Clean Development Mechanism Project Opportunities in China

Pre-Feasibility Report on a Wind Power Generation CDM Project in Northern China

Wei Zhihong
Global Climate Change Institute
Tsinghua University
Beijing, China

August 2002

Contents

Tables and Figures

Preface

The Pembina Institute for Appropriate Development and the **Tata Energy Research Institute** are exploring the application of the Clean Development Mechanism (CDM) in Asia. This multi-year project is being undertaken in collaboration with:

- **The Bangladesh University of Engineering and Technology;**
- **The Global Climate Change Institute at Tsinghua University, China; and**
- **The Centre for Research on Material and Energy at the Technology University in Bandung, Indonesia**.

The following publications have been produced by the project partners:

- *Canada's Potential Role in the Clean Development Mechanism* (2000)
- *Negotiating the CDM: A North–South Perspective* (2000)
- Reports on CDM activities and potential CDM project opportunities in Bangladesh, China, India and Indonesia (2001)
- *A User's Guide to the CDM* (2002)
- Reports on individual CDM project opportunities in Bangladesh, China, India and Indonesia (2001)

For more information on this project visit the following Web sites:

- www.teriin.org
- www.pembina.org/international_eco3.asp

The project is being undertaken with the financial support of the Government of Canada provided through the **Canadian International Development Agency (CIDA)**, online at www.acdi-cida.gc.ca, and is being implemented in collaboration with the International **Institute for Sustainable Development (IISD)**, online at www.iisd.ca.

This report was produced by the Global Climate Change Institute at Tsinghua University, China. The views expressed in this report are entirely those of the author.

1 Introduction

Renewable energy has great potential to reduce greenhouse gas emissions and mitigate the effects of climate change. To promote the development of renewable energy in China, three agencies (State Development Planning Commission, Ministry of Science and Technology, and State Economic and Trade Commission) jointly formulated the "Guidelines on Renewable Energy Development Program (1996-2010)" in 1995. The Guidelines described the goals of renewable energy development in China—to raise conversion efficiency, to reduce production cost, to expand the proportion of renewable energy in the overall energy mix, and to develop new technologies. Achieving these goals will contribute to environmental protection and sustainable development of China's economy.

Following several years of research, domestic experts have estimated the wind energy resources of China at 3,226 GW, measured at a height of 10 metres above the ground. If just 1/10 of the total amount of wind resources is available for actual use, and if this amount is further adjusted by an area coefficient of 0.785, the exploitable wind energy in China is 253 GW.[1] Compared with a total power generation capacity of 314 GW for all of China in 2000, wind energy potential is quite abundant.

Regions with rich wind energy resources are located mainly in grasslands or deserts of northwest, north, and northeast China, as well as in coastal areas and islands in east and southeast China.

Expanded use of wind resources will provide electricity to remote areas. In the near term, research is needed to develop large wind power generating units and reduce costs. In the longer term, the goal is to establish large wind power stations.

In general, for a wind farm to be viable, the annual operation time of wind turbines needs to be at least 2,000 hours per year. A wind farm would be regarded as a good investment if turbines operate 2,500 hours per year, and an excellent investment if annual operating time exceeds 3,000 hours. The quality of a power grid will not be obviously weakened as long as the proportion of wind power is less than ten percent.

By the end of 1999, China had constructed 24 wind farms in 15 provinces and regions, mainly in Xinjiang Uygur Autonomous Region (XUAR), Inner Mongolia Autonomous Region (IMAR), and Guangdong province. Total wind farm capacity was 268 MW and if small wind turbines are included,[2] total capacity of wind power was about 290 MW in 1999.

---

[1] 3,226 GW x 0.10 x 0.785 = 253 GW.

[2] The unit capacity of small wind turbines is generally around 100 W, and there are an estimated 200,000 small turbines in rural and remote areas of China.

The 1995 Guidelines on Renewable Energy Development described future development targets for wind power: "the installed capacity of wind power will reach 300-400 MW (equal to 0.25-0.32 Mtoe,[3]) in 2000 and 1,000-1,100 MW (equal to 1.08 Mtoe) in 2010, respectively." The target was reached by the end of 2000, when total capacity of wind generators was 344 MW. However, targets now seem too low and have been revised in support of faster development.

Between 2001 and 2005, a detailed survey of wind energy resources should be carried out in three provinces of northeast China, the eastern part of Inner Mongolia, the north part of Hebei, and all coastal areas including islands to find sites suitable for the construction of 4,000 MW wind farms.

Based on current policies, it is estimated that 1,500 MW of wind turbines could be installed by 2005. From 2006 to 2010, 70 percent of turbines in installed capacity should be locally manufactured, as domestically made turbines and components will cost less than imported equipment. It may be possible to reach 3,000 - 5,000 MW of total wind installations by 2010, three to five times more than the targets described in the 1995 Guidelines.

2 Objective

The wind farm described in this project is proposed for one county (the County, hereafter) of Chengde city (the City, hereafter) in Hebei province. Following the reform and opening-up of China in the 1980s, the City has experienced rapid economic development, achieving a GDP in 2000 of US$197-million. However, problems and contradictions remain, including a weak economic base, a shortage of back-up power, poor finance, and a shortage of funds. In general, the City suffers from poverty and under-development.

