to dispatch centre orders. We were informed that the local grid company would sometimes restrict the output of the wind farm during windy seasons. The project company could not provide full details of the specifics of the grid restriction but assured us that the impact on performance is very small and is accounted for in the availability figures.

Table 3.9: Operational Data of Phase II of Kangbao Wolongtushan Wind Farm

	Dec 2009	Jan 2010
Average Availability	95.1%	98.7%
Total On-grid Generation (MWh)	14,034.8	10,705.4
Utilisation Hours	283	216
Capacity Factor	38.1%	29.1%

3.3.2.2 Internal Connection and Substations

The wind farm has 33 GE 1.5 MW WTG units installed. The Phase I and the Phase II projects were designed by the same design institute, thus they are similar to each other in terms of internal connection. Each WTG is connected to a wind farm step-up transformer via a cable connection. The WTGs are divided into two groups with 17 units and 16 units separately. Each group is connected to its own 35 kV overhead collection line. Both lines are rated appropriately to carry maximum output from the turbines.

The Phase II wind farm is connected to the same wind farm step-up substation which was built in the Phase I project. A new 35 kV bus bar has been built to which the 35 kV collection lines are connected. The power collected from the 35 kV overhead lines is stepped up to 110 kV via one 50 MVA, 115/36.75 kV transformer. As in Phase I, the transformer is equipped with an on-load tap changer which is able to control voltage between 110% and 90% at the HV winding. This transformer is rated sufficiently, and has sufficient ability to maintain voltage level at the wind farm step-up substation.

Appropriate protection schemes have been applied to the wind farm, including unit protection and overcurrent protection, which seems to be the common practice for most Chinese wind farms. All circuit breakers are rated appropriately to break fault current at different locations. Lightning protection equipments have been installed to prevent lightning impact on the wind farm equipment. No significant issue has been raised regarding the equipment condition.

3.3.3 Guyuan Wind Farm Phase 1

Guyuan wind farm is located in Zhangjiakou, Hebei province, China, and is approximately 10 km from the town of Guyuan. The wind farm consists of two phases both of which are controlled and operated by the Company. Phase I is 30.6 MW and comprises 36 Gamesa G52-850 kW wind turbines. Phase I was commissioned in October 2007.

3.3.3.1 Generation and Availability

The wind farm is constructed on the north of Langyiba Mountain, which is a low mountain and hill region. The terrain of Phase I is relatively high and fluctuates greatly, varying in altitude from 1,450 m to 1,620 m. It is grassland and there is a defence forest near to the wind farm. The climate is very cold, resulting in long periods of subzero temperatures. These factors can be expected to influence performance in terms of blade icing.

A control building for both Phase I and Phase II is located close to the wind farm step-up substation. The control building includes the control centre, offices, spare parts store, accommodation and other site facilities. The Company employs one site manager, six operational personnel and eight maintenance personnel in the site office for the whole wind farm operation and maintenance. The building and facilities are of a high standard and appear well maintained.

Site roads are rough and may present access problems for heavy plant in snow and ice. When MM team visited the site in January, we were able to visit the control building, site facilities, but not the wind turbines.

Presently 36 Gamesa G52 wind turbines are operating at Phase I of Guyuan wind farm. Some minor technical maintenance issues were reported during our site visit. It was reported that some anemometers were contaminated by sand storms which resulted in WTGs stoppage. The problem was resolved by either cleaning or replacement. In addition we were informed that there had been an issue with the heating system of the wind turbines which resulted in fuses blowing. We were informed by the on-site staff that Gamesa had rectified the problem during the warranty period and that it no longer occurs. The G52 design is well established, therefore it is possible that these problems are caused by lower quality components sourced by Gamesa from domestic manufacturers, and while further similar minor issues are possible this does not present us with major concerns regarding the long-term integrity of the fleet.

The wind farm is currently maintained by on-site maintenance personnel. A service and maintenance agreement with Gamesa lasted two years and expired in July 2009. The agreement included an availability warranty of 95% (excluding scheduled maintenance, outage due to operational fault, and outage out of manufacturer's control such as grid downtime) with liquidated damages payable for shortfall. The liquidated damages were reported to have been equivalent to the loss in revenue. We were informed that previous on-site staff had received one month of training from Gamesa and had transferred their knowledge to current staff during the last year. The on-site staff carry out operation and maintenance work for Phase I wind farm. Commonly used spares (consumables and minor components) were present on site and the Company advised that major components could be sourced on relatively short notice. This provides us further confidence in provision of spare parts. Guyuan has been set a target availability of 95%, which is anticipated to be exceeded.

Operational data, including monthly production and availability has been supplied for Phase I, as shown in Table 3.10. This includes 29 months of post commissioning data for Phase I. We have therefore been able to compare actual production with predicted production, but the feasibility study was based on 35 WTG units although the actual number of installed units is 36.

We have analysed the Phase I yearly production records for 2008 — 2009. The wind farm shows a good average of 95.9% in 2008 and 96.9% in 2009, all above the 96% guarantee value. The total generation of each year is presented in Table 3.10.

We were informed during the site visit that the local grid company sometimes restricted the output of the wind farm during strong wind periods, which could result in a small loss of energy production.

Table 3.10: Operational Data of Phase I of Guyuan Wuhuaping Wind Farm

	2008	2009
Average Availability	95.9%	96.9%
Total On-grid Generation (MWh)	69,256	75,609
Utilisation Hours	2,263	2,471
Capacity Factor	25.80%	28.2%
Average Wind Speed at 70 m (m/s)	7.24 (Jan – Nov)	7.83 (Feb – Oct)

3.3.3.2 Internal Connection and Substations

The wind farm has 36 Gamesa 850 kW WTG units installed. Each turbine is connected to a WTG step-up transformer via one XLPE copper cross-bonded cable. The cable connection is rated appropriately to carry maximum output from each individual turbine.

These turbines are divided into two groups with 19 units and 17 units separately, and each group is connected to its own overhead 35 kV collection trunk line. The 35kV overhead lines are rated appropriately to carry maximum output from the wind turbines.

A 110 kV step-up substation has been built for the wind farm. Single bus bar arrangement has been applied to both the 110 kV and the 35 kV bus bars. Both 35 kV collection lines are connected to the 35 kV bus bar at the substation, and then stepped up to 110 kV via one 50 MVA, 121/36.5 kV transformer. The transformer is equipped with an on-load tap changer which is able to control voltage between 110% and 90% at the HV winding. This transformer is rated appropriately, and has sufficient ability to maintain voltage level at the wind farm step-up substation.

Appropriate protection schemes have been applied to the wind farm, including unit protection and overcurrent protection, etc, which seems to be the common practice for most Chinese wind farms. All circuit breakers are rated appropriately to break fault current at different locations. Lightning protection equipment has been installed. No significant issue has been raised regarding the equipment condition.

3.3.4 Guyuan Wind Farm Phase 2

Phase II of Guyuan wind farm is located in Zhangjiakou, Hebei province, China, and approximately 10 km away from the town of Kangbao. The rated capacity is 49.5 MW and comprises 33 GE SLE 1,500 kW wind turbines. At the date of inspection, Phase II wind farm had been in commissioning test period since December 2009 and commercial operation date commenced in January 2010.

3.3.4.1 Generation and Availability

The wind farm is constructed on Bashang Plateau, which is a low mountain and hill region. The terrain of Phase II is relative high and fluctuates greatly. It is grassland and there is a defence forest near to the wind farm. The climate is very cold, resulting in long periods of subzero temperatures. These factors can be expected to influence performance in terms of blade icing. From an operational perspective the wind farm does not present any concerns.

A control building for both Phase I and Phase II is located close to the wind farm step-up substation. The control building includes the control centre, offices, spare parts store, accommodation and other site facilities. Phase II wind farm will be operated and maintained by the some O&M team as Phase I. The building and facilities are of a high standard and appear well maintained.

Site roads are rough and could present access problems for heavy plant in snow and ice. When MM team visited the site in January, we were able to visit the control building, site facilities, but not wind turbines due to the weather conditions.

Presently 33 GE1.5sle wind turbines are being tested by GE technicians at Phase II of Guyuan wind farm. Likewise Phase II of Kangbao, a service and maintenance agreement with GE will last for one year from commissioning and includes an availability warranty of 95% (excluding scheduled maintenance and outage out with manufacturer's control such as adverse weather conditions) with liquidated damages payable for shortfall. The liquidated damages are equivalent to the loss in revenue. After one year, servicing and maintenance will be carried out by the Company. Guyuan has been set a target availability of 95%, which is expected to be exceeded.

Since the Phase II wind farm is currently in its commissioning test period, operational data, including monthly production and availability, is only available for September to December 2009. There is insufficient data available to give valuable comment on wind farm annual performance and our performance appraisal is primarily based on a review of the feasibility study.

We have carried out a review of the wind resource assessment contained in the feasibility study for Phase II Guyuan wind farm, which follows procedures set out in the recommended Chinese guidance for good practice — GB/T 18709-2002. The Company installed a 40 m mast (#0021) on site since 2005 and a 70 m mast (#0048) 2 km away from the site. The assessment is based on 30 month data from #0021 and 12 month data from #0048. The average wind speed at 70 m calculated in the feasibility study is 7.4 m/s, which indicate an average wind speed.

Three different 1,500 kW wind turbines have been investigated in the feasibility study corresponding to three different hub heights.

The project efficiency is estimated to be 62% and the annual net yield is predicted to be 116.2 GWh. As shown in Table 3.11, the initial production figures are in line with the prediction.

Table 3.11: Operational Data of Phase II of Guyuan Wuhuaping Wind Farm

	Sept 2009	Oct 2009	Nov 2009	Dec 2009
Average Availability	—	—	—	99.8%
Total On-grid Generation (MWh)	186.3	1287.1	1535.7	13836.8
Utilisation Hours	4	26	31	280
Capacity Factor	0.6%	3.5%	4.3%	37.6%

3.3.4.2 Internal Connection and Substations

Phase II of Guyuan wind farm has 33 GE 1.5 MW WTG units installed. The Phase I and the Phase II projects are designed by the same design institute, thus they are similar to each other in the terms of internal connection. Each WTG is connected to a wind farm step-up transformer via a cable connection. The WTGs are divided into two groups with 18 units and 15 units respectively. Each group is connected to its own 35 kV overhead collection line. Both lines are rated appropriately to carry maximum output from the turbines.

The Phase II wind farm is connected to the same wind farm step-up substation which was built in the phase I project. A new 35 kV bus bar has been built, to which the 35 kV collection lines are connected. The new 35 kV bus bar is connected to the Phase I 35 kV collection bus bar via one Normally-Open circuit breaker. The power collected from the 35 kV overhead lines is stepped up to 110 kV via one 50 MVA, 115/36.75 kV transformer. As in Phase I, the transformer is equipped with an on-load tap changer which is able to control voltage between 110% and 90% at the HV winding. This transformer is rated sufficiently, and has sufficient ability to maintain voltage level at the wind farm step-up substation.

Appropriate protection schemes have been applied to the wind farm, including unit protection and overcurrent protection, which seems to be the common practice for most Chinese wind farms. All circuit breakers are rated appropriately to break fault current at different locations. Lightning protection equipment has been installed. No significant issue has been raised regarding the equipment condition.

