Chinese Wind Farms

- A profitable option to coal?

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”中国的风力发电站”

Abstract

Global heating is a topic that is debated in every part of the world. The weather has become more extreme. While scientists debate over the reason for those extremes it is no doubt that emission of greenhouse gases are constantly increasing globally.

China has in the past years substantially increased their investment in energy to cope with the demands of their booming economy. Much of the increased capacity comes from burning coal in large power plants that generates electricity. At the same time China's steel industry have seen a rapid increase in terms of annual output. Steel production is another major user of coal. However in this thesis I have focused on the electricity problem and left the steel business outside of the equation.

The idea behind the thesis is to find out what it will take to reduce China's demand for coal and electricity generated from unhealthy coal power stations. How can the coal demand be replaced with renewable energy like wind power? To be able to come to any conclusion it is essential to take a look at the structure of these sectors in China, all the way from governmental policies, laws and available resources down to the pure financial side of an investment.

As part of the investigation I also came to realize that China's own resources of coal are rapidly diminishing. With an increased pace of coal demand, it may only take 22-35 years more before its resources of coal for electricity are consumed.

My conclusions in this thesis are that there are several ways to justify a swap from coal to wind. An increase in price of "electric" coal from today's level of 450 RMB/ton up to the range 1000-1200 RMB/ton will make all subsidies of wind power redundant. There are also two ways to make investment and usage of wind farms more lucrative than coal power plants, those appear through the Clean Development Mechanism scheme. If today's long-term price of CER at the climate exchange in London increases from €8/ton up to €12/ton, majority of the wind farms in China will reach an IRR above 10%. The 10% level is the industry benchmark in China for coal power plants. A wind farm owner that is less risk-averse can also play the market, hoping that the spot price in April 2008 of ca. €18/ton is there to stay. If the Chinese government decides to take away the subsidies to Wind Power, the CER price would need to increase up to €30/ton to reach an IRR of 10%.

Looking at the current situation in China where 43% of coal plants made a loss during the first two months of 2008, wind power is already more profitable than coal. Somehow it is logic, producing energy out of something that is free to use and renewable, should in the long-term be essentially cheaper to use as well.

Key Words: China, Wind power, Coal power, Electricity, CER, CDM

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1 INTRODUCTION

150 years ago, the great leader of the Native American Suquamish Tribe, Chief Seattle, said:

“We do not inherit the earth from our ancestors; we borrow it from our children.”

These wise words from long time ago about living in a sustainable environment where conservation and concern were natural habits, they are just that, something from the past that few today practice or think of.

The world has experienced more an increase of 80% in carbon dioxide (CO_2) emissions since 1970 (IPCC, 2007). The consequences are an increased pace of global warming leading to ozone layer depletion, melting ice caps, increased ocean levels, loss of biodiversity, flooding in some areas and drought in others. In China, the Himalayan “water tower” is slowly melting. It is causing flooding in certain areas during part of the year. Eventually when most of the ice has melted away it will leave previously wet areas in an arid state. Chief Seattle’s words seem no longer valid.

Since development of economies all around the world is dependent on an increased supply of energy, it is unfortunate that one of the least clean sources of energy, coal, is also among the cheapest raw materials used to generate electricity. Burning coal, results in substantial emissions of CO_2 and sulphur dioxide (SO_2). Such emissions do great damage to the air that we breathe and are responsible for the climate change that the earth is currently experiencing. “Generation of electricity is responsible for about 40% of all CO_2 emissions globally”, (BP, Vivienne Cox, 2007). Transport stands for another 20%.

“The People’s Republic of China overtook the United States in 2006 as the world's biggest emitter of CO_2“(Herald Tribune, 2007). Unless mankind drastically reduces the carbon dioxide emissions in the next 15 years, the damage done may be irreversible. One of the main reasons for China to obtain the first position is due to the fact that China has as of today about ¾ of its electricity generated from carbon intensive fossil fuels (China Coal and Mining, Demand and Supply of China Coal, 2007). At the same time, although China has ratified the Kyoto protocol it does not have a cap on its emissions under the Protocol. In China there are no taxes to be paid to the state for emissions of CO_2. Reuters reported in October 2007 that China is considering an environmental tax on polluters but until now, there is no firm decision taken.

Fortunately there are cleaner alternatives to replace coal. Renewable energy technologies including wind-, solar-, wave and biomass are developing rapidly around the world. The Kyoto protocol stipulates how much CO_2 emissions a country can have. It does also include an environmental market place whereby industrialized countries can obtain further emission rights by investing in clean energy alternatives in developing countries. This market or mechanism is called

Clean Development Mechanism (CDM) and it is monitored and controlled by the United Nations. China is one of the largest receivers of CDM investments. CDM subsidies (through sales of Carbon Emission Rights) together with the renewable energy law promulgated on January 1st 2006, are helping China to boost its installed capacity of renewable energy.

In the recent National Party Congress that ended in March 2008, China raised its target for wind power capacity to 30 Giga Watt (GW) by year 2020. By the end of 2006, the installed capacity was 2.6 GW. In the same message, it was also announced that China will have an increase of carbon-generated electricity from 365 GW to 805 GW by 2020. The good news of an increased installed base of wind power is not a reason for joy if at the same time China will install that much more coal plants. What will it eventually take to make the wind industry a cheaper alternative to coal? How large is the difference in production cost today? Can an increased price of Carbon Emission Rights (CERs) in the future make wind the preferred choice of electricity investment? Can the market forces make China miss their 2020 targets (in a positive way from an environmental point of view)? Can China have more than 30 GW of wind power and less than 805 GW of carbon generated power by 2020?

I chose China and the environment as a topic for my thesis as I have lived in the country for most of the time since the end of 1995. Seeing the smog over Beijing thickening year after year makes me wonder if this is the way it is going to be forever or are there any signs of hope for a change to the better?

1.1 PURPOSE

The purpose of the essay is to examine and answer:

What price level of Carbon Emission Rights will make wind power an equally profitable investment to carbon-generated power?

What price of coal would lift the cost to produce carbon generated electricity (RMB/kWh) to the same level as the cost of wind power?

The idea with the questions is to find out at what price levels investors in the power industry becomes interested to consider greener alternatives like wind power instead of coal power.

1.2 METHOD

Selecting research method is the basis for how the thesis shall be conducted.

In general, there are two scientific research methods, positivism and hermeneutic (Thurén, 1991). Positivism is aiming for absolute knowledge about a subject whereas hermeneutic is more about how to use existing knowledge and apply that in search of new theories and conclusions. The two research methods are also different in the sense that positivism is quantitative approach and hermeneutic is a qualitative approach.

There are two ways to make conclusions about something, examples:

All Pandas eat bamboo shoots, Pandas are often seen climbing in forests of bamboo in China, therefore if I want to see Pandas I should travel to China and search for them in forests of bamboo. This is the deductive approach. It is a step by step logic reasoning method. It makes something true or trustworthy if the reasoning is logically connected.