At the present time, development of the electric power industry in the City lags behind overall economic growth, as power generation has been decreasing in recent years. A shortage of power is becoming a key factor restricting social and economic development and must be addressed. To remove this barrier to economic development, the City government has tried many measures; for example, increasing input to power facilities, improving electric grid structure, and expanding power supply capacity were all listed in the Ninth Year Plan (1996-2000) of the City.

To help plan a development program for the electric power industry, an electric power demand study was carried out in the City in 1995. The study forecasted the City's power load for the medium term, to increase as follows:

355 MW in 1995
550 MW in 2000
771 MW in 2005
1,032 MW in 2010

[3] Mtoe is "million tons of oil equivalent."

Comparing future demand and current supply capacity, the study concluded that a power supply deficit already exists and is predicted to continue into the future. The deficit was 180-250 MW in 1995, and 450 MW in 2000. With a continuing increase in demand and no new built capacity after 2000, the shortage of power will become more serious, and demand would be met by importing electricity through the regional grid if no new power plants are built. Such imports would require retrofitting of the grid structure to increase capacity.

As part of a regional power development program, preliminary project feasibility reports were done for two thermal power units of 300 MW each in the Tenth Five-year Plan period (2001-2005) and another two thermal power units of 300 MW in the Eleventh Five-year Plan period (2006-2010), based on the design of existing large thermal plants. No decisions have yet been made about when and how to start the projects.

Because coal resources in the City are nearly exhausted and coal production is decreasing, coal for new large thermal power plants could not be locally supplied. Importing coal from other provinces would create a heavy burden for the transportation system. Furthermore, the City has no oil or natural gas, and hydro power potential is small because of minimal resources and the long period required for exploration and development. Thus other resources such as renewable energy must be developed.

Coal is the primary source of power generation in northern China, and its combustion has resulted in serious environmental pollution. If the wind resource were sufficiently utilized in the City, it would diversify power generation and make it possible to meet local demand, ease transportation tensions, and contribute to environmental protection in this part of the country.

Some hydro power generation facilities exist already in the City region and could complement wind by adjusting and stabilizing wind power and promoting grid quality. For example, hydro power has the advantage of smoothing out generation peaks and valleys that may be associated with wind generation. In summary, there are good prospects for wind power development in the County.

3 Project Description

3.1 Overview

The City is about 200 km northeast of Beijing, the capital of China. It consists of eight counties and three regions with a total area of 40,000 km^2. The City is a close neighbour to the Inner Mongolia Autonomous Region (IMAR) in the north. Total population in 2000 was 3.32 million.

The City is located in a connection area between the south part of Daxinanling Mountain and the north part of Yanshan Mountain. The County where the wind farm will be built is on the south edge of the Mongolia Plateau in smooth, open grassland without any tall trees. The average height of the plateau is 1,700-1,800 metres above sea level, and in winter the soil freezes to a depth of 1.5-2.0 metres.

The wind farm will be constructed in a State Nature Protection Region (SNPR) approved by the State Council in August 1998. The SNPR is divided into three districts: Core District, Transition District, and Experiment District. No activities are permitted in the Core District. Hunting activities and cultivation or pasturing that destroys grass cover are forbidden in the Transition District. Tourism and various reasonable development and business activities are allowed in the Experiment District for exploring and utilizing natural resources. The wind farm will be located in the Experiment District and will cover an area of about 400 km^2 (20 km on each side).

The Mongolia Plateau has a medium-warm monsoon climate, with short springs, cool summers, early frosts, and long cold winters. The annual variation in temperature is substantial, ranging from a maximum of 29.8 ºC to a minimum of -42.9 ºC; annual average temperature is -0.3 ºC. Annual average precipitation is 450-500 mm, occurring mainly in July and August, and the snow pack lasts as long as five months each year. There are 76 days per year of strong wind over Grade 6.

3.2 Wind Resources Measurement

To obtain complete and reliable meteorological information at the wind farm sites (wind speed, wind direction, temperature, atmospheric pressure, etc.), two 40-metre iron towers were built four kilometres apart and equipped with measuring instruments from the U.S. Second Wind Corporation. Two sets of instruments were fixed at heights of 10 and 40 metres in each tower to collect various kinds of data.

Wind speed data for a full year (1998-1999), collected by anemometers 1 and 2 in tower 1 and anemometer 2 in tower 2, is shown in Table 1. Small differences exist in the measurements recorded at the same heights. The annual average wind speed exceeds 8 m/s (metres/second), which shows there are abundant wind resources and that it is reasonable to build and use wind energy in the County.