3.3.5 Dongxinying Wind Farm

Dongxinying wind farm is located in Zhangjiakou, Hebei province, China, and approximately 37 km away from the town of Guyuan. The wind farm is currently under construction. It will have 199.5 MW of installed capacity and will comprise 133 Dongfang Turbine Company FD77B 1,500 kW wind turbines. Commercial operation is expected to commence in 2011. We were able to visit the site office and substation but not inside the wind farm due to the snow. Our assessment is based on a document review and a meeting with the project construction team in the site office.

3.3.5.1 Project Construction and Availability

The wind farm is constructed on the southwest mountain area of the town of Guyuan. The terrain of the wind farm is relatively high and fluctuates greatly, varying in altitude from 1,650 m to 1,860 m ASL. The climate is very cold, resulting in long periods of subzero temperatures.

A control building and an office building is located close to the wind farm step-up substation. The control centre, offices, spare parts store, accommodation and other site facilities are included in the two buildings. The buildings and facilities are of a high standard.

The wind farm is currently under construction and is expected to be operational in 2010. Construction activity had ceased by the time we carried out our inspection due to the onset of winter. Due to the extreme cold temperatures, construction is only possible between April and December. We were provided with a key milestone list for activity carried our in the second half of 2009, as shown in Table 3.12. The WTG foundations, 35 kV cable foundations, tower construction and the substation civil works are reported to be completed. Presently all of the construction works are on schedule.

Table 3.12: Construction Milestones of Dongxinying Wind Farm in the Second Half of 2009

Milestones	Project Scheduled Date	Actual Completion Date
133 WTGs foundations	15th Nov 2009	27th Jul 2009
133 Box transformers foundations	—	28th Aug 2009
Step-up substation civil work	30th Sept 2009	30th Sept 2009
Tower foundations	—	10th Oct 2009
Step-up substation operates as distribution substation	31st Oct 2009	31st Oct 2009
35 kV cable foundation & 6 circuits tower construction	30th Nov 2009	30th Nov 2009 (12 circuits tower construction)
Tower construction	—	16th Dec 2009

We were informed that the wind farm is being constructed under three separate contracts:

Table 3.13: Main Contractors of Dongxinying Wind Farm

Contracting Company	Responsibility
Hebei No. 1 Electric Power Construction Company	Civil work for the 220 kV step-up substation and 35 kV cable, 50 WTGs foundation and site road construction.
Hubei Hongyuan Power Engineering Co., Ltd	83 WTG foundations
Zhangjiakou Transmission and Distribution Engineering Company	Foundations and installation of all electric equipments (e.g. main transformers)

We note that the information available relating to the contractors' track records is not sufficient for us to provide any opinion with regard to the quality of the construction.

A total of 133 WTGs are supplied by Dongfang Turbine Company and will be delivered to the site by the end of July 2010. Two contractors including Shanghai Taisheng and Qindao Wuxiao will supply the 133 towers respectively. The supplier of the 133 box transformers has already been selected.

The project construction team described its management strategy which was noted to be reasonably consistent with that employed on other projects we have seen in China. The project construction team holds a weekly meeting with the contractors and a construction supervision company — Hebei Power Project Management Co., Ltd. We were provided with a sample of the minutes of one of these weekly meetings. Weekly construction progress, schedule, and main issues are reported by the contractors during these meetings. During these meetings, any concerns relating to progress, quality and safety were raised by the project construction team. Monthly construction reports submitted by the contractors are also handed over to the parent company for monitoring purposes. After our visit, the Company provided supporting information in the form of project schedules covering activities during 2008 and 2009, and sample construction reports, which provide further confidence in the management of the project.

Since the wind farm is under construction, there was not sufficient data available to give valuable comment on wind farm annual performance and our performance appraisal is primarily based on a review of the feasibility study.

We have carried out a review of the wind resource assessment contained in the feasibility study for the wind farm, which follows procedures set out in the recommended Chinese guidance for good practice — GB/T 18709-2002.

The Company installed three 10 m masts and three 70 m masts on site. The assessment is based on 12 month data from May 2006 to April 2007 of each mast. The average wind speed at 65 m calculated in the feasibility study is 7.72 m/s, 6.77 m/s and 7.23 m/s at 3 70m masts respectively.

The wind farm occupies a very large area and the terrain across the site is fairly complex, characterised by a series of ridges. The met masts are positioned on the northern peripheries of the wind farm at lower altitude than most of the turbine positions. In our opinion, the measurement campaign would have benefited from additional met masts.

Reference data from a nearby reference station was assessed in order to investigate the long-term average wind speed trends. We were not aware of any adjustment to the site data and it is assumed that the measurement period represents the long-term average conditions.

WAsP software has been used to extrapolate the average wind speed across the site. Where more than one met mast is present, we believe it is the international best practice to validate the wind flow model by cross predicting between each mast. As this was not included in the feasibility study, we would expect the result may not be as accurate as what we would expect to see in the European practice.

Layouts and energy yield predictions have been calculated for a variety of different turbine types. The source of the power curves used in the energy calculations is not specified. The constructed wind farm comprises Dongfang Turbine Company 1,500 kW wind turbines with a hub height of 61.5m. However, the energy yield has been assessed assuming an unspecified 1,500 kW wind turbine and a 65m hub height.

The total project efficiency estimated in the feasibility study is 74.3%, which is conservative, providing some comfort. The Net Yield proposed in the feasibility study is 405.7 GWh/year equivalent to a capacity factor of 23.2%.

In the other projects, it has been the case that any inaccuracy in the calculated average wind speed has been broadly compensated by conservative estimated efficiency.

During the operational phase of the project, the project construction team will be replaced by an operational and maintenance team. A two year availability guarantee of 95% is included in the Dongfang Turbine Company supply agreement. An assumed availability of 95% has been included in the energy yield predictions with a further loss factor of 98% allowed for adverse weather (cold climate). It is expected that the availability of the wind farm is likely to be impacted by the extreme cold and accessibility during winter. We understand that measures are being implemented to improve the accessibility and the assumed availability seems reasonable at this stage. The fulfilment of operation and maintenance training has been agreed with Dongfang Turbine Company and contained in the supply agreement.

3.3.5.2 Internal Connection and Substations

The Dongxinying wind farm has 133 Dongfang Turbine Company FD77B WTG units installed. Each turbine is connected to a WTG step-up transformer via three parallel cables. The overall rating of these three cables is sufficient for the power output from each individual turbine.

The turbines are divided into twelve groups. Each group is connected to its own 35 kV collection line. The 35 kV collection system consists only of overhead lines. Each line uses the same conductor type, and is rated appropriately to carry maximum output from the connected turbines.

A 220 kV step-up substation has been built for the wind farm. The power generated from turbines is collected via twelve 35 kV collection lines, and is then transferred to the 35 kV bus bar at the step-up substation. The 35 kV bus bar is divided into two sections, each having six collection lines connected. At each section, the power is stepped up to the 220 kV via one 120 MVA, 242/38.5 kV transformer. This transformer is rated sufficiently, and has sufficient ability to maintain voltage level at the wind farm step-up substation.

Proper protection schemes have been applied to the wind farm, including unit protection and overcurrent protection, which seems to be the common practice for most Chinese wind farms. All circuit breakers are rated appropriately to break fault current at different locations. Lightning protection equipments have been installed. No significant issue has been raised regarding the equipment condition.

3.3.6 Haixing Wind Farm

The 49.5 MW Haixing wind farm, in the Cangzhou area on the east coast of China began, operating in September 2008. Our assessment is based on a site visit carried out on the 20th January 2010, discussions with the wind farm operators and a review of relevant documents.

3.3.6.1 Generation and Availability

Despite the proximity to significantly urbanised surroundings, the terrain immediately adjacent the wind farm is conducive to favourable wind conditions characterised by large saltpans extending eastwards as far as the coast. The prevailing wind direction is southwest, but the site experiences stronger, less frequent spells of easterly winds which blow in from the open sea and contain most of the energy. The nearby city of Huanghua is expanding rapidly, but the unfavourable ground conditions around the wind farm are expected to prevent the city infringing on the wind farm.

The wind farm currently has 49.5 MW of installed capacity made up of 33 Dongfang Turbine Company 1.5MW wind turbines with a hub height of 61.5 m and rotor diameter of 77 m. The wind farm may be extended to 200MW. The site includes a central control building and substation. The control building facilities include the control room, protection panels, meeting rooms, accommodation and offices. The substation is installed outside the control building and includes a single 50 MVA transformer. A nearby electrical annex contains reactor banks for power factor compensation. The inter array cables are overhead lines and the wind turbine transformers and switch gear are external to the wind turbines. It is expected that the high saline environment will increase the likelihood of corrosion.

Preconstruction estimates of the average annual energy yield were carried out by Heibei Electrical Power Design Institute (河北省電力勘測設計研究院) and are included in the feasibility study.

We noted that the wind resource assessment appears to have adopted some assumptions that may affect the accuracy of the predicted average wind speed.

In the other projects, it has generally been the case that any inaccuracy in the calculated average wind speed has been broadly compensated by a conservative estimated efficiency. In this project some loss assumptions used in the feasibility study are consistent with commonly used assumptions in Europe and are therefore less conservative.

The predicted annual net yield is 109.5 MWh (capacity factor 25.3%) as proposed in the feasibility study. The recorded generational and capacity factor during 2009 was 92.1 GWh and 21.2% respectively, as shown in Table 3.14.

Table 3.14: Operational Data of Haixing Wind Farm

	2009
Average Availability	96.0%
Total On-grid Generation (MWh)	92,112
Utilisation Hours	1,860
Capacity Factor	21.2%
Average Wind Speed at 70 m (m/s)	5.7 (Jan – Sept)

The annual average hub height wind speed recorded during 2009 is 5.5m/s. This wind speed is the average wind speed recorded across all of the nacelle anemometers and will therefore be subject to wake influence from the rotor and other wind turbines.

We do not have a reliable reference data station with which to correlate and compare the 2009 data to determine whether the 2009 period represents a high or a low wind speed year. As an alternative we have extracted 15 years wind speed data sets from the closest NCAR data node. The srf 42 m NCAR data set indicates that 2009 was slightly below average wind speed year and the u10 data set indicates that 2009 was an average wind speed year. The correlation of NCAR monthly mean wind speeds with the recorded nacelle anemometer wind speeds is good suggesting that the NCAR data set is a good representation of the wind farm wind climate. Our analysis is not conclusive, but it provides a good indication that the wind speeds during 2009 were close to the long-term average.

The reported average availability during 2009 was 95.9% which is good, especially for a first operating year. During this period a teething problem in the generators was identified which resulted in a batch recall by Dongfang Turbine Company. A program of replacement was underway at the time of the site visit with half of the units replaced. Other maintenance issue was gearbox oil leakages which were solved when our site visit took place. A consequence of the gearbox oil leaks was that oil drained in to the pitch control mechanisms causing damage and in some cases causing the loss of pitch control. It was reported that on each of these few occasions the turbine automatically shut down without over-speeding or causing further damage. We expect that this should not be a major issue now.

Dongfang Turbine Company has a spare parts depot on the site which is used to supply the region. This depot holds minor parts only but offers an obvious advantage for the Haixing wind farm operation. The Haixing operators have a spare parts holding of consumables and minor components. It is reported that major components can be delivered promptly if needed.

Presently the wind farm is operating under an availability guarantee provided by Dongfang Turbine Company which will expire in October 2010. During this period the turbine availability is guaranteed at 95%. Dongfang Turbine Company also has the responsibility of training the Haixing operators. We expect that after October 2010 the Haixing operations team will be able to maintain the good turbine availability achieved thus far, since initial teething problems should now have been resolved and the maintenance activities, including a fleet-wide major component change, will have provided the Haixing technicians with some valuable experience. Accordingly the Company has set a target turbine availability of >95%.