Senator Barack Obama is popular among voters of African origin. In USA there are more people of African origin than any other. Consequently Senator Obama will win the Democrat election and become their candidate for President. It is an inductive approach. Conclusions are made based on empirical facts.

The scientific method chosen for the thesis is based upon positivism and inductive reasoning. In terms of data gathering, the data are almost entirely second hand data. One interview was made with an employee of China National Grid and it falls under the category of primary data. There has also been a regular discussion with Dr Alex Westlake who is co-founder of Clearworld Ltd, a company active in the Chinese renewable energy sector.

Second hand data is gathered from environmental laws and regulations in China together with analysis of registered CDM projects at the UNFCCC website. These CDM projects are related to wind power investments in China during 2006-2008. In the CDM Project Design Documentation, most of the investment cases are using a baseline to compare with. The baseline is based on data from a coal plant investment. Thereby it is also possible to find information about costs for building new coal plants embedded inside the wind farm documentation. Additionally financial reports from Chinese companies active in the coal and power sectors have been analysed.

1.3 LIMITATIONS OF THE STUDY

Neither the technical feasibility of greater grid penetration by wind power nor cost for transmission of electricity will be considered. It is assumed that these costs will exist anyway, no matter which technology is used. The assumption is somewhat flawed as different technologies have different characteristics. For instance coal can be transported to any place for power generation as long as the infrastructure allows it(roads, railroads, seaports). Coal is mainly found in three regions of China, in the North(Inner Mongolia, Shanxi, Shaanxi), in the West(Xinjiang) and in the South(Guizhou).

To transport electricity over large distances have been a challenge in the past due to loss of power when transporting AC for large distances. ASEA Brown Bovery (ABB), who considers themselves undisputed leader in the HVDC business, has developed a solution using High Voltage Direct Current: “Using HVDC to interconnect two points in a power grid, in many cases is the best economic alternative, and furthermore it has excellent environmental benefits” (ABB, 2008). As a conclusion, the cost for transporting coal to where it is needed for power generation should be balanced with cost for building High Voltage Direct Current transport grids. It is an area for further research. In my thesis it is assumed that these costs are even.

Size and capacity of domestic wind power manufacturing industry in China is growing at a rapid pace. However there are still barriers in terms of know-how and technology to overcome for Chinese manufacturers before they catch up with foreign players in China. To estimate the growth of the industry in China and thereby being able to calculate if the industry can cope with the expected growth is outside the scope of the thesis.

1.4 DISPOSITION

After the introductory chapter the thesis will continue with economic theories that are related to environmental economics, public goods, market economy and investments. Chapter 2 ends with a summary of previous research in these fields.

Chapter 3 contains information about the laws and regulations related to the environment in China as well as the concession process, taxes and subsidies for new wind power projects in China.

Chapter 4 gives an overview of China's wind resource and wind power industry. After that follows chapter 5 about cost development for the wind industry in China and benchmark data for coal plants. It also takes a look at the coal industry in China.

Chapter 6 covers a discussion and a conclusion of the findings.

References and an appendix are found in chapters 7 and 8.

2 ECONOMIC THEORY

The chapter deals with several economic theories. Wind and carbon-generated power involves matters like environment, public goods and governmental interventions through taxes, subsidies and quotas. There is also the investment side of building new plants like Internal Rate of Return and Net Present Value. These theories are all included here as a base for the Chinese applications and economics that the thesis covers in chapters 3 to 6.

2.1 ENVIRONMENTAL PRINCIPLES AND INSTRUMENTS

In environmental economics there are certain principles and instruments to be used if a government wants to secure healthy and sustainable growth.

One of the leading minds in the field of environmental economics, Mr. Tom Tietenberg (2003) suggests five principles to pursue.

Those five principles are summarized here below:

- *Full-cost*, goods making less damage to the environment should also be cheaper.

- Environmental policies should be *cost-effective* so that there are enough incentives to implement them.

- Land should be owned and taken care of by someone, thereby ensuring that the owner take good care of his property. Owner should be given *property rights* to pollute. If they pollute less than their limit, they should be able to sell those remaining pollution rights to others and benefit from that.

- Usage of the environment must be *sustainable*. Used resources should be replaced or cleaned up so that they can be reused again and again. This is the sustainable principle.

- The population in a country needs to be well educated and knowledgeable about the environment. They need to know the results of their own or other's actions. This is the *information* principle.

The sustainability principle can be compared with the indigenous tribes in New Guinea who still today only take from the forest what they need and at the same time ensure that new plants and trees are planted in return for what has been taken (Diamond, 2005, page 281). Thereby they ensure a sustainable environment for the future. Civilizations like the one on Easter Island who cut down all the trees on the island without ensuring that new were planted, today lives on a tree-free island. To value a natural resource can be difficult, especially to put a value on the resource for future extraction.

Another issue concerning the sustainability principle is that the depletion of natural resources is not included in the national income calculations. According to the Hicksian definition (Adger, 1992), all other incomes should be accounted for, otherwise there is a risk of overusing the assets. With the depletion of natural resources that occurs today, many countries would have a declining net national product (NNP).

It is common that a poor country do not have the possibilities to combine environmental protection with economic growth (Panayotou, 1994). It hurts development and slows down economic growth if money needs to be spent on such matters. In rich developed countries, it is a cost that can be afforded but in poorer countries, environment is given a lower priority.

Not considering the full-cost of a product is something that helps a country in the short-term but becomes costly in the long-term. For this reason it is important to use economic instruments like charging for usage of scarce resources by internalizing the external costs so that consumers and producers also pay for that cost as part of the price of such goods. If it does not happen, resources may become undervalued and excessively consumed.

2.2 PUBLIC GOODS AND EXTERNALITIES

Government often intervenes in the market place as they do not think that such can handle public goods and externalities (Cowen, 1999).

Examples of public goods are health care, education, public sewer, police, national defence, etc. and a clean environment.

Characteristics for Public Goods are that they are "non-excludable" and "non-rival" in consumption (Krugman, 2005, page 477). Goods that are "non-excludable" are those that you can use no matter if you pay for them or not. Air, rain-water, wind are typical examples of that. "Non-rival" goods are those that can be consumed by someone while others also can still consume it. If you go to the cinema and watch a movie, others may still follow your example and watch the same movie. Many of the benefits of renewable energy are public benefits. If a company or an individual choose renewable energy before other types, it helps to reduce pollution for everyone. It provides an environmental benefit to the public at large. A customer who is willing to pay more for electricity from renewable energy still has to breathe the same air as the neighbour who might choose not to pay more. Public goods can lead to the existence of "free riders". Some will benefit from the contributions of others.