Table 1 Wind Speed

Height (m)	Tower 1		Tower 2
	Anemometer 1	Anemometer 2	Anemometer 2
10	8.03 m/s	7.91 m/s	7.98 m/s
40	9.51 m/s	9.41 m/s	9.43 m/s

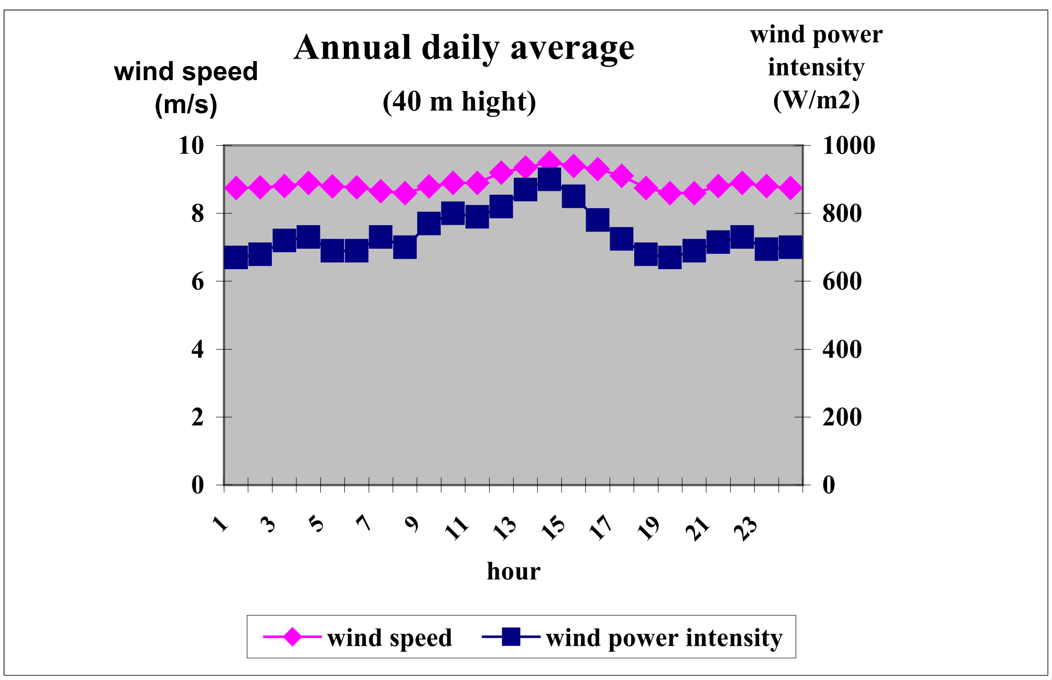
Analysis of data collected from the towers reveals that:

- Wind resources, influenced by topography and airflow, are abundant at the site; the prevailing wind direction is from the northwest and north to the southeast and south.
- Duration of effective wind speed (3-25 m/s) is around 8,250 hours annually.
- Average annual wind density is 743 watts/m^2.
- High wind speed occurs during the day with low speeds at night.
- Average monthly wind speed is highest from November to February (over 10 m/s), and lowest in July and August (below 6 m/s).
- Average annual atmospheric pressure is 811 Pa.
- Average annual temperature is -5.9 ºC, and there are 432 hours per year in which the temperature is equal to or less than -30 ºC.

Figure 1 shows the annual daily average wind speed and intensity measured at a height of 40 metres.

In conclusion, the factors that favour wind power development at this site are stable wind direction, excessive hours of effective wind speed, no destructive wind speed, good wind quality, and abundant wind resources. Factors that could have negative impacts on wind generators are many hours of low temperatures and increased elevation above sea level. With a minimum temperature of -43 ºC, blade freezing issues will also need to be addressed in the project design.

Figure 1 Wind Speed and Intensity



3.3 Wind Farm Capacity

Based on landform and transportation conditions in the area of the wind farm sites, total capacity of wind generators in the County could be planned up to about 238 MW. If activities permitted in the Transition District were altered in future, 185 MW could be added to the wind farm development program. The Mongolia Plateau extends to IMAR in the north, and another wind farm with capacity of 600 MW could be developed in a long-term program in the IMAR area.

Though abundant wind energy resources exist in the County, wind farms should be developed gradually, taking into account factors such as local social and economic development, technology, funds, and policies of promoting renewable energy. A reasonable and realistic program of developing wind farms in the County needs to be drafted, based on the actual situation. Development plans for the medium term (within 15 years) and long term (beyond 15 years) have been prepared. The medium-term plan is composed of four phases, with a specific size of wind farm to be built in each phase, to a capacity of 171.7 MW (see Table 2). Another 66.3 MW will be developed in the long term, resulting in a total capacity of 238 MW in the County.

Table 2 Wind Farm Capacity

Medium term				
Phase	Time period (year)	Wind generator	Total capacity (MW)	Electricity per year (MWh)
1	1st – 2nd	660 kW × 4	2.64	6,336
2	2nd – 6th	1,300 kW × 52	67.6	162,240
3	7th – 11th	1,300 kW × 48	62.4	149,760
4	12th – 16th	1,300 kW × 30	39.0	93,600
Long term				
5	Beyond 16th	1,300 kW × 51	66.3	159,120

The Danish concept designs featuring three vanes, upstream wind direction, horizontal axis, and rigid hub have been adopted by most of the wind generators in the world, and unit capacity continues to increase. Production and sales of wind generators with unit capacity less than 600 kW for wind farms are decreasing in both international and domestic markets. The unit capacity series of wind generators presently includes 660 kW, 750 kW, 800 kW, 900 kW, 1,000 kW, 1,300 kW, 1,500 kW, 1,650 kW, 2,000 kW, 2,500 kW, and 3,000 kW.