Based on the first year performance, the Company has set an annual production target of 84.0 GWh for Haixing wind farm. We consider this easily achievable and expect the production recorded during 2009 of 93.8

GWh to be representative of future average annual production, although future expansion of the wind farm will slightly reduce the performance of the existing installed wind turbines.

3.3.6.2 Internal Connection and Substations

The Haixing wind farm has 33 Dongfang Turbine Company FD77A 1.5 MW WTG units installed. Each turbine is connected to a WTG step-up transformer via one XLPE copper cross-bonded cable. The cable connection is rated appropriately to carry maximum output from each individual turbine.

These turbines are divided into three groups, and each group is connected to its own 35 kV collection trunk line. Each of the 3 lines consists of only overhead line connection, and is rated appropriately to carry maximum output from the connected wind turbines.

A 110 kV step-up substation has been built for the wind farm. Single bus bar arrangement has been applied to both the 110 kV and the 35 kV bus bars. The three 35 kV collection lines are connected to the 35 kV bus bar at the substation, and stepped up to 110 kV via one 50 MVA, 115/36.75 kV transformer. The transformer is equipped with an on-load tap changer which is able to control voltage between 110% and 90% at the HV winding. This transformer is rated sufficiently, and has sufficient capability to maintain voltage level at the wind farm step-up substation.

Appropriate protection schemes have been applied to the wind farm, including unit protection and overcurrent protection, which seems to be the common practice for most Chinese wind farms. All circuit breakers are rated appropriately to break fault current at different locations. Lightning protection equipments have been installed. No significant issue has been raised regarding the equipment condition.

3.3.7 Chongli Wind Farm Phase 1

Chongli Qingshanying wind farm is located in Zhangjiakou, Hebei province, China, and is approximately 38 km away from the town of Chongli. The wind farm consists of two phases, both controlled and operated by the Company. Phase I is 49.3 MW and comprises 58 Gamesa G52-850 kW wind turbines. Phase I was commissioned in November 2008.

3.3.7.1 Generation and Availability

The wind farm is constructed on the mountains along Qingshui River, Qingsanying County, which is a medium and low mountain region. The terrain of Phase I is relative high and fluctuates greatly, varying in altitude from 1,700 m to 2,043 m. The climate is very cold, resulting in long periods of subzero temperatures. These factors can be expected to influence performance in terms of blade icing. From an operational perspective the wind farm does not present any concerns.

A control building for both Phase I and Phase II is located close to the wind farm step-up substation. The control building includes the control centre, offices, spare parts store, accommodation and other site facilities. The Company employs one site manager, six operational personnel and nine maintenance personnel in the site office for the whole wind farm operation and maintenance. The building and facilities are of a high standard and appear well maintained.

Site roads are rough and may present access problems for heavy plant in snow and ice. When MM team visited the site in January, we were able to visit the control building, site facilities, but not the wind turbines due to the snow and ice on site.

Presently 58 Gamesa G52 wind turbines are operating in Phase I of Chongli wind farm. Some technical maintenance issues were reported during our site visit. A technical issue on one of the turbine's blades was identified, but Gamesa has since rectified the problem.

The 35 kV overhead lines were experiencing faults on the date of inspection. The reason was explained to be tension issue. The lines were not installed with tension in accordance with the design and wind speeds of approximately 20 m/s caused the lines to vibrate and swing significantly causing faults and protection tripping. During discussion with the maintenance staff we were told that the problem was being resolved by systematic modification to the correct design tension. We also noticed that the SCADA system in the central control room did not show the correct generation figures, due to a telecommunication cable failure. We understood that the operational staff had referred this to the manufacturer. At that time they were monitoring the generation via a meter installed at the connect point to the grid. These are minor technical issues and we do not expect them to cause any impact on the operation of the wind farm.

The wind farm is currently under a service and maintenance agreement with Gamesa lasting two years and will expire in November 2010. It includes an availability warranty of 95% (excluding scheduled maintenance, outage due to operational faults, and outage out of manufacturer's control such as grid downtime) with liquidated damages payable for shortfall. The liquidated damages are reported to be equivalent to the loss in revenue. We consider the terms adequate for projects of this type. We were informed that over a dozen on-site staff had received a few weeks of training from Gamesa. After the expiration of the agreement, the on-site staff will carry out the operation and maintenance work for the Phase I wind farm. Commonly used spare parts were retained on site and the company advised that major spare parts could be sourced at short notice, which provides further confidence.

Operational data including monthly production and availability has been supplied for Phase I, as shown in Table 3.15. This includes 12 months of post commissioning data for Phase I. We have therefore been able to compare actual production with predicted production.

We have carried out a review of the wind resource assessment contained in the feasibility study for Chongli Phase I which follows procedures set out in the recommended Chinese guidance for good practice — GB/T 18709-2002.

The Company installed three met masts for measuring data for the preconstruction feasibility study, including a 10 m mast (#0013) on site, at 1,737 m ASL, with data measured during 2004 to 2006; a 40 m mast (#0011) nearby, at 1,567 m ASL, with data measured during 2004 to 2005; and a 10 m mast (#0012) nearby, at 1,691 m ASL, with data measured during 2004 to 2006. The assessment is based on 18 month data from #0013, 15 month data from #0011 and 18 month data from #0012. The average wind speed at 55 m and 65 m calculated in the feasibility study varies between 7.5 m/s and 10.7 m/s at mast #0012. The wind speeds recorded at mast #0012 at 10m are exceptionally high and are not in keeping with data recorded at the other two masts. We consider that the site average hub height wind speed is much more likely to be closer to 7.5 m/s. This is backed up by the data recorded during the production period.

Energy yield predictions for 81 wind turbine positions have been calculated despite the wind farm comprising only 58 turbines. We understand that the approach followed by the design institute was to optimise the layout for maximum capacity and then the most optimal turbine positions were then exploited. The slight drawback in this approach is that the wake influences will not be captured in the constructed layout.

A project efficiency of 59% has been assumed which is below our expectation, this can be considered to be very conservative.

The Net Yield prediction for the wind farm is 113.1GWh/year which is very close to the reported production during 2009.

We have analysed the Phase I yearly production records for 2009. The wind farm shows a good average of 97.6%, above the 95% guaranteed value. The total generation of each year is presented in Table 3.15. Comparing the actual generation with the forecast made in the feasibility study as presented earlier in this report, we are able to confirm that Phase I generates the electricity as expected.

Likewise, we were informed that the local grid company will sometimes restrict the output of the wind farm during windy seasons.

Table 3.15: Operational Data of Phase I of Chongli Wind Farm Phase I

	Average availability	Total on-grid generation (MWh)	Utilisation hours	Capacity factor	Average wind speed at 40 m (m/s)
2009	97.6%	119,046	2,415	27.6%	7.5 (Jan – Sept)
2008	—	—	—	—	7.5
2007	—	—	—	—	6.9

3.3.7.2 Internal Connection and Substations

The Chongli Phase I wind farm has 58 Gamesa G-52 850 kW WTG units installed. Each turbine is connected to a WTG step-up transformer via one XLPE copper cross-bonded cable. The cable connection is rated appropriately to carry maximum output from each individual turbine.

These turbines are divided into three groups, and each group is connected to its own 35 kV collection trunk line. All three of these lines consist of only overhead conductors, and all are rated appropriately to carry maximum output from the wind turbines.

A 110 kV step-up substation has been built for the wind farm. Single bus bar arrangement has been applied to both the 110 kV and the 35 kV bus bars. The three 35 kV collection lines are connected to the 35 kV bus bar at the substation, and then stepped up to 110 kV via one 50 MVA, 115/36.75 kV transformer. The transformer is equipped with an on-load tap changer which is able to control voltage between 110% and 90% at the HV winding. This transformer is rated sufficiently, and has sufficient ability to maintain voltage level at the wind farm step-up substation.

Appropriate protection schemes have been applied to the wind farm, including unit protection and overcurrent protection, which seems to be the common practice for most Chinese wind farms. All circuit breakers are rated appropriately to break fault current at different locations. Lightning protection equipments have been installed. No significant issue has been raised regarding the equipment condition.

3.3.8 Chongli Wind Farm Phase 2

Phase II of Chongli wind farm is located in Zhangjiakou, Hebei province, China, and approximate 38 km away from the town of Chongli. It has a rated capacity of 49.3 MW and comprises 58 Vestas V52-850 kW wind turbines. 29 WTGs of Phase II were commissioned in March 2009, while the remaining 29 units were commissioned in June 2009.

3.3.8.1 Generation and Availability

The wind farm is constructed on the west of Zhangjiakou — Guyuan Highway, which is a low mountain and hill region. The terrain of Phase II is relatively high and fluctuates greatly, varying in altitude from 1,463 m to 1,694 m. It is grassland or low-lying and there is a small number of trees on the hills. The climate is very cold, resulting in long periods of subzero temperatures. These factors can be expected to influence performance in terms of blade icing. From an operational perspective the wind farm does not present any concerns.

A control building for both Phase I and Phase II is located close to the wind farm step-up substation. The control building includes the control centre, offices, spare parts store, accommodation and other site facilities. Phase II wind farm is being operated and maintained by the same O&M team as Phase I. The building and facilities are of a high standard and appear well maintained.

Site roads are rough and may present access problems for heavy plant in snow and ice. When MM team visited the site in January, we were able to visit the control building, site facilities, but not the wind turbines.

Presently 58 Vestas V52-850 wind turbines are under a service and maintenance agreement with Vestas that will last for two years from commissioning and includes an availability warranty of 95% (excluding scheduled maintenance and outage out of manufacturer's control such as adverse weather conditions) with liquidated damages payable for shortfall. The liquidated damages are equivalent to the loss in revenue. After two years, servicing and maintenance will be carried out by the Company.

We were provided with operational data including monthly production and availability in 2009, although it has been commissioned only since March 2009. We have therefore been able to compare actual production with predicted production.

We have carried out a review of the wind resource assessment contained in the feasibility study for Phase II Chongli wind farm, which follows procedures set out in the recommended Chinese guidance for good practice — GB/T 18709-2002. The Company installed a 10 m mast (#1) on site since September 2005 and a 70 m mast (#2) 3 km away from the site. The assessment is based on 18 months of data from #1 and 11 months of data from #2. The average wind speed at 55 m calculated in the feasibility study is 8.6 m/s, which indicates a good wind speed.

The site appears to consist of complex terrain. This increases the error in wind flow modelling and can be mitigated by carrying out a more rigorous measurement campaign.

Layouts have been developed for 85 wind turbine layouts whereas the wind farm only comprises only 58 turbines. We understand that the approach followed by the design institute was to optimise the layout for maximum capacity and then the most optimal turbine positions were exploited. The slight drawback in this approach is that the wake influences will not be captured in the constructed layout.

The total project efficiency is estimated to be 62.1% which can be considered to be conservative from the European perspective, but we understand that this is in line with the common industry practice in China.

The predicted Net Yield for 58 850kW wind turbines at 55m hub height is 109.0 GWh/year. This is slightly higher than the reported production for 2009.

We have analysed the Phase II yearly production records for 2009. The wind farm shows a good average of 99.26% since commissioning, above the 95% guaranteed value. The total generation in 2009 is presented in Table 3.16.