"Externalities occur when one person's actions affect another person's well-being and the relevant costs and benefits are not reflected in market prices" (Cowen, 1999). A positive externality arises when you on a snowy winter's day remove the snow on the pavement outside your house. Although you are by law obliged to do so, you may not do it as often as if you were paid for it. All users of that stretch of pavement will benefit from that act. A negative externality arises when one person's actions harm another. A factory owner that pollute may totally disregard the impact his action has on others. Externalities from Coal Power plants are among others, increased cases of asthma, bronchitis and heart-attacks (Roberts, 2008). In USA, generating electricity from coal stands for 2/3 of the total SO_2 and ¼ of the total NO_x emissions in the country (Roberts, 2008).

Wind power has both positive and negative externalities. The positive is that it creates energy without CO_2 emissions. Although I may not be the one that uses the electricity that it produces it helps me to be able to continue breath fresh air. The negative externality is often mentioned by those who are against wind power and construction of tall wind mills. Wind mills are said to spoil the view and create noise. Some antagonists even mention that the rotating blades kill birds. Wind power stations in the neighbourhood is said to reduce value of property for those who do not own the wind mill.

Considering the externalities for both a coal power station and a wind power station, I take it that anyone who can choose to live beside one of them quickly selects the wind option. However the third option of not living near to any one of them is certainly the most favourable one.

2.3 INVESTMENT THEORY

2.3.1 Internal Rate of Return and Net Present Value

Before undertaking an investment, the investor needs to be aware about the relative prospects of the money invested. Will this give a good return or not? Is it the best way the money can be spent or are there other alternatives? To find out, the investor needs to calculate the investment's Internal Rate of Return (IRR) and its Net Present Value (NPV). IRR can be compared to the interest rate one obtains when lending money to the bank. To understand NPV one can ask how much money do I need to put in to the bank on January 1st if I want the net to be 100 by December 31st and the interest rate that the bank pays is 5%? The answer is calculated as x * 1.05 = 100, x = 95.24.

If the investment runs over several years, there might be annual dividends (returns) on the investment that create a positive cash-flow back to the investor. Furthermore it might also be a residual value of the investment once the investment period is over. All those future cash-flows need to be "converted" into today's value of money, i.e. the NPV.

To calculate the return of an investment, it is needed to consider:
C_0= the initial investment cost
C_t= regular (often annual) dividends (or coupons), over t time-periods
r = Internal Rate of Return
n = length of the investment (periods)
N = NPV of the residual value at the end of the investment

Graphically it can be explained as with the following cash-flows:

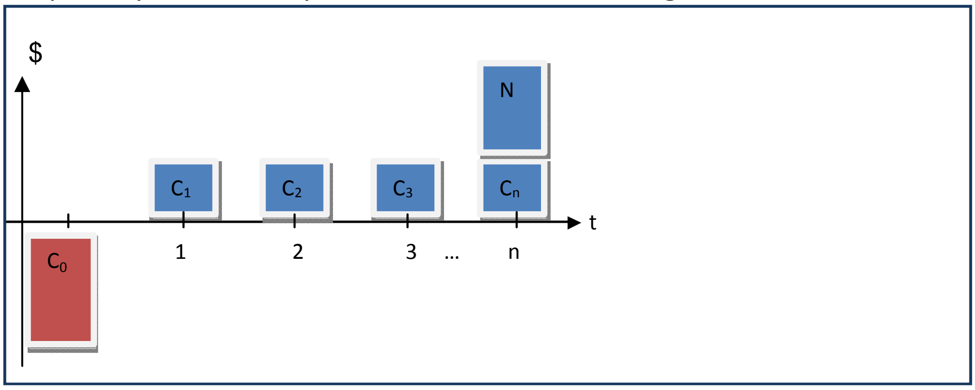

Figure 1: Cash flows for an investment over *n* years

To find the internal rate of return, find the value(s) of *r* that satisfies the following equation (Hässel, 2001, page 382):

$$NPV = C_0 + \sum_{t=1}^{n} \frac{Ct}{(1+r)^t} = 0$$

It is not feasible to only focus on *r;* it should only be used to decide if a project is worth to invest in or not, depending on the wanted amount of return. If the risk is reasonable and the NPV is positive, the project could be accepted but only after also considering what the opportunity cost of the investment is. How else could the money be spent? If there are two options to choose from, pick the one with higher NPV whatever their IRR is.

As shall be seen later on in the thesis, a power company can compare IRR and NPV for investments in wind power with carbon generated power. Naturally it can also compare two wind power or two carbon generated power projects with each other.

In the case of China who has a central planned economy, a state-owned power company might not have a choice. Some investments must be undertaken even if the alternative is not the most profitable one, in order to meet governmental targets.

2.3.2 Fixed and Variable costs

As part of the IRR and NPV calculations, the investor must look at costs and revenues throughout the lifetime of the project.

Costs are further separated into fixed and variable costs. Taking a wind farm (a cluster of wind power towers) in China as an example; fixed costs are related to construction. Construction costs can be further broken-down into planning, design, purchase of land, equipment, amortization, depreciation etc.

Costs to connect the wind farm to the national grid are paid by power grid companies according to China's renewable energy law.

Variable costs are operation, maintenance and taxes (income, value added, city and education tax).

Variable revenue comes naturally from sales of electricity where a price is paid per kWh produced. Because of the Kyoto protocol and the CDM, a wind farm in China can also receive additional income from selling Carbon Emission Rights, see chapter 2.4.1, "Trading of emission rights". The amount of CERs is based upon how many tons of carbon dioxide that will not be emitted in to the air because of the new wind farm. There are rules for how the figure shall be calculated, monitored and verified by UN appointed third parties.

The size of the output, i.e. the amount of electricity produced, decides the Average Fixed and Variable Costs (AFC and AVC), the sum of AFC and AVC gives the total Average Cost (AC).

Another important parameter to consider is the Marginal Cost (MC). If a plant is already running at full capacity, how expensive will it be to produce one more kWh? That additional kWh can render a substantial Marginal Cost (Krugman & Wells, 2005, page 220).

Fixed and Variable costs are grouped as follows:

Fixed Costs	Variable Costs
Construction	Fuel / raw material
	CO_2 emission fees
	Operation & Maintenance
	Taxes (Income, VAT, City, Education)

Table 1: Fixed and variable costs for a power plant, a wind farm have no fuel or CO_2 emission costs.

Any public company would on top of these costs add a revenue goal, a certain percentage overhead on top of all the costs that equals the return of the investment to the company's shareholders. Furthermore another cost for company overhead (head-quarters, offices, board, marketing and so forth) is also to be added on top of the costs. By summing up the fixed, variable and overhead costs, a company can calculate the price they are willing to sell for in order to meet the desired financial return.

2.4 POLLUTION CONTROL

2.4.1 Trading of emission rights

The Kyoto Protocol states that industrialised countries are required to reduce their emissions of greenhouse gases (Carbonpositive, 2007). Each country is assigned a certain amount of CO_2 emissions to reduce. United Kingdom are for instance obliged to reduce 584 000, Spain 261 000 and Sweden 61 000 kilotons (or Gigagram) of CO_2 emissions annually. Each country accordingly distributes the national target among all its domestic producers so each polluter knows how much emissions he should reduce.