Wind generators with unit capacity of 660 kW that have been used frequently in recent years in China will be chosen for Phase 1, taking into account wind resources, domestic experience in building wind farms, and preliminary technical and economic analyses and comparisons. Wind generators with unit capacity of 1,300 kW, which are now in use abroad, will be adopted in

Phases 2, 3, 4, and 5. Wind generator hubs will be located at a height of 40 m for units with capacity of 660 kW and at 60 m for those with unit capacity of 1,300 kW.

3.4 Transportation

Railway and road are the two main transportation modes around the City. There are four railway lines through the City area with a total length of 530 km. In addition, there are three state highways (No. 101, 111, 112), 15 provincial roads and 25 county roads, for a total roadway length of about 5,220 km. The No. 111 state highway runs through the County, and one road connecting to the SNPR has been built since 2000. Thus, the transportation system in the area is convenient and adequate for transporting wind generators and other equipment to the wind farm sites from sea ports by the Bo Sea or via large cities such as Beijing, Tianjin, and others near the County.

3.5 Power Grid

The City's grid is one part of the Beijing-Tianjin-Tangshan Power Grid. In the City area, there is one 220 kV transformer substation with a capacity of 240 MVA and one 220 kV transmission line with a total length of 90 km, as well as twenty 110 kV transformer substations with total capacity of 704 MVA and twenty-six 110 kV transmission lines with a total length of 749 km.

There is a large thermal power plant in the City with a capacity of 200 MW. Additional power comes from 16 small hydro power stations with total capacity of 10.6 MW, and 19 small thermal power plants with total capacity of 37.6 MW. Four enterprise-owned thermal power plants are presently under construction with total capacity of 93 MW.

Although wind power generation can be more random than other sources, it is important to build wind farms into the electricity power grid. This will maintain stability for the wind generators' operations and achieve better economic benefits while developing wind energy on a large scale. On the other hand, power quality of the whole grid is influenced by the addition of wind power, and the proportion of wind power to total volume of the grid is limited to five percent in China. Globally, this proportion is around 10 percent and, in some countries, it can exceed 10 percent.

New transformer substations and transmission lines will be needed to connect wind farms with the regional grid. In Phase 1, 35 kV box-transformer substations will be built and connected to the transformer substation being constructed during Phase 2. One new 110 kV transformer substation will be built in Phase 2 to transmit wind power to the City grid. Another new 110 kV transformer substation, also connected to the City grid, will be constructed in Phase 3 and expanded in Phase 4.

3.6 Environmental Benefits

In this region, wind power is used mainly as a substitute for coal-fired power. Reductions in air emissions can be calculated given the electricity production and coal intensity per unit of power generation. Assuming the coal intensity to be 370 gce[4]/kWh in the base year and then decreasing by 3 gce/kWh per year, coal combustion mitigation and emission reduction of major air pollutants per year can be estimated (see Tables 3 and 4).

Table 3 Coal Substitution per Year

	Base year	2nd - 6th year	7th - 11th year	12th - 16th year	Beyond 16th year
Total capacity (MW)	0	2.64	70.24	132.64	171.64
Power generation (MWh)	0	6,649	167,199	315,399	408,024
Coal intensity (gce/kWh)	370	367-355	352-340	337-325	322
Coal substitution (Kt)	0	3.4	83.1	150.1	185.7

Table 4 Emission Reductions of Air Pollutants per Year

	Base year	2nd - 6th year	7th - 11th year	12th - 16th year	Beyond 16th year
CO_2 (Ktonnes)	0	8	180	325	402
SO_2 (tonnes)	0	111	2,792	5,265	6,814
CO (tonnes)	0	1	22	41	53
NOx (tonnes)	0	37	931	1,758	2,273

4 Investment

4.1 Investment Analysis

Investment capital is divided into two components—equity capital and loans. Equity capital is expected to account for 20 percent of total investment in all phases of the project; loans will be obtained from domestic and foreign banks or other financial institutions. The equity capital would be provided by local implementation agencies, for example, a local utility company.

Because of many uncertainties, financial analyses are only made for the medium term; i.e., for 171.6 MW of wind farm construction in Phases 1, 2, 3, and 4 over 15 years. The long-term project and its funding will be considered after experience is gained over the medium term.

[4] Grams of (standard) coal equivalent

In many cases, wind sites are far from existing power grids, requiring consideration of the cost of extending the transmission line. Therefore, wind farm development needs to be coordinated with the extension of power grids during the planning stages.

Investment estimates for the wind farm project are shown in Table 5.

Information from provincial power companies indicates that 960 MW of wind projects had secured funding by the end of 2000, suggesting that financing is not the main barrier to wind power development in China.

Table 5 Investment Estimates, million US$

Item	Phase 1	Phase 2	Phase 3	Phase 4
Capacity (MW)	2.64	67.6	62.4	39.0
1. Total static investment	3.66	68.87	71.33	42.27
(1) Facilities & installation	2.35	57.19	52.21	33.77
(2) Construction	0.15	2.64	2.90	1.64
(3) Auxiliary engineering	0.03	0.35	0.56	0.35
(4) Other expenditures	0.21	2.49	2.73	1.76
(5) Grid-in engineering	0.85	4.72	11.12	3.76
(6) Basic preparation	0.08	1.48	1.80	1.00
2. Interest in construction period	0.00	1.70	1.77	1.05
3. Total engineering investment	3.66	70.58	73.10	43.32
Static unit investment (US$/kW)	1,388	1,019	1,143	1,084
Unit engineering investment (US$/kW)	1,388	1,044	1,171	1,111

4.2 Policies

Most of the completed wind farms in China were financed by loans, with subsidized interest provided by the State Economic and Trade Commission (SETC) for technical innovation projects, and soft loans provided by foreign governments. Due to low interest rates and longer payback periods, these loans result in lower wind power tariffs during the payback period. In the future, soft loans are expected to decrease while commercial bank loans with higher interest rates and shorter payback periods will increase. This will result in higher wind tariffs during the payback period, which is a barrier for large scale wind farm development.