Table 3.16: Operational Data of Chongli Wind Farm Phase II

	2009
Average Availability (Jul – Dec)	99.26%
Total On-grid Generation (MWh)	101,624
Utilisation Hours	2,061
Capacity Factor	23.5%

3.3.8.2 Internal Connection and Substations

The Chongli Phase II wind farm has 58 Vestas V-52 850 kW WTG units installed. Each turbine is connected to a WTG step-up transformer via one XLPE copper cross-bonded cable. The cable connection is rated appropriately to carry maximum output from each individual turbine.

These turbines are divided into two groups, and each group is connected to its own 35 kV collection trunk line. Both lines consist of only overhead line connection, and are rated appropriately to carry maximum output from the wind turbines.

A 110 kV step-up substation has been built for the wind farm. Single bus bar arrangement has been applied to both the 110 kV and the 35 kV bus bars. Both 35 kV collection lines are connected to the 35 kV bus bar at the substation, and then stepped up to 110 kV via one 50 MVA, 115/36.75 kV transformer. The transformer is equipped with an on-load tap changer which is able to control voltage between 110% and 90% at the HV winding. This transformer is rated sufficiently, and has sufficient capability to maintain voltage level at the wind farm step-up substation.

Appropriate protection schemes have been applied to the wind farm, including unit protection and overcurrent protection, which seems to be the common practice for most Chinese wind farms. All circuit breakers are rated appropriately to break fault current at different locations. Lightning protection equipments have been installed. No significant issue has been raised regarding the equipment condition.

3.3.9 Yuxian Wind Farm Phase 1

Yuxian Wind Farm Phase I is located in Zhangjiakou, Hebei province, China, and is approximately 50 km from the town of Yuxian. The wind farm consists of two phases owned and operated by the Company. Phase I is 49.5 MW and comprises 33 Dongfang Turbine Company FD70B 1,500kW wind turbines. Phase I was commissioned in January 2009.

3.3.9.1 Generation and Availability

The wind farm is constructed on grassland on a plateau at the top of a mountain. The terrain of Phase I is relatively high and flat, varying in altitude from 1,900 m to 2,050 m. It does not present any concerns regarding shading, channelling or excessive gradient which could cause adverse wind conditions. The climate is very cold, resulting in long periods of subzero temperatures. These factors can be expected to influence performance in terms of blade icing. From an operational perspective the wind farm does not present any concerns.

A control building for both Phase I and Phase II is located close to the wind farm step-up substation. The control building includes the control centre, offices, spare parts store, accommodation and other site facilities. The Company employs one site manager and fourteen personnel in the site office for the whole wind farm operation and maintenance. The building and facilities are of a high standard and generally appear well maintained.

Site roads are good and should not present access problems for heavy plant in snow and ice. When MM team visited the site in January, we were able to visit the control building, site facilities and wind turbines. We were informed that the Company employed an icebreaking snow sweeper for clearing the site roads during winter season.

Currently 33 Dongfang Turbine Company FD70B wind turbines are operating in Phase I of Yuxian wind farm. Some technical teething problems were discussed during our site visit. For instance, there were some unexpected stoppages due to lack of familiarity with the newly installed technology. Four staff from the manufacturer are present on site to carry out maintenance who were investigating the issue. Spare parts delivery time was another potential issue. To address this, a spare parts store has been built to stock containing for common failure items. The site manager advised that as they gain a better understanding of the equipment, they intend to improve the situation by retaining strategic spares as required.

The wind farm is currently under a service and maintenance agreement with Dongfang Turbine Company lasting two years from commissioning. It includes an availability warranty of 95% (excluding scheduled maintenance, outage due to operational fault, and outage out of manufacturer's control such as grid downtime or adverse weather conditions) with liquidated damages payable for shortfall. The liquidated damages are reported to be equivalent to the cost of wind turbines and no greater than 10% of the total contract fee. We were informed that about seven on-site personnel had received training for 20 days from Dongfang Turbine Company.

Operational data including monthly production and availability has been supplied for Phase I for 2009, as shown in Table 3.17. We have therefore been able to compare actual production with predicted production.

We have carried out a high level review of the wind resource assessment contained in the feasibility study for Yuxian Phase I which follows procedures set out in the recommended Chinese guidance for good practice — GB/T 18709-2002. The Company installed a 40 m mast (#0014) on site since 2004. The assessment is based on 15 month data from #0014. The average wind speed at 65 m calculated in the feasibility study is 8.3 m/s, which indicates a good wind speed.

The total project efficiency is estimated at 67.5% which can be considered to be conservative. The predicted Net Yield is 118.4 GWh/year.

We have analysed the Phase I monthly production records for 2009. The wind farm experienced low availability during the first several months of 2009 due to the reasons mentioned above, resulting in a total availability of 87% and a production of 92 GWh. If the production were to be adjusted to the guaranteed availability level of 95%, after the teething troubles have been resolved by the manufacturer, then the production would increase to approximately 100 GWh.

Table 3.17: Operational Data of Yuxian Wind Farm Phase I

	Average availability	Total on-grid generation (MWh)	Utilisation hours	Capacity factor	Average wind speed at 40 m (m/s)
2009	87%	91,668	1,856	21%	6.5 (Mar – Sept)
2008	—	—	—	—	8.1
2007	—	—	—	—	7.4

3.3.9.2 Internal Connection and Substations

The Yuxian Phase I wind farm has 33 Dongfang Turbine Company FD70B 1.5 MW WTG units installed. Each turbine is connected to a WTG step-up transformer via 1 XLPE copper cross-bonded cable. The cable connection is rated appropriately to carry maximum output from each individual turbine.

These turbines are divided into three groups, each with 11 wind turbines. Each group is connected to its own 35 kV collection trunk line which consists of both overhead line and underground cable connection. The conductor type for the overhead line is LGJ-185/30, while for the underground cable, it is YJV22-26/35-3*240. The maximum current carry capacity for the conductors are 530 A and 557 A respectively, both of which are able to withstand the maximum power output from 11 wind turbines in each group

A 110 kV step-up substation has been built for the wind farm. Single bus bar arrangement has been applied to both the 110 kV and the 35 kV bus bars. Three 35 kV collection lines are connected to the 35 kV bus bar at the substation, and then stepped up to 110 kV via one 50 MVA, 115/36.75 kV transformer. The transformer is equipped with an on-load tap changer which is able to control voltage between 110% and 90% at the HV winding. This transformer is rated sufficiently, and has sufficient ability to maintain voltage level at the wind farm step-up substation.

Appropriate protection schemes have been applied to the wind farm, including unit protection and overcurrent protection, which seems to be the common practice for most Chinese wind farms. All circuit breakers are rated appropriately to break fault current at different locations. Lightning protection equipments have been installed.

3.3.10 Yuxian Wind Farm Phase 2

Yuxian wind farm is located in Zhangjiakou, Hebei province, China, and approximately 50 km away from the town of Yuxian. Phase II is 49.5 MW and comprises 23 Dongfang Turbine Company FD77B 1,500 kW wind turbines and 10 FD70B 1,500 kW wind turbines. Phase II was commissioned in November 2009.

3.3.10.1 Generation and Availability

The wind farm is constructed on grassland on the top of a mountain. The terrain of Phase II is relatively high and fluctuates slightly, varying in altitude from 1,600 m to 2,100 m. There are valleys and steep slopes on the northern, western and southern boundary. It is surrounded by trees. The climate is very cold, resulting in long periods of subzero temperatures. These factors can be expected to influence performance in terms of blade icing. From an operational perspective the wind farm does not present any concerns.

A control building for both Phase I and Phase II is located close to the wind farm step-up substation. The control building includes the control centre, offices, spare parts store, accommodation and other site facilities as mentioned in section 3.3.9. Phase II wind farm is operated and maintained by the same O&M team as Phase I.

Presently 33 Dongfang Turbine Company FD77B/FD70B wind turbines are operating in Phase II of Yuxian wind farm. Similar technical maintenance issues were reported during our site visit as those reported for Phase I.

The wind farm is currently under a service and maintenance agreement with Dongfang Turbine Company lasting two years from commissioning. The agreement includes an availability warranty of 95% (excluding scheduled maintenance, outage due to operational fault, and outage out of manufacturer's control such as grid downtime or adverse weather conditions) with liquidated damages payable for shortfall. The liquidated damages are reported to be equivalent to the cost of wind turbines and no greater than 10% of the total contract fee.

Operational data, including monthly production and availability has been supplied for Phase II in 2009, as shown in Table 3.18. Since Phase II was commissioned in November 2009, there is insufficient data available to give valuable comment on wind farm annual performance and our performance appraisal is primarily based on a review of the feasibility study.

We have carried out a review of the wind resource assessment contained in the feasibility study for Yuxian Phase II which follows procedures set out in the recommended Chinese guidance for good practice — GB/T 18709-2002. The Company installed a 40 m mast (#0014) on site since 2004 (as used in Phase I). The assessment is based on 30 months of data from #0014. The average wind speed at 65 m calculated in the feasibility study is 8.3 m/s, which indicate a good wind speed.

The project efficiency is estimated to be 65.3% which can be considered to be conservative. The Net Yield is predicted to be 112.2 GWh/year.

Only four months production data is available from Phase II which is insufficient to verify the energy yield prediction. As shown in Table 3.18, although the average WTG availability over this short period is lower than the annual guaranteed level of 95%, it is not unusual in the first few months of operation. The calculated capacity factors are higher than predicted value of 26% when the wind farm was commissioned in November 2009 and do not present any concerns.

Table 3.18: Operational Data of Yuxian Wind Farm Phase II

	Sept 2009	Oct 2009	Nov - Dec 2009
Average Availability	—	—	89.7%
Total On-grid Generation (MWh)	4,928	7,443	24,379
Utilisation Hours	100	150	492
Capacity Factor	14%	20%	34%

3.3.10.2 Internal Connection and Substations

The Yuxian Phase II wind farm has 33 Dongfang Turbine Company FD77B/FD70B 1.5 MW WTG units installed. The Phase I and the Phase II projects are designed by the same design institute, thus they are similar to each other in terms of internal connection. Each WTG is connected to a wind farm step-up transformer via a cable connection. The WTGs are divided into three groups. Each group is connected to its own 35 kV underground cable collection line. All three lines are rated appropriately to carry maximum output from the turbines.

The Phase II wind farm is connected to the same wind farm step-up substation which was built in the Phase I project. A new 35 kV bus bar has been built, to which the 35 kV collection lines are connected. The power collected from the 35 kV cables are stepped up to 110 kV via one 100 MVA, 115/36.75 kV transformer. As in Phase I, the transformer is equipped with an on-load tap changer which is able to control voltage between 110% and 90% at the HV winding. This transformer is rated sufficiently, and has sufficient ability to maintain voltage level at the wind farm step-up substation.

Appropriate protection schemes have been applied to the wind farm, including unit protection and overcurrent protection, which seems to be the common practice for most Chinese wind farms. All circuit breakers are rated appropriately to break fault current at different locations. Lightning protection equipments have been installed. No significant issue has been raised regarding the equipment condition.

3.3.11 Chengde Weichang Yudaokou Wind Farm

The 150 MW Chengde Weichang Yudaokou wind farm is currently under construction and will comprise 100 Sinovel 1.5 MW wind turbines of 65m hub height and 77m rotor diameter. We were unable to visit the site during our visit as the approach roads were blocked with snow. Our assessment is therefore based on a document review and meetings with the construction project team.