A polluter can, if he wants to, buy emission rights to pollute more. The emission rights are traded at the climate exchange most often through companies who specialize in such trading.

Developing countries can sell emission rights for projects that are approved by United Nations. As an example, a new wind farm in China with a capacity of 100 MW and annual output of 219200 MWh estimate that by setting up the plant, they save 200 kilotons of CO_2 emissions annually. As they count that the alternative to the wind farm would be a coal plant, there is a saving of CO_2 emissions by setting up the wind farm instead. Then the plant can sell 200 000 emission rights annually at the same Climate Exchange.

This is how trading of emissions work on a high level. Through the flexible scheme national targets can be met at the same time as investment in renewable energy in (poorer) developing countries receives a boost.

2.4.2 Taxes and Subsidies

It is common that governments around the world intervene in a market as discussed in chapters 2.1 and 2.2. Most commonly they do so to protect and aid domestic companies from foreign competition. The protective measures can take several forms.

One way is to subsidize a company or sector by giving money for each product produced. "A Pigouvian subsidy is a payment designed to encourage activities that yield external benefits" (Krugman, 2005, page 470).

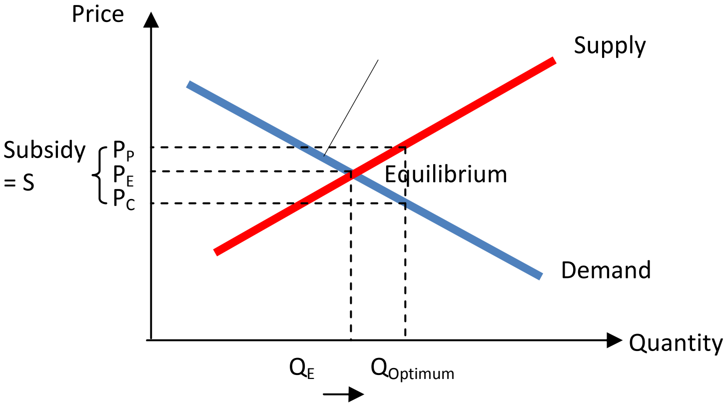

Figure 2: Optimal Pigouvian subsidy (Krugman, 2005, page 470)

Note how the price paid to producers after subsidy is higher than the equilibrium price while at the same the price paid by consumers is becoming lower. Another option is to set taxes lower for domestic companies in a sector or alternatively to raise taxes for imported goods. It is also possible to discourage purchase of certain goods by adding a value added tax on top of the price of the goods which is to be paid by all consumers of the goods. Tax policy always have two ambitions (Krugman, 2005, page 494), the tax should be efficient so that direct and indirect costs of collecting taxes are minimized. The tax should also be as fair as possible. The ones who obtain the benefits should also pay the tax. Problems often arise for governments because of difficulties to achieve both ambitions at the same time.

Excise taxes are also applied to electricity. Customers may need to pay VAT on top of the cost of electricity. The price obtained by producers is lower than what the customers pay. It results in a dead-weight loss in the market.

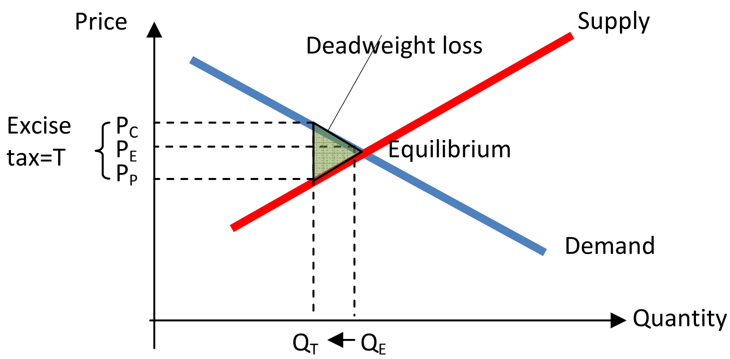

Figure 3: Dead-weight loss from excise tax (Krugman, 2005, page 494)

Another option is to work with quotas, only allowing a certain amount of a product to be imported or produced. The Clean Development Mechanism is partly built on a quota system. A country is assigned a quota of how much it can pollute.

In many countries around the world, incentives via taxes, subsidies and quotas are used to make renewable energy more economically viable. In chapter 3.3 I will evaluate what China is doing in the matter.

2.5 PREVIOUS RESEARCH

A list of previous research can be found in Chapter 8.1. Here follows a short summary of the most important findings:

China has up to now expanded its economy without much environmental considerations - develop first and clean up later (Wahrby, 2007). Josefin Öjner (2006) is positive that the implementation of the CDM in China will help to boost investments in renewable energy and China will have the necessary setup to deal with it. Cap-Gemini (2006) suggests that “Chinese” forecasts of how much power capacity that will be required in 2020 are underestimated. Cap-Gemini further suggests that another 30% more of power capacity needs to be built to keep up with economic development.

Andrew Michener (2007) and Rio Tinto (2007) both argue that coal will become a scarce resource globally and it will have an impact on China’s coal powered economy in the future.

3 ENVIRONMENTAL LAWS AND REGULATIONS IN CHINA

China has a complex web of policy makers and major players who contribute and give opinions about environmental laws and regulations in China, those are:

- National Development and Reform Committee (NDRC)
- Ministry of Science and Technology (MOST)
- Ministry of Finance (MOF)
- Ministry of Construction (MCon)
- State Environment Protection Agency (SEPA)
- Major oil companies: CNNC, Sinopec, CNOOC and Sino-Chem.
- Major power generation companies: Huaneng, Datang, Huadian, Guodian, China Power investment group and Guohua Electric.
- Major power grid companies: State grid and Southern grid
- Major coal producers: China Coal, Yankuang and Datong.

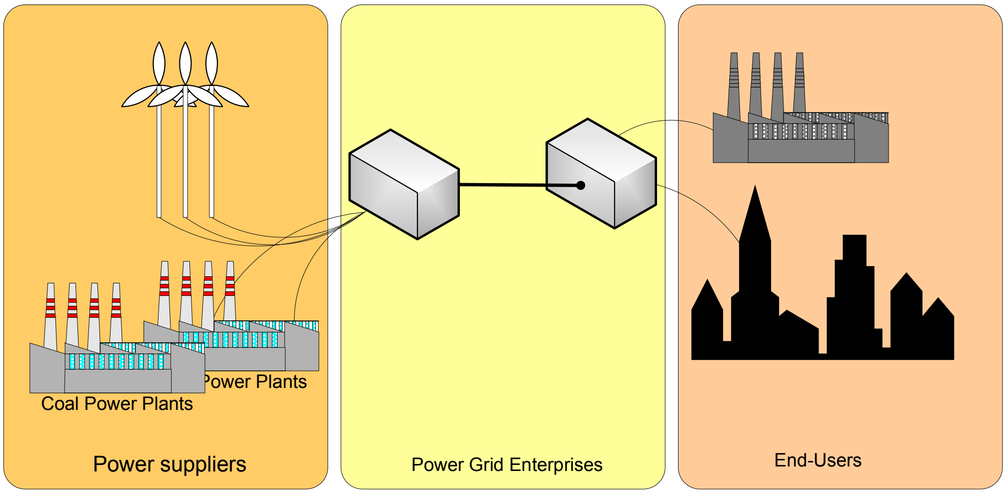

Figure 4: Overview of the major power players in China

Mining companies that provide coal to the power plants and manufacturers of wind turbines are for simplicity not part of figure 4. Power suppliers sell their generated electricity to the grid enterprises who in their turn sell the electricity further to the end-users. Thus there are two prices to distinguish; the price power producing companies receive when selling electricity to the grid and the price that the end-users pay to the power grid companies.