At the beginning of 1999, the Ministry of Science and Technology and the State Development Planning Commission (SDPC) developed a policy for helping renewable energy projects raise funds. SDPC will assist proprietors to get domestic bank loans if they intend to build medium or large renewable energy power projects with a capacity of more than three MW. If the funds come from state capital construction loans provided by domestic banks, a financial interest discount of two percent will be granted. To obtain the interest discount, equity input of the renewable energy projects must account for 35 percent or more of the total investment of the project.

Incentive policies from administrative agencies are in an early phase. To date, the policies stipulate that wind generation must be connected to power grids, and that all electricity generated by wind should be purchased by power grids. This will enable the owners to borrow money from commercial banks to construct wind farms.

The present price of wind electricity in China is about 2.4 times higher than that of coal-fired power; this difference amounting to 0.036-0.048 US cents/kWh. Though the cost of wind power will continue to drop, however, and in the meantime, the price difference between wind and coal can be paid for out of the profit of the electric power bureau.

An important way to reduce the price of wind power is to decrease the cost of wind turbines. Equipment costs generally represent 60-70 percent of the total initial investment for wind farm projects. If more turbine components were built locally, equipment costs could be reduced by 15 percent and still maintain quality. One financial policy incentive was issued by SDPC in 1999 to encourage use of materials made in China. If the project uses imported power generation equipment, the marginal investment profit of renewable energy power projects in the loan payback period cannot exceed the loan interest during the same loan payback period by more than three percent. However, if domestic equipment is used, the marginal investment profit can exceed the loan interest during the same loan payback period by five percent.

5 Financial Analysis

Basic assumptions made in support of financial analysis for the project are shown in Table 6.

Table 6 Information for Financial Analysis

Item	Unit	Phase 1	Phase 2	Phase 3	Phase 4
Construction period	year	1	1	1	1
Annual utilization hours	hour	2,400	2,400	2,400	2,400
Annual power generation	MWh	6,336	162,240	149,760	93,600
Capacity available factor	%	27	27	27	27
Wind farm lifetime	year	20	20	20	20
Equity capital share	%	20	20	20	20
Loan share	%	80	80	80	80
Domestic loan interest rate	%	6.21	6.21	6.21	6.21
Loan payback period	year	15	15	15	15
O&M rate in investment	%	2.7	3.1	3.0	2.9
Income tax rate	%	33	33	33	33
Sales tax	%	0.3	0.3	0.3	0.3
Standard discount rate	%	12	12	12	12
Sale price (including VAT)	US cents/kWh	0.0937	0.0690	0.0775	0.0726

Sensitivity analysis of financial rate of return (F-IRR) was done by testing alternative assumptions of several principal variables affecting F-IRR in order to evaluate their effect on financial viability of the projects. In this case study of a wind farm project, sensitivity analyses of investment and electricity sale price were selected because they are the most important factors. Calculated results are shown in Table 7 and indicate that F-IRR in all scenarios will be higher than the discount rate of 12 percent, so the project in all phases would remain financially viable even if the sale price decreases by five percent or investment increases by five percent.

Table 7 Sensitivity Analysis of Financial Rate of Return (F-IRR)

Scenarios	Phase 1	Phase 2	Phase 3	Phase 4
1 Reference case				
F-IRR (%)	16.3	14.3	14.6	14.4
Payback period (year)	8.4	9.5	9.3	9.5
2 5% decrease in power sale price				
F-IRR (%)	14.2	12.3	12.6	12.4
Payback period (year)	9.6	11.1	10.8	11.0
SI	2.62	2.86	2.82	2.82
3 5% increase in investment				
F-IRR (%)	14.9	12.9	13.2	13.0
Payback period (year)	9.3	10.7	10.4	10.6
SI	-1.77	-1.98	-1.99	-1.95

Note: Sensitivity indicator (SI) = (percentage change in F-IRR)/(percentage change in variable tested).

Details of the financial analysis for each phase are given in Annex Tables 1-4

6 CO_2 Emission Reduction Analysis

6.1 Baseline Project Selection

As part of the power supply development program being planned by Chengde City to meet its increasing electricity demand, new power plants would be built and/or existing plants expanded. Developing wind farms in the City could be one way to replace some capacity of coal power plants. Thus, it is reasonable to choose coal power plants as the baseline for this case study. To correctly compare CDM and baseline projects, the size of both projects should be matched. Total capacity of the four phases of the proposed wind farm is about 172 MW, which is a large wind power project for China. However, this capacity could be achieved by a medium size coal power plant. To improve energy efficiency, new coal power plants for 300 MW and 600 MW are being given priority in China. Thus, in this study, data for the baseline project is based mainly on a 300 MW coal thermal power plant.