3.3.11.1 Generation and Availability

The wind farm is currently under construction and is expected to be operational by winter 2010. Construction activity ceased in November 2009 due to the onset of winter. Due to the cold temperatures, construction is only possible between April and December. Presently all of the foundations and the substation civil works are reported to be complete. Some equipment has been delivered to the site.

'The Company's project site based team currently comprises six people and is responsible for overseeing construction activities. Three of the team members have previous experience in managing the construction of wind farms for the Company that are now currently operational. The project team interviewed only provided us generic information on matters relating to the wind farm operation strategy, wind farm electrical design, equipment specification, contracting arrangements or project schedule.

The wind farm is being constructed through a number of construction contracts. Managing these construction contracts and associated interfaces could be complex and requires a high level of project management capability. The project management strategy we observed consisted largely of regular reporting back to the parent company where we understood that major project management decisions and strategy was carried out. This approach is broadly consistent with other projects MM has seen in China and in our opinion should present no concerns. After our visit, the head office provided project schedules covering activities during 2008 and 2009, and sample construction reports, which provide further confidence in the project management.

The wind turbine delivery and erection (three separate contracts) are still out to tender (as of mid January 2010). Also the 35kV inter array cable supplier has not yet been selected. Site staff informed us that these contracts will be in place by the middle of February in time for the restart of construction and that details are being managed by the parent company.

All 150 MW is expected to begin operation by the end of 2011. The intended completion date allows for two construction windows of eight months. Although we have not seen a detailed schedule of activities, in our opinion, this is sufficient time to complete construction providing that two installation teams are contracted as intended and the turbine delivery erection and cable supply contracts are in place as scheduled.

The expected average annual energy yield has been calculated in the feasibility study carried out by the Northwest Power Design Institute (西北電力設計院) in line with Chinese guidance standard — GB/T 18709-2002.

MM noted the wind resource assessment appears to have been derived from fewer masts than would have been ideal. This could introduce inaccuracy in the predicted wind speeds and in the energy yield.

It should be noted that any optimistic assumptions in the calculated average wind speed is expected to be countered by the generous loss allowances — these include a turbine availability of 95% and electrical efficiency of 95%. Other loss allowances include weather, blade contamination and power curve performance — which are applied to give a total estimated wind farm efficiency of 74.1%. This is a conservative estimate even with expectation that Chengde Weichang Yudaokou will experience slightly higher than average energy losses due to the extreme cold, (power consumption of nacelle heaters, blade icing and reduced availability due to seasonal inaccessibility of the wind farm)

The annual average Net Yield prediction is 313 GWh, equating to a capacity factor of 24%. The generous loss assumptions in this assessment are applied to provide some comfort and confidence. When our assessment was undertaken there was insufficient production data to verify the prediction. However, from our review of the full portfolio of wind farms: where preconstruction estimates have been compared to production records, the reported production generally corresponds reasonably well to the predicted energy yield. Our expectation is that actual operational data should be largely in line with the prediction presented in the feasibility study.

During the operational phase of the project, the construction management team will be replaced by an operations team. The current project company team was only able to provide high level information on the operations arrangements. It is reported that the Company's already well-established operations strategy will be implemented.

It is reported that the operation and maintenance team will comprise 22 personnel, some of which will be relocated from other operational projects. The fulfilment of operation and maintenance training has been agreed with Sinovel and contained in the supply agreement. Four members of the operations team are currently working on the construction of the wind farm as part of the training program.

A two-year availability guarantee of 95% is also contained in the Sinovel supply contract. We understand that measures are being implemented to improve the accessibility and the assumed availability seems reasonable at this stage.

3.3.11.2 Internal Connection and Substations

The Chengde Weichang Yudaokou wind farm was still under construction when our visit took place. According to the wind farm feasibility report, 100 Sinovel 1.5 MW WTG units will be installed in the wind farm. Each turbine will be connected to a step-up transformer via a cable connection. According to the cable type proposed in the feasibility study report, the cable should be able to carry maximum output from each individual turbine.

The turbines are divided into nine groups, each connected to its own 35 kV collection cable circuit. The collection system consists of cables only.

A 220 kV step-up substation will be built for the wind farm. The power generated from turbines are collected via four 35 kV collection lines, and then transferred to the 35 kV bus bar at the step-up substation. The single bus bar arrangement will be applied to both voltage levels. According to the wind farm feasibility report, at the 35 kV collection bus bar, the power is stepped up to the 220 kV via two 100 MVA, 220/35 kV transformer. According to the transformer specification, the transformer is equipped with an on-load tap changer which is able to control voltage between 110% and 90% of its nominal voltage at the HV winding. We consider that this transformer is rated appropriately and has sufficient ability to maintain voltage level at the wind farm step-up substation.

According to the wind farm feasibility report, appropriate protection schemes have been designed for the wind farm, including unit protection and overcurrent protection, which seems to be the common practice for most Chinese wind farms. All circuit breakers are rated appropriately to break fault current at different locations. Lightning protection equipments will be installed to prevent lightning impact on the wind farm equipment.

3.4 Operational and Maintenance Arrangements

To adequately operate a wind farm, it is necessary to have an experienced team to constantly monitor the wind turbines, to ensure prompt resolution of any problem that may occur to wind turbines, and to avoid downtime which could lead to reduction electricity production. Following the site visits to the representative wind farms, we acknowledge that the overall the Company strategy is primarily to rely on wind turbine manufacturers during the warranty period for maintenance, while developing the knowledge and capabilities of its internal staff and subsequently to handover this responsibility to its own team.

The warranty provided by the manufacturers for the wind farms is on average for a two year period, in line with current industry standards, and is similar to wind farms in other countries. MM considers this warranty duration generally acceptable for all wind turbine technologies which have proven track record and sound experience.

For a wind farm, high availability is vital in order to maximise revenue. A number of factors could affect the availability of which O&M arrangement is likely to have the greatest impact. There is a commercial balance between the O&M cost and availability and it needs to be considered carefully in contract negotiations. Liquidated damages are the key buffer against poor availability. Finally, care is needed during the contract negotiation of the O&M contract with respect to the definition of "availability"; turbine suppliers will endeavour to define within availability some events that the Company would expect to consider as non-availability.

All turbine supply agreements that MM has reviewed include training programs arranged by the manufacturers. These are usually comprehensive, and include several weeks of training in factories and on site, covering most of the topics and problems that may occur. The service team is trained to use the maintenance manual, keeping records of faults, operation and control of turbines, erection methods for replacement, maintenance procedures, trouble shooting, and spare parts management. MM understood that in addition to the standard training, on-site staff also assist manufacturer's teams during scheduled and unscheduled maintenance; MM appreciates the potential experience gained by the team through this arrangement.

According to the maintenance records on site, and interviews with manufacturers' on-site staff, for the wind farms which are still in the warranty period, the scheduled maintenance has been carried out in accordance with the defined in the turbine supply agreement.

An operational and maintenance team employed for each wind farm is trained by the WTG suppliers and is in position to assist during the warranty period, and will be responsible for performance maintenance activities on wind turbines at a later date. The maintenance manual will be guidance to the Company to carry out the maintenance activities. A daily O&M Log recording run-time status of electric equipments and WTGs is reported to the Company during the whole operating period.

Electric Safety Manual (for cable, substation and plant) issued by the National Grid Company is kept on site as safety guidance for good practice. Safety responsibilities of each person are clearly defined. It was noted that no Accident Record book is kept on the wind farm site, and the site managers said that no accidents had occurred. If there is any accident, it will be recorded on the Daily O&M Log. We would suggest an Accident Record should have been set up as a good practice especially on the sites in remote locations with extreme weather conditions.

3.5 Conclusions

All of the wind farms we visited had the equipment supplied by well-known international or domestic manufacturers that employ proven technologies or have credible track records in the market. We are of the view that the turbine technologies are in accordance with current industrial standards, and the sites were built to a high standard.

All plants are well operated and maintained. Although a teething problem caused lower availability at the Yuxian wind farm due to lack of familiarity with the European design, we were informed that measures were being taken to resolve this. As such we do not consider this would be a problem in the future.

We have reviewed the energy yield predictions for each of the visited sites and where possible compared the predicted generation with the reported production.

The energy yield assessment methodology used in each wind farm is consistent and is based on the current Chinese standards — GB/T 18709-2002 and GB/T 18710-2002. These standards have been derived from western publications and are broadly consistent with wider international practice but lack detail in some areas.

MM notes that methodology of some of the wind resource assessments could introduce inaccuracy in the predicted energy yields. This is countered by the very generous loss allowances which are applied to the gross yield predictions to arrive at a Net Yield prediction. The relatively low estimated project efficiencies provide some comfort and confidence to us.

Regarding the full portfolio of wind farms, where preconstruction estimates have been compared to production records, the reported production corresponds reasonably well to the predicted energy yield. The actual average energy yield is within 5% of the predicted average energy yield.

Confirming the energy yield would require a more detailed study of the production and operational data from the wind farms, coupled with analysis of a reference wind data source. Given the limited production data, the fact the production data is generally from the first year of operation and the high level scope of our analysis we are generally comfortable with the energy yield forecasts supplied.

All of the substations had adequate electrical equipment installed to export electricity via overhead circuits to the power grids. The substation equipment is appropriately sized to withstand system faults and reactive compensation is installed in all of the wind farms to meet technical requirements of the power grid.

4. Grid Connection Assessment

4.1 Introduction

Our findings of the grid connection assessment presented in this section of the report are limited to the 11 representative wind farms. The assessment has been undertaken largely based on the data provided by the Company during the site visits and the following documents:

- Feasibility study reports
- Grid connection study reports
- Single line diagrams of grid connections
- Single line diagrams of internal energy collection systems in the wind farms
- Feedback to Mott MacDonald's Questionnaire
- Site visit records

All data collected from the site visits is assumed to be the latest, and has been cross-referenced with the wind farm grid connection reports. No software study has been conducted during the assessment. The grid connection assessment has been conducted for all 11 wind farms within the portfolio of the Company. The purpose of this assessment is to determine:

- whether all equipment including grid transformers, export cable/overhead line has been rated appropriately to export full generation from the wind farm;
- whether the reactive power compensation is sufficient to provide support for voltage control and power factor adjustment at the wind farm grid connection point;
- the ability of the local network to evacuate the power generated from the wind farms and any potential problem such as voltage/frequency deviation, system overloading which may be caused by the grid connection of the wind farm.

It should be noted that when assessing the impact of the wind farm connections on the local network and system operation, we have relied on the network topologies supplied to us in the above reports. MM has not undertaken any independent simulation or calculation to validate the inputs and results in the studies conducted by different Chinese design institutes.

We expect any changes of the network configurations in the local power grids after commissioning of the wind farms to reinforce the local network capability and to improve the system operation and performance, which will ultimately benefit the wind farm connections and operations.

To determine whether a wind farm could be connected to a power grid it is common practice to investigate the following:

- capability of transmission circuits and transformers for power evacuation from the dedicated step-up substations at wind farm sites to the grid connection points;
- network configurations at the grid connection points and potential operational issues in the local power grids;
- reactive power capability of the wind farms to meet grid connection requirements;
- arrangements of internal energy collection systems;
- potential impact of system faults on wind farm operations;
- power quality issues of the wind farm connections to the grid.

It is crucial to examine the above technical issues in order to identify risks which may affect normal operation of the wind farms and subsequent impact on power export to the grids. Our assessment is therefore centred on these issues. Where the term "Chinese design institutes" is used, it refers to the following design institutes in the PRC. All of these institutes are independent third parties to the Company.