The rest of the chapter deals more in detail with China's environmental framework.

3.1 THE 11TH 5-YEAR PLAN

The 11th 5-year plan from the Chinese government was issued in September 2007. It is a compilation of 14 chapters that contains the mission and vision for what China should focus on in the coming 5 years. Here I highlight areas that are of concern to production and consumption of electricity.

The third chapter of the plan deals with the issue of “Optimizing and Upgrading Industrial Structure”. It is here specifically mentioned that coal should be the basic resource. Efforts shall be made though to diversify the energy production. Renewable energy shall be promoted.

In chapter six, “building a resource-conserving and environment-friendly society”, the message is that the Chinese society should be built on goods that are friendly to the environment. Resources shall be made more efficiently with less need of energy. There is a target set for the year 2020 that says that the consumption per capita shall be reduced with 20%

From the start of the 11th-five-year-plan, the NDRC declared that; “all PC (Pulverized Coal) plants, except those for CHP (Combined Heat and Power) applications, must be 600 MW and above, with supercritical/ ultra supercritical steam parameters.” The purpose of this declaration is two-folded. Using less but large plants that run with higher efficiency saves coal resources and thereby also emits less CO_2.

3.2 THE RENEWABLE ENERGY LAW

On January 1st 2006, the new renewable energy law in China became effective. Purpose of the law is to increase the footprint of renewable energy in China. It involves support to development, production and implementation of such energy technologies. Additionally, the law also has the purpose to protect the environment and to achieve sustainable development.

Non-fossil energy of wind, solar, water, biomass, geothermal and ocean etc. are all covered by the law.

The law states (but does not specify the values) that there are mid- and long-term targets for how much renewable energy capacity the country should have. From those target levels, energy departments throughout China shall make plans on regional levels for how to reach those targets. Once those plans are ready and approved, they should be published and available to the public. Renewable energy law, article 11: “Standardization authorities of the State Council shall set and publicize technical standard for renewable energy.”

The government is funding research and development. They ensure that standardization work and construction of independent renewable energy projects for domestic use in rural areas are going ahead. The government also support localized production of the equipment needed for renewable energy.

Article 14 state that grid enterprises shall agree with renewable energy companies so that connection of such energy sources to the grid are made. The law thereby enforce those connections to happen. However, on March 27th 2008, the website China environmental law published details that the law did not work as effectively as expected. The words used in the law had not been clear enough which lead to that on many occasions,grid companies had managed to avoid the realization of such work. Therefore some additional descriptions were added including key performance indicators for local politicians that measure how well they do their job.

In the construction of renewable power generation projects, if there is more than one applicant for project license, the licensee shall be determined through a tender.

It is not yet stated in the law but after more than a year since the law became effective, it was concluded that it is not the contender that offers the lowest price that shall be awarded the contract but the one who is closest to the medium price of all the tender participants (Junfeng, 2007). It was realized that in some projects, contenders offered low prices to win the contract but could later on not become profitable. The current practice during concessions is still that the medium price wins the contest.

Article 19 explains that “the bid-winning price should be implemented”. Although a benchmark to other similar projects in the area needs to be made. It is deemed unfair if one project in a region obtain a price that is different to another project of the same character in that same area. The price difference between renewable energy and conventional energy that grid companies have to pay shall be shared among all customers to the grid through a surcharge that covers those additional costs.

The national targets in the NDRC’s plan include:

Energy Source	2005	2010	2020
Hydro	115 GW	190 GW	300 GW
Wind	1.3 GW	5 GW *	30 GW
Solar Photo Voltaic	.07 GW	.30 GW	1.8 GW
Solar hot water	80 million m^2	150 million m^2	300 million m^2
Biomass power (from agricultural & forestry waste)	2 GW	5.5 GW	30 GW
Coal	365 GW	593 GW	805 GW

Table 2: China NDRC targets for 2010 and 2020 (Source: China Environmental Law, 2008)

*) It was stated in a separate report by NDRC that the target for 2010 and wind power was raised from 5 to 10 GW. The raise was probably because the capacity by end of 2007 had already reached 5.6 GW, although 1.4 GW were still not connected to the grid. Another 4 GW is expected to be built during 2008 according to Reuter’s (2008-01-16).

China targets to raise the share of renewable energy to 10% by 2010 and 15% by 2020. Those targets do not only include electricity but also fuel costs for transport. The total picture including actual data of 2005 and target values for electricity capacity in 2010 and 2020.

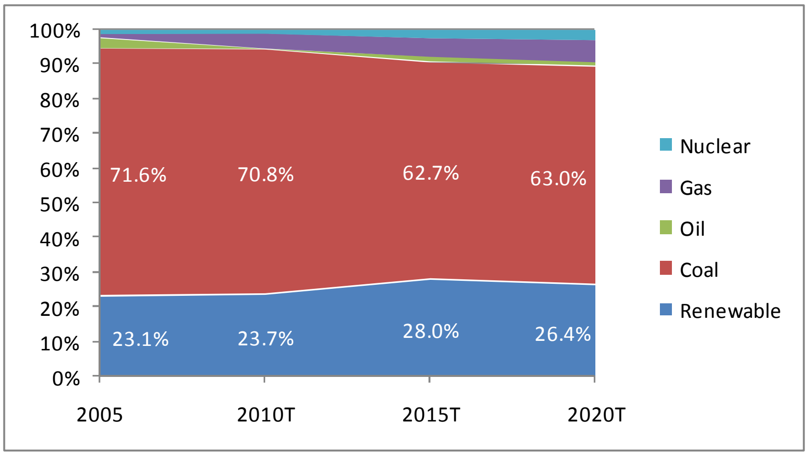

Figure 5: China's capacity in percentage for different energy sources, actual 2005 and targets for 2010, 2015 and 2020 (Source: NDRC).

The sum of solar (0.1%), biomass (2.3%), wind (0.6%) and hydro (23%) altogether amounts to about 26% by 2020. Note that wind has a capacity factor of 25% and solar 20%. It means that those technologies are only productive 25% and 20% of the time. Nuclear, Coal, Biomass, Oil and Gas are estimated with a capacity factor of 100%.