6.2 System Boundary Definition

In general, the system boundary of CDM projects is defined to cover all greenhouse gas emission sources relating to both the CDM project and baseline project. In practice, it is common to select the project physical boundary as the system boundary. In this case study, the baseline project will be built near an existing plant and grid, but the CDM project is far from the grid, so new transformer stations and transmission lines will be needed. Thus the system boundary for the baseline project is the boundary of the baseline coal plant, while the system boundary for the CDM project includes the wind farm itself as well as the required new transmission lines.

For any system boundary, there is the issue of emission leakage. For example, in this study, emissions during the production and transportation of energy and energy-intensive products needed for constructing and operating both baseline and CDM projects (such as coal, steel, and cement) are considered indirect emissions outside the system boundary and regarded as carbon leakage. Some studies carried out in China show that indirect emissions during construction occurred only once, making the difference between the baseline project and the CDM project generally small. If the indirect emissions are averaged over the lifetime of the project (about 20 years), the leakage has very little impact on the incremental cost of CDM projects and can be ignored.

6.3 Claim Period for Emission Reduction

Three claim periods of seven years each are assumed for the emissions reductions from each phase of the CDM project, for a total of 21 years for each phase.

6.4 Certified Emissions Reduction (CER) Production

Table 8 shows the expected annual production of certified emissions reductions from each phase of the CDM project, and the value of these CERs at different price levels.

Table 8 CER Production from Each Phase of the CDM Project

	CER Price	Phase 1	Phase 2	Phase 3	Phase 4
Capacity (MW)		3	68	62	39
Baseline Plant Efficiency (gce/kWh)		351	346	331	322
Annual CER production (ktonnes/yr)		8	172	145	77
Annual Income from Sale of CERs	US$5	$40,000	$860,000	$725,000	$385,000
	US$10	$80,000	$1,720,000	$1,450,000	$770,000
	US$15	$120,000	$2,580,000	$2,175,000	$1,155,000

6.5 Calculation of Incremental Cost of Emission Reduction

$$IC = \frac{AC_{CDM} - AC_{Baseline}}{AE_{Baseline} - AE_{CDM}}$$

where

IC	Incremental cost of CO_2 emission reduction
$AC_{Baseline}$	Annual cost of baseline project
AC_{CDM}	Annual cost of wind CDM project
$AE_{Baseline}$	Annual CO_2 emissions of baseline project
AE_{CDM}	Annual CO_2 emissions of wind CDM project

Major technical and financial parameters for the baseline project are assumed to be those of a 300 MW coal-fired power plant (see Table 9). However, because of the differences in total capacity and utilization hours of the two types of plants, it is reasonable to base the comparison on generation of the same annual amount of electricity. In this case study, about 30 percent of baseline project capacity could generate the same amount of electricity as the wind CDM project. Additionally, it is assumed that the annual cost of the baseline project includes capital, operating and maintenance, and fuel costs, and the annual cost of the wind CDM project includes the same components except fuel cost.

Table 9 Technical and Financial Data for a Baseline 300 MW Coal-Fired Power Plant

Item	Unit	Quantity
1 Investment	US$	630
2 Construction period	Year	2.5
3 Life time	Year	25
4 Annual utilization hours	Hour	4,760
5 Capacity available factor	%	55
6 Generation efficiency	%	33.2
7 O&M cost	US cents/kWh	0.73
8 Fuel cost	US cents/kWh	1.09

The wind CDM project will produce significant environmental benefits. By fully replacing coal combustion, 0.46 million tonnes of CO_2 would be reduced annually during the lifetime of the wind CDM project. The incremental cost of obtaining these CO_2 reductions is US$133/tonne CO_2, or US$16.79-million per year.

7 Annex: Financial Analysis

Annex Table 1 Financial analysis of wind farm project – Phase 1 (,000 US$)

Year	Capital	Loan	Depreciation	Interest	O&M	Gross income	VAT	Benefit	Income tax	Net benefit	TNPV
1	732.55									-732.55	-732.55
2		195.35	183.14	181.97	98.89	593.71	1.78	127.93	42.22	73.51	65.63
3		195.35	183.14	169.83	98.89	593.71	1.78	140.06	46.22	81.63	65.08
4		195.35	183.14	157.70	98.89	593.71	1.78	152.19	50.22	89.76	63.89
5		195.35	183.14	145.57	98.89	593.71	1.78	164.33	54.23	97.89	62.21
6		195.35	183.14	133.44	98.89	593.71	1.78	176.46	58.23	106.02	60.16
7		195.35	183.14	121.31	98.89	593.71	1.78	188.59	62.23	114.14	57.83
8		195.35	183.14	109.18	98.89	593.71	1.78	200.72	66.24	122.27	55.31
9		195.35	183.14	97.05	98.89	593.71	1.78	212.85	70.24	130.40	52.67
10		195.35	183.14	84.92	98.89	593.71	1.78	224.98	74.24	138.53	49.95
11		195.35	183.14	72.79	98.89	593.71	1.78	237.11	78.25	146.66	47.22
12		195.35	183.14	60.66	98.89	593.71	1.78	249.24	82.25	154.78	44.50
13		195.35	183.14	48.52	98.89	593.71	1.78	261.37	86.25	162.91	41.82
14		195.35	183.14	36.39	98.89	593.71	1.78	273.51	90.26	171.04	39.20
15		195.35	183.14	24.26	98.89	593.71	1.78	285.64	94.26	179.17	36.66
16		195.35	183.14	12.13	98.89	593.71	1.78	297.77	98.26	187.30	34.22
17			183.14		98.89	593.71	1.78	309.90	102.27	390.77	63.74
18			183.14		98.89	593.71	1.78	309.90	102.27	390.77	56.91
19			183.14		98.89	593.71	1.78	309.90	102.27	390.77	50.82
20			183.14		98.89	593.71	1.78	309.90	102.27	390.77	45.37
21			183.14		98.89	593.71	1.78	309.90	102.27	390.77	40.51
Total	732.55	2,930.21	3,662.76	1,455.73	1,977.89	11,874.25		4,742.25	1,564.94	3,177.30	301.14
F-IRR										**16.30%**	