1. North China Power Engineering (Beijing) Co. Ltd (北京國電華北電力工程技術有限公司): a high technology enterprise supplying high-level engineering consultation, survey & design and engineering construction services.
2. Hebei Electric Power Design Research Institute (河北省電力勘測設計研究院): mainly provides engineering and consulting services in the PRC and Hebei Province for electric power industry, such as power systems design, survey and assessment on coal power projects.

The results of the studies conducted by these Chinese design institutes demonstrate whether or not the wind farms could be connected to the grid, what system enhancements are required to accommodate the wind power, and set the requirements for key equipment such as main transformers, switchgears and circuits. The studies and results provide Mott MacDonald with evidence of adequacy of the grid connection schemes and confirm the grid capability to deliver the wind power to the systems.

4.2 Key Issues Addressed in Grid Connection Studies

Generally all wind farms are properly connected to the grid. The wind farm step-up transformers have sufficient capability to export full power from the wind farm to the grid, and are equipped with on-load tap changers which are able to maintain required voltage level at the wind farm step-up substation. The reactive power compensation at each wind farm was found to be sufficient to provide support for the purpose of voltage regulation and power factor adjustment.

Each wind farm is connected to the grid substation via a single overhead line connection. All lines are rated appropriately to export full capacity of the wind farms to the grid. This is the common practice for most Chinese wind farms, though it is not compliant with the 'N-1' security contingency.

The 11 wind farms are mainly connected to four regional power grids. Seven wind farms are connected to the Zhangbei regional power grid, which are:

- Kangbao wind farms (Phase I and Phase II)
- Guyuan wind farms (Phase I and Phase II)
- Dongxinying wind farm
- Chongli wind farms (Phase I and Phase II)

Apart from the Dongxinying wind farm, the other six wind farms share the same constraint. Although there is no constraint for these wind farms to export their full capacity to the grid connection substations, the power from all of these is eventually directed to the 220 kV Zhangbei substation. According to the wind farm grid connection report, by 2009, the total power transferred from the wind farms to the Zhangbei substation has reached 428 MW which is higher than the total transformer capacity at the substation, which is 420 MVA. It is likely these transformers will be overloaded during a certain scenario when most wind farms are generating high amounts of power. It is suggested in the grid connection reports that either the existing transformers will be upgraded or new transformer units will be installed. It is expected with such reinforcement that the potential overloading problem will be solved.

The Haixing wind farm is connected to the Cangzhou power grid, while the Yuxian Phase I and Phase II wind farms are connected to the Baoding power grid. A common situation is shared between these three wind farms. It is reported in the wind farm grid connection reports that when the voltage levels at the grid connection substations are at maximum, the wind farms can not operate at lagging power factor, and when the voltage levels at the grid connection substations are at minimum, the wind farms can not operate at leading power factor. Otherwise the voltage levels at other distribution substations will be affected. However, such a scenario can be avoided by introducing active network management, such as transformer tap changing and power factor correction at the wind farms.

The Chengde Weichang Yudaokou wind farm is connected to the Chengde power grid. This wind farm is properly connected to the grid, and no potential problem has been identified at present. However, as reported in the wind farm grid connection report, after the wind farm is commissioned, the total power transferred to the nearby 220 kV substation will have reached 600 MW, which will be very close to the maximum transmission line capacity of

670 MW. It is suggested that if the installed capacity of wind farms keeps increasing, certain network reinforcement will have to be conducted in order to prevent any overloading condition on the existing network and maintain 'N-1' security compliance.

4.3 Grid Connection of Each Wind Farm

4.3.1 Kangbao Wind Farm Phase 1

The Kangbao wind farm is located in the north of Zhangjiakou city, and is connected to the Zhangbei regional power grid. There are 40 750 kW Goldwind WTG units installed in the wind farm and the total capacity of this wind farm is 30 MW. The Phase II wind farm has a total capacity of 49.5 MW.

A wind farm step-up substation has been built for this wind farm. Two 50 MVA transformers have been installed in the substation to export power to the grid, one for each phase. Each transformer is equipped with one on-load tap changer which has 17 steps in total. Each transformer is connected to a separate 35 kV collection bus bar, and then stepped up to 110 kV. Both transformers are sufficiently rated in order to export the full power from the wind farm as well as to maintain appropriate voltage level at the wind farm step-up substation.

The total capacity of the reactive power compensation device is 24 MVar, of which 11 MVar has been installed at the 35 kV bus bar in Phase I wind farm and 13 MVar has been installed for the Phase II wind farm. According to the wind farm feasibility reports, the WTG units are self-adjusted and do not require external reactive power support, and the reactive power compensation installed in the wind farms is able to provide the reactive power required in the grid code.

The wind farm step-up substation is connected to the 110 kV Kangbao substation located in the Zhangbei regional power grid. The connection is via a single overhead line, and the conductor type is LGJ-150. The maximum capacity of this line is 88 MVA which is far more than required to export full power from the wind farm step-up substation to the local power grid. Though it is common practice for the local wind farm to be connected to the grid via a single circuit, it is unlikely to be compliant with the 'N-1' contingency requirement.

No major issues have been identified regarding the grid connection condition of the Kangbao wind farm for both Phase I and Phase II. However, it has been noted that the grid connection substation, the 110 kV Kangbao substation, is connected to the 220 kV Zhangbei substation. According to the regional wind energy development scheme, many other wind farms have been connected or are about to be connected to the 220 kV Zhangbei substation. The 220 kV Zhangbei substation may not have enough capacity to transfer power from 110 kV to 220 kV due to excessive amount of power generated from all of these wind farms. At present there are two 120 MVA $^{220}/_{110}$ kV transformers installed in the Zhangbei substation, and another 180 MVA has been installed in 2008. However, due to the grid transformer overloading issue in the 220 kV Zhangbei substation described in section 4.2, it is possible that under certain circumstance, when many wind farms generating maximum power, the power output from the Kangbao Phase I wind farm may be curtailed.

4.3.2 Kangbao Wind Farm Phase 2

The wind farm has 33 GE 1.5 MW WTG installed. The total capacity of this phase is 49.5 MW.

The Phase II wind farm shares the same wind farm step-up substation with the Phase I wind farm, but is connected to a separate 35 kV collection bus bar. The power generated from the Phase II wind farm is stepped-up to 110 kV via one 50 MVA transformer, and is then transferred to the grid. The total reactive power support installed for this phase is around 13 MVar. The wind farm step-up substation is connected to the 110 kV Kangbao substation, using the same single LGJ-150 overhead line as used for Phase I. The maximum capacity of this line is 88 MVA, and is therefore sufficient to carry full power generated from both Phase I and Phase II wind farms. It is considered there is no constraint for the power to be transferred from the wind farm to the grid connection substation.

The same issue has been raised for the Phase I wind farm regarding to grid capability to accommodate large amount of power coming from several wind farms connected to the same substation. According to the feasibility report of the Sanxiatian wind farm, it has been confirmed that another 180 MVA transformer has been installed at the 220 kV Zhangbei substation. Including the existing two 120 MVA transformers, the total capacity at the 220 kV substation has reached to 420 MVA. However, by 2009, the total net power transferred from wind farms to the 110 kV bus bar at the Zhangbei substation has been 428 MW. Therefore, it is apparent that the grid does not have enough capability to step up such power to the 220 kV bus bar and dispatch any further. To allow for this, the generation from these wind farms, including that of Kangbao Sanxiatian wind farm, may be curtailed during periods of high output.

4.3.3 Guyuan Wind Farm Phase 1

The Guyuan Phase I wind farm is connected to the Zhangbei regional power grid. Phase I project has 36 Gamesa 850 WTG units installed, and the total capacity is 30.6 MW. The wind farm is connected to the 110 kV Guyuan substation. The Phase II project has a total capacity of 49.5 MW, and is connected to the same grid substation.

A wind farm step-up substation has been built for this wind farm. One 50 MVA 110/35 kV transformer has been installed to transfer power from the wind farm to the grid. This transformer is equipped with an on-load tap changer which has 19 steps in total. This transformer is rated appropriately, and is considered being able to maintain required voltage profile at the wind farm step-up substation.

Reactive power compensation devices have been installed at the 35 kV bus bar at the wind farm step-up substation. The total capacity is 11 MVar. According to the wind farm grid connection report, 8 MVar of reactive power support is required from this compensation equipment, thus the actual sizes of capacitors are considered to be sufficient.

The wind farm step-up substation is connected to the 110 kV Guyuan substation via a single overhead line circuit. The conductor type is LGJ-240, and its maximum capacity is 114 MVA. It is more than sufficient to transfer the full power generated from the wind farm. However, it is noticed that the 110 kV Guyuan substation is connected to the 110 kV bus bar at the 220 kV Zhangbei substation. It has been reported, according to the wind farm grid connection report and our site visit, that the 220 kV Zhangbei substation does not have sufficient transformer capacity to step-up all power generated from the connected wind farms. We understand that by 2009, the total net power transferred to the substation from wind farms had reached 428 MW, but the substation only had three transformers whose total rating is 420 MVA. The generation from all these wind farms, including the Guyuan Phase I wind farm may have to be curtailed during certain scenarios.

4.3.4 Guyuan Wind Farm Phase 2

The Phase II project of the Guyuan wind farm has 33 GE 1.5 MW WTG units installed and the total installed capacity is 49.5 MW. It is located to the east of the Phase I project, and shares the same wind farm step-up substation.

A second 50 MVA transformer has been installed for the Phase II project. The technical detail of this new transformer is unavailable, but it is expected to be of the same configuration as the first unit. The second unit is sized appropriately to export full power from the Phase II project, and since these two transformers are connected to the same 35 kV collection bus bar, it is considered the voltage profile controllability will be improved due to the contribution from the second unit.

There is a total of 13 MVar of reactive power compensation devices installed at the 35 kV bus bar at the wind farm step-up transformer. According to the grid connection report, at least 10 MVar of reactive power compensation is required during operation. Thus it is considered that the wind farm has sufficient reactive power support.

The wind farm step-up substation connected to the grid substation via the same single LGJ-240 overhead line as Phase I. The line is able to carry 114 MVA of power maximum, hence is quite sufficient to transfer full power from both Phase I and Phase II projects. However, it is noticed that the 110 kV Guyuan substation is connected to the 110 kV bus bar at the 220 kV Zhangbei substation. It has been reported, according to the wind farm grid connection report and our site visit, that the 220 kV Zhangbei substation does not have sufficient transformer capacity to step-up all power generated from the connected wind farms. By 2009, the total net power transferred to the substation from wind farms reached 428 MW, but the substation only had three transformers whose overall rating totals 420 MVA. Apparently, the generation from all these wind farms, including the Guyuan Phase I wind farm, may have to be curtailed during certain scenarios. According to the grid connection report, either an upgrade of the existing transformers or installation of new transformer units is recommended.

4.3.5 Dongxinying Wind Farm

The Dongxinying wind farm is connected to the Zhangbei regional power grid. It has 133 Dongfang Turbine Company FD77A WTG units installed, and the total installed capacity of this wind farm is 199.5 MW.

A wind farm step-up substation has been built for the grid connection of wind farms in that area called the 220 kV Dongxinying step-up substation. Two 120 MVA 220/35 kV transformers have been installed for the Dongxinying wind farm, each equipped with an on-load tap changer which has 18 steps in total. The transformers are sized appropriately. Given the number of tap steps available it is considered these transformers should have sufficient ability to maintain the required voltage level.