3.3 TAXES, SUBSIDIES AND INVESTMENT IN RENEWABLE ENERGY IN CHINA

When new wind power plants are built, the concession period is between 20-25 years. A rule of thumb is that a project should break-even after 10-12 years. They should also give an IRR of 8% which is set as the industrial benchmark IRR for wind power. The IRR benchmark for coal plants is 10%.

The Chinese government also grants tax benefits to projects listed in the renewable energy industrial development catalogue and financial institutions may offer preferential loan with “financial interest” subsidy. Tax benefits can be that for a certain number of years, owners of wind farms do not need to pay income tax at all or they pay 15% income tax instead of 33%.

A form of subsidy that is in use is that wind farms that obtain a higher price for their goods (electricity) for the first 30000 hours (13.6 “wind power” years) of full load. If the market price of electricity is x RMB/kWh, the wind farms receive $x+s$ RMB/kWh for the first 30000 hours. The delta cost s is something that the grid company distributes to all customers. After those 30000 hours have passed, the average grid price should be used. Thus coal plants obtain slightly less than the market price whereas wind farms obtain more than the market price. The subsidy is currently crucial for wind farms to get into business (together with CER revenues), without it there is not a business case to build such plants in the first place.

See more about tax benefits and subsidies in chapter 2.4.2. Both these two measures contribute to a lower price of electricity from that plant. Subsidized loans reduce the cost of construction whereby lower taxes helps to bring down the variable cost, see chapter 2.3.2.

The NDRC have according to China Daily (2007-09-05) estimated that:

> ”2 trillion Yuan ($US 265 billion) of investment will be needed to meet the renewable energy target by 2020.”

It is the large state-owned energy companies that are to make those investments. As presented in chapter 2.1, to ensure cost-effectiveness, there will be clear incentives to invest in renewable energy. As an example, “green electricity” will be paid by a higher price than carbon generated electricity.

During a conference in February 2008, Gao Guosheng, the director general of climate change at Beijing's National Development and Reform Commission said that when it comes to funding of renewable energy projects;

> “To 90 percent we rely on the Chinese government and enterprises”.

Reuter’s news agency further reported Gao saying that:

> “China looked forward to international cooperation, but he commented that, for example, foreign capital deployed through the U.N.-led clean development mechanism (CDM) was making only a small difference to the attractiveness of wind power in China.”

My own understanding after analyzing 39 CDM projects covering the period from 2006 to 2008 and a total capacity of 2.24 GW is that none of those projects would have gone ahead without the income from CDM. Those 39 projects cover about 25-30% of all the wind farm projects during that time period (January 2006 to April 2008). Thus as I see it, CDM is of vital importance to expand China’s wind industry.

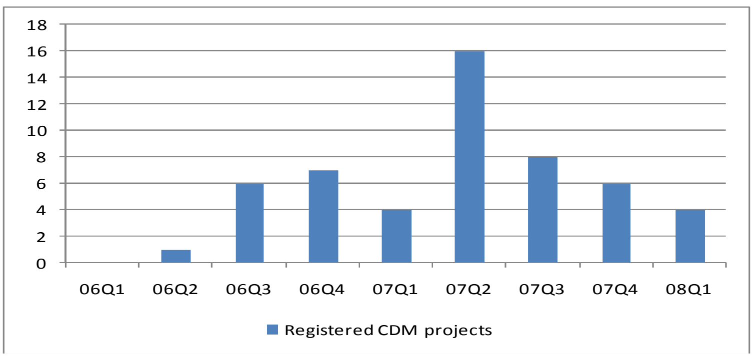

Figure 6: Number of registered CDM wind power projects in China per quarter (source: United Nations CDM web)

Since the renewable energy law was implemented in China (on January 1st 2006), there have been 53 projects registered (April 22nd 2008). Number of projects in 2007 saw an increase by 243% comparing with 2006. Besides the renewable energy law, government pressure on the five major power companies is another reason for recent increase in projects. As shall be seen in the next sub-chapter, the prospect of increased profits from these investments also plays part of the increase.

3.4 TRADING OF CARBON EMISSION RIGHTS

In the Chinese wind farm CDM projects that I have surveyed, a CER price range of €5-8/ton have been used to calculate IRR and NPV. What does it mean? Is the price reasonable or fantasy? How are the CERs sold once the project has started?

CERs are traded on the European Climate Exchange in London. There are often middle-men involved. Such middle-men are companies that specialize in purchasing CERs from developing countries and act as agents to find buyers.

During the project design phase, the developer follows a predefined way of calculating how much emissions of carbon that is saved by the implementation of this particular wind farm on an annual basis. That is translated into an equivalent volume of CERs that can be sold. Chinese power companies most commonly enter into contract the CERs on a long-term basis (7 years), with buyers (middle-men) selling them into the EU and other markets. Currently some sellers are not selling long-term contracts. They instead want to sell at the spot price or via a fixed plus float contract (Westlake). The reason is that current (2008-04) spot price for CERs is much higher than for long-term contracts. December 08 contracts of the European equivalent to CERs (EU-ETS) are selling for €24/ton. CERs are normally trading at about 75% of that price (ca. €18/ton). Upfront long-term CER contracts currently (April 2008) trade at €8/ton. Thus anyone who is less risk-averse can take a gamble and bet on that he will make more money by frequent trading of CERs than to make a deal with a fixed price for 7 years.

In effect, the NDRC has set a minimum floor price for wholesale CERs (which are currently €8 per CER) and projects with lower CER prices will have difficulty to obtain approval. (US$10.06 = €6.3, 2008-04-18).

In Europe the EU Credit price is driven by:
1) Dark spread - difference between coal and gas/oil prices (if coal is cheap it is easier to burn coal and buy off-sets)
2) Spark spread – difference between electricity sales and production price – it is sometimes easier not to produce than to produce

3.5 PRICE OF COAL AND ELECTRICITY IN CHINA

In China, it is the State Council who set the price of electricity. They thereby dictate how much the public and private sector should pay for the electricity that they buy from power grid companies and for how much power producers will receive from power grid. The price of coal is set by the coal producers.

In 2004, the government introduced a mechanism that tied power tariffs to the price of coal. If the coal price rises by more than 5% over a six-month period, power tariffs will also be raised. When coal price goes up, it is for the power companies and the public to share those costs in a 70-30 split. Despite an increase of the coal price of about 10-15% during the first quarter of 2008, the state council has not been willing to raise the price of electricity since they do not want to increase the Consumer Price Index even further.