Annex Table 2 Financial analysis of wind farm project – Phase 2 (,000 US$)

Year	Capital	Loan	Depreciation	Interest	O&M	Gross income	VAT	Benefit	Income tax	Net benefit	TNPV
1	14,125.62									-14,125.62	-14,125.62
2		3,766.83	3,531.40	3,508.80	2,189.47	11,195.74	33.59	1,932.47	637.72	1,059.33	945.83
3		3,766.83	3,531.40	3,274.88	2,189.47	11,195.74	33.59	2,166.39	714.91	1,216.06	969.43
4		3,766.83	3,531.40	3,040.96	2,189.47	11,195.74	33.59	2,400.31	792.10	1,372.78	977.12
5		3,766.83	3,531.40	2,807.04	2,189.47	11,195.74	33.59	2,634.23	869.30	1,529.51	972.03
6		3,766.83	3,531.40	2,573.12	2,189.47	11,195.74	33.59	2,868.15	946.49	1,686.24	956.82
7		3,766.83	3,531.40	2,339.20	2,189.47	11,195.74	33.59	3,102.07	1,023.68	1,842.96	933.70
8		3,766.83	3,531.40	2,105.28	2,189.47	11,195.74	33.59	3,335.99	1,100.88	1,999.69	904.56
9		3,766.83	3,531.40	1,871.36	2,189.47	11,195.74	33.59	3,569.91	1,178.07	2,156.42	870.94
10		3,766.83	3,531.40	1,637.44	2,189.47	11,195.74	33.59	3,803.83	1,255.27	2,313.14	834.14
11		3,766.83	3,531.40	1,403.52	2,189.47	11,195.74	33.59	4,037.75	1,332.46	2,469.87	795.23
12		3,766.83	3,531.40	1,169.60	2,189.47	11,195.74	33.59	4,271.68	1,409.65	2,626.60	755.08
13		3,766.83	3,531.40	935.68	2,189.47	11,195.74	33.59	4,505.60	1,486.85	2,783.32	714.41
14		3,766.83	3,531.40	701.76	2,189.47	11,195.74	33.59	4,739.52	1,564.04	2,940.05	673.78
15		3,766.83	3,531.40	467.84	2,189.47	11,195.74	33.59	4,973.44	1,641.23	3,096.78	633.66
16		3,766.83	3,531.40	233.92	2,189.47	11,195.74	33.59	5,207.36	1,718.43	3,253.50	594.40
17			3,531.40		2,189.47	11,195.74	33.59	5,441.28	1,795.62	7,177.06	1,170.73
18			3,531.40		2,189.47	11,195.74	33.59	5,441.28	1,795.62	7,177.06	1,045.30
19			3,531.40		2,189.47	11,195.74	33.59	5,441.28	1,795.62	7,177.06	933.30
20			3,531.40		2,189.47	11,195.74	33.59	5,441.28	1,795.62	7,177.06	833.31
21			3,531.40		2,189.47	11,195.74	33.59	5,441.28	1,795.62	7,177.06	744.02
Total	14,125.62	56,502.47	70,628.09	28,070.43	43,789.41	223,914.77	671.74	80,755.10	26,649.18	54,105.92	3,132.19
F-IRR										**14.30%**	

Annex Table 3 Financial analysis of wind farm project – Phase 3 (,000 US$)