Two sets of 30 MVar shunt capacitors and one set of 28 MVar shunt reactors are available at the 35 kV side of the Dongxinying step-up substation for this wind farm. According to the wind farm grid connection report, the total reactive power support required from the capacitors is approximately 50 MVar in order to compensate reactive power losses across the windings of the 220/35 kV transformers and the WTG step-up transformers. It is considered that the reactive power compensation configuration of the Dongxinying step-up substation is sufficient to maintain the voltage level as required by the grid code.

The 220 kV Dongxinying step-up substation is connected to the 500 kV Guyuan substation via one LGJ-630 overhead line. According to the manufacturer data, the line is able to carry a maximum power of 733 MVA, which is sufficient to transfer full power from the wind farm to the grid. The 500 kV Guyuan substation is a key substation on the ‘West — East’ power transmission corridors which transfer power from the generation centre located in West China to the load centre in the east. According to the grid connection report, by 2015, 1,400 MW of power will be transferred to the 500 kW Guyuan substation from wind farms. It has been reported another two 750 MVA transformers are being installed at this substation. It is expected the substation will have sufficient transformer capacity to accommodate the power generated from the wind farms.

4.3.6 Haixing Wind Farm

The Haixing wind farm is connected to the Cangzhou power grid. It has 33 Dongfang Turbine Company FD77A WTG units installed, and the total installed capacity is 49.5 MW.

A wind farm step-up substation has been built for the purpose of wind farm grid connection. One 50 MVA 110/35 kV transformer has been installed at the substation. This transformer is equipped with an on-load tap changer with 17 steps, and is able to maintain voltage level between 90% and 110%. This transformer is rated appropriately and is considered to have sufficient capability to control voltage profile at the wind farm step-up substation.

No reactive power compensation scheme has been mentioned in the wind farm grid connection report. However, it is reported that the wind farm has a reactive power capability of between -16.3 MVar and +16.3 MVar, based on the reactive power ability of the wind generators. We have been informed that two sets of reactive power compensation devices have been installed in the wind farm, with capacities of 4 MVar and 6 Mvar respectively. With such capability the wind farm is considered to be able maintain required power factor at the wind farm step-up substation.

The wind farm step-up substation is connected to the 110 kV Gangcheng substation via one LGJ-240 overhead line connection. The conductor is able to carry a maximum power of 114 MVA, thus it is easily sufficient to transfer full power generated from the wind farm. All power will be transferred to the 220 kV Linhai substation, where it is stepped up to the 220 kV bus-bar via two 180 MVA transformers and dispatched to the local transmission network. It is expected that the local power grid will have sufficient capacity to accommodate the power generated from the wind farm.

According to the wind farm grid connection report, however, the wind farm has an impact on the voltage regulation of the grid connection substation. According to the load flow result presented in the report, the wind farm can not be running at lagging power factor when the voltage at the grid connection substation reaches maximum, and can not be running at the leading power factor when the voltage at the grid connection substation reaches minimum. It is also reported that under certain circumstances, some WTG units may have to be disconnected due to voltage limits. However, such scenarios are expected to be avoided by introducing active network management during wind farm operation.

4.3.7 Chongli Wind Farm Phase 1

The Chongli Phase I wind farm is located in the north of Zhangjiakou city, connected to the Zhangbei regional power grid. It has 58 Gamesa G52 850 kW WTG units installed, and the total installed capacity is 49.3 MW.

A wind farm step-up substation has been built for the purpose of wind farm grid connection. One 50 MVA 110/35 kV transformer has been installed at the substation. This transformer is equipped with an on-load tap changer with 17 steps, and is able to maintain voltage level between 90% and 110%. The transformer is rated appropriately and is considered as having sufficient capability to control voltage profile at the wind farm step-up substation.

Two sets of shunt capacitors have been installed at the 35 kV bus-bar at the wind farm step-up substation, one with 4.012MVar and the other with 6.008 MVar. According to the grid connection report, the recommended reactive power compensation is 11.17 MVar. The recommended value was calculated based on the assumption that the 50MVA step-up transformer impedance is 14%, but according to rating plate information obtained during the site visit, the actual impedance of the transformer is 10.6% at nominal tap position. Thus the actual reactive power demand is calculated as around 9.5 MVar. It is considered the reactive power compensation has sufficient capacity to meet the requirement.

The wind farm step-up substation is connected to the 110 kV Laiyuan substation via a single LGJ-185 overhead line. The conductor is able to carry maximum power of 98 MVA, thus is quite sufficient to transfer full power generated from the wind farm. The grid connection substation is then connected to the 220 kV Zhangbei substation, where the 220/110 kV transformers may be overloaded when many wind farms are generating maximum power during windy days, as described in section 4.2. It is considered under such circumstance, the power output from the Phase I wind farm could be curtailed.

4.3.8 Chongli Wind Farm Phase 2

The Chongli Phase II wind farm is located in the north of Zhangjiakou city, connected to the Zhangbei regional power grid. It has 58 Vestas V52 850 kW WTG units, and the total installed capacity is 49.5 MW.

The Phase II wind farm shares the same wind farm step-up substation with the Phase I wind farm. An additional 50 MVA 110/35 kV transformer has been installed at the substation. This transformer is equipped with an on-load tap changer with 17 steps, and is able to maintain voltage level between 90% and 110%. The transformer is rated appropriately and is considered to have sufficient capability to control voltage profile at the wind farm step-up substation.

Two sets of shunt capacitors have been installed at the 35 kV bus-bar at the wind farm step-up substation, one with 4.012MVar and the other with 6.008 MVar. According to the grid connection report, the recommended reactive power compensation is 11.17 MVar. The recommended value was calculated based on the assumption that the 50MVA step-up transformer impedance is 14% and we were not able to view this transformer during the site visit but expect it to be similar to that of the similar Phase I transformer (10.6% at nominal tap position). The actual reactive power demand with this impedance is thus calculated as around 9.5 MVar in total indicating that the reactive power compensation has sufficient capacity to meet the requirement.

The wind farm step-up substation is connected to the 110 kV Laiyuan substation via the same single LGJ-185 overhead line that was built for the Phase I project. The conductor is able to carry a maximum power of 98 MVA, thus it is sufficient to transfer full power generated from both wind farms. The grid connection substation is connected to the 220 kV Zhangbei substation, where the 220/110 kV transformers may be overloaded when many wind farms are generating maximum power during windy days, as described in section 4.2. It is considered that under such circumstance, the power output from the Phase II wind farm may be curtailed.

4.3.9 Yuxian Wind Farm Phase 1

The Yuxian wind farm is located in Baoding city, connected to the Baoding power grid. It has 33 Dongfang Turbine Company FD70B WTGs units installed, and the total installed capacity is 49.5 MW.

A wind farm step-up substation has been built for the wind farm. One 50 MVA 110/35 kV transformer has been installed to transfer power from the wind farm to the grid. The transformer is equipped with an on-load tap changer which has 17 steps and is able to control voltage between 90% and 110% at the wind farm step-up substation. The transformer is rated appropriately and considered to have sufficient ability to maintain required voltage level.

Two sets of shunt capacitors have been installed at the 35 kV bus-bar at the wind farm step-up substation, one with 4.012MVar and the other with 6.008 MVar, which appears to be the common practice for wind farm reactive power compensation schemes in the local area. According to the wind farm grid connection report, the same configuration has been recommended that each 35 kV bus bar should have two shunt capacitor banks installed of 4 MVar and 6 MVar separately. The report did not provide sufficient supporting data to validate this figure, but based on similar installations discussed above, we anticipate that it should be sufficient to meet the requirement.

The wind farm step-up substation is connected to the 110 kV Laiyun substation via one LGJ-240 overhead line connection. The conductor is able to carry maximum power of 114 MVA, thus it is more than sufficient to transfer full power generated from the wind farm. All power will be transferred to the 220 kV Baishishan substation, where it is then stepped up to the 220 kV bus-bar via two 180 MVA transformers and dispatched to the local transmission network. It is reported that the demand for new electricity generation in the local power grid is high, despite two new coal-fired power plants having been commissioned recently. It is expected that the local power grid will have sufficient capacity to accommodate the power generated from the wind farm.

According to the wind farm grid connection report, however, the wind farm will have some impact on the voltage regulation of the grid connection substation. The load flow results presented in the report indicate that, the wind farm can not be running at lagging power factor when the voltage at the grid connection substation reaches maximum, and can not be running at the leading power factor when the voltage at the grid connection substation reaches minimum. It is also reported that under certain circumstances, some WTG units may have to be disconnected due to voltage limits. However, such scenarios can be avoided by introducing active network management during wind farm operation. Besides, with proper control of the shunt capacitors and wind turbines, in our opinion it is also practical to achieve the desired power factor in order to minimise the impact on the system voltage.

4.3.10 Yuxian Wind Farm Phase 2

The Yuxian Phase II wind farm is located in Baoding city and is connected to the Baoding power grid. It has 23 Dongfang Turbine Company FD77B 1,500 kW wind turbines and 10 FD70B 1,500 kW wind turbines installed: the total installed capacity is 49.5 MW.

The Phase II wind farm shares the same wind farm step-up substation with the Phase I project, but is connected to a separate 35 kV bus-bar. One 100 MVA, 110/35 kV transformer has been installed to transfer power from the wind farm to the grid. The transformer is equipped with an on-load tap changer which has 17 steps and is able to control voltage between 90% and 110% at the wind farm step-up substation. The transformer rating is more than sufficient to transfer full power from the wind farm and is considered to have sufficient capability to maintain required voltage level.

Two sets of shunt capacitors have been installed at the 35 kV bus-bar at the wind farm step-up substation, one with 4.012 MVar and the other with 6.008 MVar, which appears to be the common practice for wind farm reactive power compensation schemes in the local area. According to the wind farm grid connection report, the same configuration has been recommended that each 35 kV bus bar should have two shunt capacitor banks installed of 4 MVar and 6 MVar separately. The report did not provide sufficient supporting data to validate this figure based on similar installations discussed above, we anticipate that it should be sufficient to meet the requirement.

The wind farm step-up substation is connected to the 110 kV Laiyun substation via one LGJ-240 overhead line connection which was built for the Phase I wind farm. The conductor is able to carry a maximum apparent power of 114 MVA, thus it is capable of transferring full power generated from both wind farms. All power will be transferred to the 220 kV Baishishan substation, where it is then stepped up to the 220 kV bus-bar via two 180 MVA transformers and dispatched to the local transmission network. It is reported the demand for electricity generation in the local power grid is high, despite two new coal-fired power plants having been commissioned recently. It is therefore expected the local power grid will have sufficient capacity to accommodate the power generated from the wind farm.

According to the wind farm grid connection report the wind farm will have some impact on the voltage regulation of the grid connection substation. According to the load flow result presented in the report, the wind farm can not be running at lagging power factor when the voltage at the grid connection substation reaches maximum, and can not be running at the leading power factor when the voltage at the grid connection substation reaches minimum. It is also reported under certain circumstance, some WTG units may have to be disconnected due to voltage limits. However, such scenarios are expected to be avoided by introducing active network management during wind farm operation. Furthermore, with proper control of the shunt capacitors and wind turbines, it is also practical to achieve the desired power factor in order to minimise the impact on the system voltage.