3.6 THE ENVIRONMENTAL PRINCIPLES AND ECONOMIC INSTRUMENTS IN CHINA

The full-cost principle; ”Goods making less damage to the environment should also be cheaper” Comparing an average Chinese coal power station with a European equivalent, it is not evident to say that the full-cost principle is in place. In Europe, it is standard for power stations to have desulphurization and high standards of waste treatment installed which makes usage of coal much more clean and costly than in comparison to China. Chinese authorities are though aware about the problem. Many mines and power stations have been shut down in the past year because of environmental concerns. Redesign of existing power stations is ongoing to make them reduce their amount of emissions. Mining in itself is also a growing environmental problem, Andrew Minchener (2007) mentions that large areas of land around mines are becoming polluted with waste from coal mines, affecting water and agricultural resources. Additionally large emissions of methane have been release in to the air. Those are costs that have not been reflected by the Chinese coal price.

Goods that are produced in a process that damages the environment should also bear the full-cost for that damage. It is not happening in China. It is the society as a whole who has to bear the costs of the pollution. According to The Economist (2008-03-13), “Pan Yue, a deputy minister at the State Environmental Protection Administration (SEPA), China's paramount environmental regulator, estimates the annual cost of environmental damage at 8-13% of GDP”. A common topic that is reported in media is related to pollution of water. When water is polluted, it is plain to see for the average citizen that there are dead fish in the water. There is nothing to argue about that water is not healthy. If the air is polluted by toxic gas, it is not always obvious to see what is going on.

“Environmental policies should be cost-effective so that there are enough incentives to implement them.” China is already following this principle. They allow for wind farms to receive 60-80% higher payment per kWh than what coal power stations receive. It has contributed to the recent boom in wind farm development.

The property-right principle: There is today no domestic system in the Chinese socialist market economy that deals with trading of pollution rights.

The sustainability principle: After several years of flooding of the Yangtze River, authorities became aware of that the root cause was partly related to the extensive logging done further up the river. China took the usual pragmatic approach and shut down all logging in China. All timber needed had to be imported for a while until more sustainable forest industry were in place. Every year more trees are planted north of Beijing to stop the growth of the desert, however as that area receives less rain for every year, creating a sustainable forest is not working as well as expected. China's hunger for coal is not sustainable, as shall be seen in the next Chapter, China is rapidly consuming their resources of coal. To replace the existing coal is a process that takes millions of years.

The information principle, a well informed and educated population helps to keep the environment green. The information age has certainly helped Chinese citizens to become much more aware of what is happening in their country when industries pollute rivers, lakes and the sky. Still the official media are trying to control what is told and not told. When for instance the World Bank issued a report saying that air and water pollution in China was guilty for 750000 deaths annually, World Bank were asked to remove that part of their report. However there is also in the media and among officials an increasing awareness about the environmental problems in China. China Daily reported on 2008-04-23 that 3822 government officials had been prosecuted between 2004 and 2007. The reasons were dereliction of duty that had caused damage to the natural environment and wasted resources.

4 CHINA'S WIND POWER INDUSTRY

The chapter is a short introduction to China's wind power industry.

National Development and Reform Commission (NDRC) has released a report that contains the medium- and long-term development plan for renewable energy in China (Li Junfeng, 2007). By 2010, China should be ready to produce domestically the renewable energy equipment that it uses. 10 years later (2020), the domestic production should be based mainly on Chinese Intellectual Property Rights (IPR).

Since I took part in the GSM expansion in China during the 90'ies, I can see the similarities to the Chinese development of its Telecommunication sector. In the 1990s all GSM networks built in China were built on foreign technology and standards. Step by step China began to work on the standards that included new services only provided in China. At the same time a few Chinese companies (Huawei, ZTE and Datang) began their first steps to build their own GSM systems. When European vendors began to promote WCDMA, Chinese politicians wanted instead a Chinese mobile system of the third generation (3G) of wireless technology to be implemented. A technology based upon Chinese standards and Intellectual Property Rights (IPRs). On April 1st 2008, China launched their first 3G networks in some key cities using the Chinese standard (TD-SCDMA).

Considering the development of telecommunications in the past 12-13 years and now a clear vision of where the renewable energy sector is heading, foreign vendors of such equipment should be alerted. For them to ensure a bright future in China, they should be quick to follow Chinese standardization development in the sector. They should ensure that their products are manufactured in China.

4.1 DOMESTIC PRODUCTION

In China all the major global producers are present, REpower (Germany), Gamesa Wind Power (Spain), GE Energy (USA), Vestas Wind Systems (Denmark) and Suzlon (India).

In recent years China has seen a booming local wind industry. Xinjiang Goldwind is together with more than 10 other Chinese vendors increasing their market share in China. Xinjiang Goldwind has currently the largest domestic market share. Dalian Heavy Industry Co. Ltd is the domestic producer of wind power that can produce nodes with the largest capacity (1.5 MW).

Many of the smaller Chinese suppliers have entered in to Joint Ventures with foreign partners or they produce using a license from a foreign supplier who might not have set up their own production in China.

4.2 WIND RESOURCES

China is relatively rich of wind resources. China has a large land mass and a long coastline. China Meteorology Research Institute (Junfeng, 2007) has estimated that China has on land about 253 GW and at the ocean another 750 GW of potential wind power capacity. All in all just above 1000 GW. One should remember though that building wind farms at sea might cost up to 25% more than at land.

To summarize the chapter; considering wind resources, the political backup, the strategy to build a wind industry in China based on Chinese IPRs and (a growing) domestic production, the ones who come out on top of the battle in China, can be sure of a large market-share globally. These factors altogether may lead to compounding effects that paves the way for a much larger installed base of wind farms in the future than is currently planned.

5 COST CURVES

The purpose of the chapter is to show what decides the price of wind powered and carbon generated electricity. Without this knowledge and insight, it is not possible to give answers to the two main questions of the thesis.

5.1 WIND

Statistics in the chapter are based upon investigations of Project Design Documents submitted to the CDM board at United Nations in the past two years. The projects are all related to China and renewable energy projects for wind power. I have checked key data from 39 projects that are summarized here. Further details are included in the Appendix, Chapter 8.4.

In average, a wind farm project in China has the following characteristics:

- Cost per capacity of kW: 9340 RMB/kW
- 1 MWh saves about 1 ton of emitted carbon dioxide.
- 1 MW of installed capacity annually saves about 2200 tons of emitted carbon dioxide.
- Average grid price received is 0.55 RMB/kWh
- CER revenue is expected to be in the range of € 5-8 (/ton of CO_2)

Average numbers on a year by year basis:

Item	2006	2007	2008
Cost/capacity (RMB/kW)	9010	9690	9350
Tariff (RMB/kWh) excl VAT	0.557	0.53	0.55
CER price assumption (€/ton)	6.39	7.34	8.77
IRR without CDM (%)	7.2	6.7	6.3
IRR with CDM (%)	9.4	8.9	8.8

Table 3: CDM Project Design statistics for Chinese wind farms 2006-2008.

Cost/capacity is too volatile to be able to say where the industry is going. With an increase of Chinese domestic suppliers, prices are not likely to see a substantial change in the coming years. The expected average tariff from the concessions is stable around 0.55 RMB/kWh.