Year	Capital	Loan	Depreciation	Interest	O&M	Gross income	VAT	Benefit	Income tax	Net benefit	TNPV
1	14,610.36									-14,610.36	-14,610.36
2		3,896.10	3,652.59	3,629.21	2,191.55	11,603.68	34.81	2,095.51	691.52	1,160.49	1,036.15
3		3,896.10	3,652.59	3,387.27	2,191.55	11,603.68	34.81	2,337.46	771.36	1,322.59	1,054.36
4		3,896.10	3,652.59	3,145.32	2,191.55	11,603.68	34.81	2,579.41	851.20	1,484.70	1,056.78
5		3,896.10	3,652.59	2,903.37	2,191.55	11,603.68	34.81	2,821.35	931.05	1,646.80	1,046.57
6		3,896.10	3,652.59	2,661.42	2,191.55	11,603.68	34.81	3,063.30	1,010.89	1,808.91	1,026.42
7		3,896.10	3,652.59	2,419.48	2,191.55	11,603.68	34.81	3,305.25	1,090.73	1,971.01	998.58
8		3,896.10	3,652.59	2,177.53	2,191.55	11,603.68	34.81	3,547.20	1,170.57	2,133.11	964.91
9		3,896.10	3,652.59	1,935.58	2,191.55	11,603.68	34.81	3,789.14	1,250.42	2,295.22	927.00
10		3,896.10	3,652.59	1,693.63	2,191.55	11,603.68	34.81	4,031.09	1,330.26	2,457.32	886.14
11		3,896.10	3,652.59	1,451.69	2,191.55	11,603.68	34.81	4,273.04	1,410.10	2,619.43	843.39
12		3,896.10	3,652.59	1,209.74	2,191.55	11,603.68	34.81	4,514.99	1,489.95	2,781.53	799.62
13		3,896.10	3,652.59	967.79	2,191.55	11,603.68	34.81	4,756.93	1,569.79	2,943.64	755.56
14		3,896.10	3,652.59	725.84	2,191.55	11,603.68	34.81	4,998.88	1,649.63	3,105.74	711.76
15		3,896.10	3,652.59	483.90	2,191.55	11,603.68	34.81	5,240.83	1,729.47	3,267.85	668.67
16		3,896.10	3,652.59	241.95	2,191.55	11,603.68	34.81	5,482.78	1,809.32	3,429.95	626.64
17			3,652.59		2,191.55	11,603.68	34.81	5,724.72	1,889.16	7,488.16	1,221.48
18			3,652.59		2,191.55	11,603.68	34.81	5,724.72	1,889.16	7,488.16	1,090.61
19			3,652.59		2,191.55	11,603.68	34.81	5,724.72	1,889.16	7,488.16	973.76
20			3,652.59		2,191.55	11,603.68	34.81	5,724.72	1,889.16	7,488.16	869.43
21			3,652.59		2,191.55	11,603.68	34.81	5,724.72	1,889.16	7,488.16	776.27
Total	14,610.36	58,441.45	73,051.82	29,033.71	43,831.09	232,073.61	696.22	85,460.77	28,202.05	57,258.71	3,723.72
F-IRR										**14.65%**	

Annex Table 4 Financial analysis of wind farm project – Phase 4 (,000 US$)

Year	Capital	Loan	Depreciation	Interest	O&M	Gross income	VAT	Benefit	Income tax	Net benefit	TNPV
1	8,664.04									-8,664.04	-8,664.04
2		2,310.41	2,166.01	2,152.15	1,256.29	6,799.03	20.40	1,204.19	397.38	662.41	591.43
3		2,310.41	2,166.01	2,008.67	1,256.29	6,799.03	20.40	1,347.67	444.73	758.54	604.70
4		2,310.41	2,166.01	1,865.20	1,256.29	6,799.03	20.40	1,491.14	492.08	854.66	608.33
5		2,310.41	2,166.01	1,721.72	1,256.29	6,799.03	20.40	1,634.62	539.42	950.79	604.25
6		2,310.41	2,166.01	1,578.24	1,256.29	6,799.03	20.40	1,778.09	586.77	1,046.92	594.05
7		2,310.41	2,166.01	1,434.77	1,256.29	6,799.03	20.40	1,921.57	634.12	1,143.05	579.11
8		2,310.41	2,166.01	1,291.29	1,256.29	6,799.03	20.40	2,065.05	681.47	1,239.18	560.54
9		2,310.41	2,166.01	1,147.81	1,256.29	6,799.03	20.40	2,208.52	728.81	1,335.31	539.31
10		2,310.41	2,166.01	1,004.34	1,256.29	6,799.03	20.40	2,352.00	776.16	1,431.44	516.19
11		2,310.41	2,166.01	860.86	1,256.29	6,799.03	20.40	2,495.48	823.51	1,527.57	491.84
12		2,310.41	2,166.01	717.38	1,256.29	6,799.03	20.40	2,638.95	870.85	1,623.70	466.77
13		2,310.41	2,166.01	573.91	1,256.29	6,799.03	20.40	2,782.43	918.20	1,719.83	441.44
14		2,310.41	2,166.01	430.43	1,256.29	6,799.03	20.40	2,925.91	965.55	1,815.96	416.17
15		2,310.41	2,166.01	286.95	1,256.29	6,799.03	20.40	3,069.38	1,012.90	1,912.09	391.25
16		2,310.41	2,166.01	143.48	1,256.29	6,799.03	20.40	3,212.86	1,060.24	2,008.22	366.89
17			2,166.01		1,256.29	6,799.03	20.40	3,356.34	1,107.59	4,414.76	720.14
18			2,166.01		1,256.29	6,799.03	20.40	3,356.34	1,107.59	4,414.76	642.98
19			2,166.01		1,256.29	6,799.03	20.40	3,356.34	1,107.59	4,414.76	574.09
20			2,166.01		1,256.29	6,799.03	20.40	3,356.34	1,107.59	4,414.76	512.58
21			2,166.01		1,256.29	6,799.03	20.40	3,356.34	1,107.59	4,414.76	457.66
Total	8,664.04	34,656.17	43,320.22	17,217.19	25,125.73	135,980.63	407.94	49,909.56	16,470.15	33,439.40	2,015.70
F-IRR										**14.41%**	