4.3.11 Chengde Weichang Yudaokou Wind Farm

The Chengde Weichang Yudaokou wind farm is located in the north of Chengde city, and is connected to the Chengde power grid. It has 100 Sinovel SL-1500 WTG units installed, and the total capacity is 150 MW.

A wind farm step-up substation has been built for the wind farm. Two 100 MVA 220/35 kV transformers have been installed for the purpose of wind farm grid connection, and each unit is equipped with an on-load tap changer with 17 steps and is able to control voltage level between 90% and 110% at the wind farm step-up transformer. It is considered that the wind farm step-up substation has sufficient transformer capacity to transfer full power generated from the wind farm to the grid.

Two sets of Static Var Compensator (SVC) reactive power compensation equipment have been utilized in this wind farm with a total capability of 32.8 MVar for each set. Each set is able to provide 30 MVar reactive power support as shunt capacitors or absorb 2.8 MVar reactive power as shunt reactors. According to the wind farm grid connection report, the total reactive power demand of the wind farm is around 33 MVar, thus with two SVCs installed, the system is more than sufficient to meet the requirements of reactive power support.

The wind farm step-up substation is connected to the 220 kV Weichang switching station via one LGJ-240 overhead line connection. This line is able to carry 232 MVA power at its maximum loading ability at 220 kV, and is more than sufficient to export full power from the step-up substation to the power grid. The power from the wind farm is then transferred to the 220 kV Longcheng substation and dispatched to the main power grid. According to the load flow results presented in the wind farm grid connection report, there will not be any overloading issue in the local power grid with the grid connection of the Yudaokou wind farm, and the demand for electricity generation is still high, thus it is considered the local power grid will have sufficient capacity to accommodate the power generated from the wind farm.

However, it is also reported after the Yudaokou wind farm is commissioned, the total power generated from wind farms in the local area will reach 600 MW. This is very close to the maximum capacity of the line connecting the 220 kV Longcheng substation to the rest of the grid, which is 670 MVA. If the installed capacity of wind farms keeps increasing, certain network reinforcement will have to be conducted in order to prevent any overloading condition on the existing network and maintain ‘N-1’ security compliance.

4.4 Conclusions

The grid connection assessment has been conducted for all 11 wind farms within the portfolio of the Company. In general all wind farms are properly connected to the power grids, and there is no major constraint identified regarding the power output from the wind farms to the grid connection substations. All equipment is rated appropriately, and the reactive power compensation schemes are sufficient to provide necessary support to maintain voltage level and power factor correction.

However, grid connection reports have identified that network reinforcement will be required to accommodate power generated from some of the wind farms, including the Kangbao Phase I and Phase II wind farms, the Guyuan Phase I and Phase II wind farms, and the Chongli Phase I and Phase II wind farms. It has been identified that the transformer capacity has to be upgraded in order to enhance the network capability.

Although there is no constraint for these wind farms to export their full capacity to the grid connection substations, the total power transferred from the wind farms to the Zhangbei substation has reached 428 MW, which is higher than the total 420 MVA transformer capacity at the substation. It is possible that these transformers will become overloaded during certain scenarios when most wind farms are generating high amounts of power.

The Company advised that discussions have been held with the local grid company. The grid company confirmed the existence of the potential overloading issue in the 220 kV Zhangbei substation, and advised that it plans to shift the supply to the Guyuan power grid from the existing 220 kV Zhangbei substation to the 220 kV Chabei substation. This will reduce the power injection from wind farms connected to the Guyuan power grid that transmits generation into the Zhangbei substation by 30 MW + 49.5 MW (the installed capacity of Guyuan Phase I and Phase II wind farms), and eventually mitigate the transformer loading stress in the Zhangbei substation. We do not have any information confirming the timescale of the planned reinforcement.

In addition, according to the load flow results in the grid connection reports, potentially there could be voltage regulation issues during operation of Yuxian Phase I and Phase II wind farms In our opinion, with proper control of reactive power compensation and of the wind turbines, it should be possible to achieve the desired power factor at the wind farm terminal and thus it will not affect the system voltage.

The Company reported that, in practice, there is no problem regarding power output from the Yuxian Phase I and Phase II wind farms. Given the situation both wind farms have sufficient reactive power compensation to control power factor at the wind farm terminals, we consider that with proper control of the var compensation devices, by achieving the desirable power factor at the wind farm terminals, the power output from the wind farms will not be affected by the system voltage level.

Conclusions and Recommendations

During the course of our technical appraisal, Mott MacDonald engineers visited all representative wind farms situated in Hebei Province, with the exception of Chengde Weichang Yudaokou wind farm (due to severe weather). Mott MacDonald had discussions with the technical staff in the local project teams in order to inspect the assets, gain a better understanding of the operational practice used and the management organisation in place, as well as to collect operational data of each plant.

We were impressed by the enthusiasm and diligence of the site staff, who provided responses to our technical questionnaire and attended meetings and discussions with us despite being very busy.

All of the wind farms we visited had the equipment supplied by well-known international or domestic manufacturers that employ proven technologies or have track records in the market. We are of the view that the turbine technologies are in accordance with current industrial standards, and all of the sites were built to a high standard, some exceeding our expectations. All plants are well operated and maintained.

Turbine availability and power generation were the two key operational performance indictors we used in our appraisal. We are able to confirm that the availability of the majority of the wind farms reviewed was higher than the manufacturer's guarantee of 95% and the actual electricity generation was also in line with the forecasts made in feasibility studies. Where we observed that availability was below 95%, in our opinion the issues had been identified and plans appeared to have been put in place to resolve these problems.

All of the wind farms we reviewed either had their own dedicated substations or shared substations with another wind farm. All of the substations had adequate electrical equipment installed to export electricity via overhead circuits to the power grids. The substation equipment is appropriately sized to withstand system faults and reactive compensation is installed in all of the wind farms to meet technical requirements of the power grid.

In general all wind farms are properly connected to the power grids, and there is no major constraint identified regarding the power output from the wind farms to the grid connection substations.

However, certain network reinforcement plans have been suggested by the grid connection reports that transformer capacity has to be upgraded in order to enhance the network capability to accommodate power generated from some of the wind farms, including the Kangbao Phase I and Phase II wind farms, the Guyuan Phase I and Phase II wind farms, and the Chongli Phase I and Phase II wind farms. The Company reported that the local grid company plans to implement reinforcements to resolve this issue.

In addition, according to the load flow results in the grid connection reports, potentially there could be voltage regulation issues during the operation of Yuxian Phase I and Phase II wind farms. However, we were advised that in practice there is no problem regarding power output from the Yuxian Phase I and Phase II wind farms. In our opinion this is reasonable as with proper control of reactive power compensation and of the wind turbines, we consider that it should be practical to achieve the desired power factor at the wind farm terminal, thus it will not affect the system voltage.

Three wind farms that we visited were still under construction. We found that the project management strategy was different from what we would expect for similar projects in Europe and relied generally on reporting to head office, but this is normal practice in the Chinese industry and in our opinion is satisfactory. We did find evidence of project implementation monitoring and of activity schedules and resolution of issues as well as regular reporting from the contractors. Project schedules and weekly construction reports were also supplied by head office which provide further confidence in the project management.

Appendices

A.1. List of Key Documents Reviewed

Ref	Document title
1	Feasibility Study Report of Phase I of Kangbao Wolongtushan Wind Farm
2	Feasibility Study Report of Phase II of Kangbao Wolongtushan Wind Farm
3	Feasibility Study Report of Phase I of Guyuan Wuhuaping Wind Farm
4	Feasibility Study Report of Phase II of Guyuan Wuhuaping Wind Farm
5	Feasibility Study Report of Guyuan Dongxinying Wind Farm
6	Feasibility Study Report of Haixing Wind Farm
7	Feasibility Study Report of Phase I of Congli Qingsanying Wind Farm
8	Feasibility Study Report of Phase II of Congli Qingsanying Wind Farm
9	Feasibility Study Report of Phase I of Yuxian Kongzhongcaoyuan Wind Farm
10	Feasibility Study Report of Phase II of Yuxian Kongzhongcaoyuan Wind Farm
11	Feasibility Study Report of Weichang Yudaokou Wind Farm
12	Grid Connection Study Report of Phase I of Kangbao Wolongtushan Wind Farm
13	Grid Connection Study Report of Phase II of Kangbao Wolongtushan Wind Farm
14	Grid Connection Study Report of Phase I of Guyuan Wuhuaping Wind Farm
15	Grid Connection Study Report of Phase II of Guyuan Wuhuaping Wind Farm
16	Grid Connection Study Report of Guyuan Dongxinying Wind Farm
17	Feasibility Study Report of Haixing Wind Farm
18	Grid Connection Study Report of Phase I of Congli Qingsanying Wind Farm
19	Grid Connection Study Report of Phase II of Congli Qingsanying Wind Farm
20	Grid Connection Study Report of Phase I of Yuxian Kongzhongcaoyuan Wind Farm
21	Grid Connection Study Report of Phase II of Yuxian Kongzhongcaoyuan Wind Farm
22	Grid Connection Study Report of Weichang Yudaokou Wind Farm
23	WTG Supply Agreement of Phase I of Kangbao Wolongtushan Wind Farm
24	WTG Supply Agreement of Phase II of Kangbao Wolongtushan Wind Farm
25	WTG Supply Agreement of Phase I of Guyuan Wuhuaping Wind Farm
26	WTG Supply Agreement of Phase II of Guyuan Wuhuaping Wind Farm
27	WTG Supply Agreement of Guyuan Dongxinying Wind Farm
28	WTG Supply Agreement of Haixing Wind Farm
29	WTG Supply Agreement of Congli Qingsanying Wind Farm
30	WTG Supply Agreement of Congli Qingsanying Wind Farm
31	WTG Supply Agreement of Yuxian Kongzhongcaoyuan Wind Farm
32	WTG Supply Agreement of Yuxian Kongzhongcaoyuan Wind Farm
33	WTG Supply Agreement of Weichang Yudaokou Wind Farm
34	Met Mast Data (Wind Speed and Wind Direction) of Each Phase I Wind Farm
35	Monthly Generation Data of Each Wind Farm

Glossary

ASL	Above Sea Level
COD	Commercial Operation Date
DFSTW/Dongfang Turbine Company	Dongfangg Steam Turbine Works
HECIC	HeBei Construction & Investment Group Co., Ltd
HECICNE	HECIC New-Energy Co., Ltd
GB/T	Guobiao/Tuijian, Chinese National Standard, Recommended
GE	the General Electric Company, Energy
GL	Germanischer Lloyd
IEC	International Electrotechnical Commission
IPE	Implementation in Production and Erection
MCP	Measure Correlate Predict
MM	Mott MacDonald Limited
NCAR	National Centre for Atmospheric Research
O&M	Operation and Maintenance
SCADA	System Control and Data Acquisition
TC	Technical Consultant
WAsP	Wind Atlas Analysis and Application Program
WTG	Wind Turbine Generator
Units	
GWh	Giga Watt hour (electric generation)
kA	kilo Ampere (power)
kV	kilo voltage (electric)
m	metre (length)
m^2	square metre (area)
m/s	metre per second (velocity)
MPa	Mega Pascal (pressure)
MW	Mega Watt (electric)
MVA	Mega Volt Ampere (apparent power)
MVar	Mega Volt-ampere reactance (reactive power)
V	Voltage (electric)
W/m^2	Watt per square metre (power density)
%	percent
°C	Degrees Centigrade (temperature)