NDRC announced on 22nd of February 2008 that "wind farms all across the country will receive 0.51-0.61 RMB/kWh depending on the quality of the wind resources". The average price that I calculated to 0.55 RMB/kWh is within that range. Price of grid electricity by the end of 2007 in China is about 0.3 RMB/kWh. See details in Appendix, Chapter 8.3. It means that there is a subsidy of 0.21-0.31 RMB/kWh to wind farms that is shared among all customers connected to the power grid. Considering year 2010 with a total capacity of 10 GW, generating about 20 TWh annually and a subsidy of 0.21-0.31 RMB/kWh, it will cost 4.2-6.3 Billion RMB in subsidies for that year. It is a cost that is paid by all users of the grid.

The expected price to be received from CER contracts is increasing at a steady pace year by year, while at the same time, the expected IRR, with and without the CDM is dropping. It is due to that variable costs are increasing (see chapter 2.3.2). Inflation in China is at a level of 8.3% during the past year (Time, 2008) and it affects operation and maintenance costs.

As part of the Project Design Documentation on the UNFCCC web there is also often but not always a copy of a form that is used to calculate the IRR. IRR including CDM revenue depends on the price of CER. I did several tests to find out at what CER price level a project reaches the IRR benchmark for coal power plants at 10%, see details in Appendix, Chapter 8.4. Out of 11 randomly selected projects, 9 reach an IRR of 10% when CERs are traded at € 12/ton. Consider the scenario that wind power plants would not receive subsidies. It means that wind power plants would receive the same tariff of 0.31 RMB/kWh that coal power plants receive. In such a case the CERs needs to trade at around € 30/ton for wind power plants to reach an IRR of 10%.

Taking Jiangsu Qidong 91.5 MW wind farm, and its' IRR analysis as an example, it is possible to deduce the cash-flow analysis referred to in chapter 2.3.1.

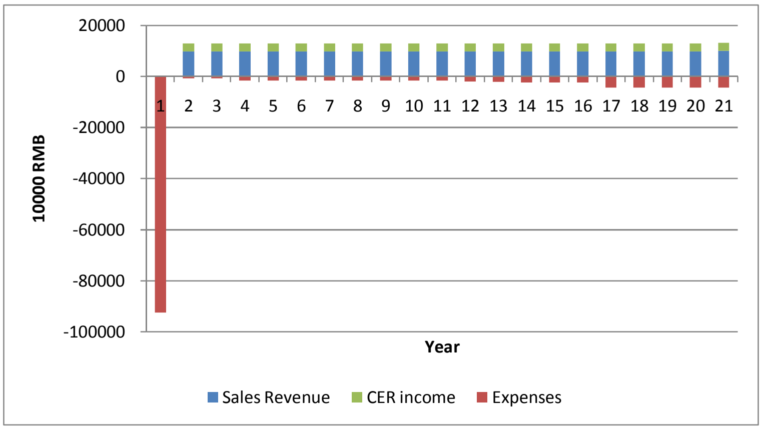

Figure 7: Jiangsu Qidong 100 MW wind farm, cash-flow overview.

Sales revenue is sales of electricity and CER income is exactly that. Expenses can be divided into costs related to construction (fixed costs) and operation & maintenance + taxes (variable costs). Note that there is no estimated residual value at the end of the life-time of the project. Expenses begin to increase after that the investment break-even after 10 years because of income tax. After 16 years, there is no more depreciation left. Since thereby pre-tax earnings increase, the cost of tax increases as well. Summing up all fixed and variable costs for the wind farm in Jiangsu Qidong:

Fixed Costs	(MRMB)	Variable Costs	(MRMB)
Construction	1513.9	Fuel / raw material	0
Licenses	0	CO2 emission fees	0
		Operation & Maintenance	320.4
		Taxes (Income, VAT, City, Education)	172.7

Table 4: Fixed and variable costs for Jiangsu Qidong wind farm in Net Present Value.

Depreciation and amortization costs are part of construction costs. Cost split is 75.4% construction, 16% operation & maintenance and 8.6% are taxes.

5.2 COAL

The price of coal in China depends on quality and which region it comes from. Different type of coal gives different amount of energy in return, depending on how "pure" it is. I will here show how the price of coal impact on price of electricity in China. When analyzing the financial reports of Huaneng and Datang (see excerpts included in Appendix 8.3), I found that they estimate coal costs to stand for 0.14-0.17 RMB/kWh in 2007. As they sold electricity at 0.3 RMB/kWh, they had to cover overhead costs and revenue for the remaining 0.13-0.16 RMB/kWh.

In a speech by Patrick Clerens (2007, page 10) at The European Power Plant Suppliers Association, the following diagram was presented:

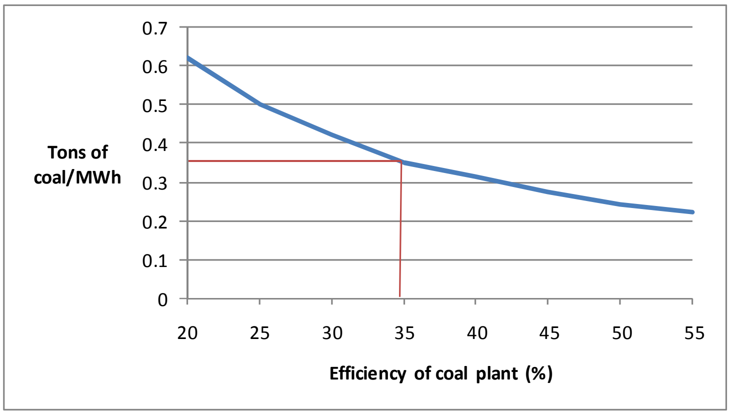

Figure 8: Efficiency level of coal power stations generating electricity and tons of coal/MWh. (Source: Patrick Clerens)

Huaneng show in their annual report for 2007 that the average coal consumption was 328.77 g/kWh; 29 g lower than the nation's average. Average value for China in 2007 is 328.77+29 ≈ 358 g. Cross-checking Figure 8 it means an efficiency of ≈ 34%. It is also confirmed by Andrew Minchener (2007) writing that "larger power plants are running at efficiency levels of 28-35%".

One of the largest coal producing companies in China, China Shenhua Energy Company Ltd list in their annual report for 2007 that standard (weighted average) "electrical" coal price in 2007 was 431 RMB/ton. Since Shenhua also owns some coal power plants, railways and ports, they also list that their (weighted average) fuel cost was 0.14 RMB/kWh, the same level as Datang International Power. As a reference, the fourth largest coal producer in China, Yanzhou Coal Mining, received according to China Daily (2008-04-22) an average of 414 RMB/ton of coal in 2007.

Calculating average efficiency of ton/MWh * price RMB/ton give us the cost of purchasing coal during 2007: 0.358 ton/MWh * 431 RMB/ton ≈154 RMB/MWh = 0.154 RMB/kWh.

If we assume that coal power producing companies' costs for overhead and transport/logistic costs are held constant, it is possible to derive the following graph that shows relation between coal price and price of the electricity sold to power grid.

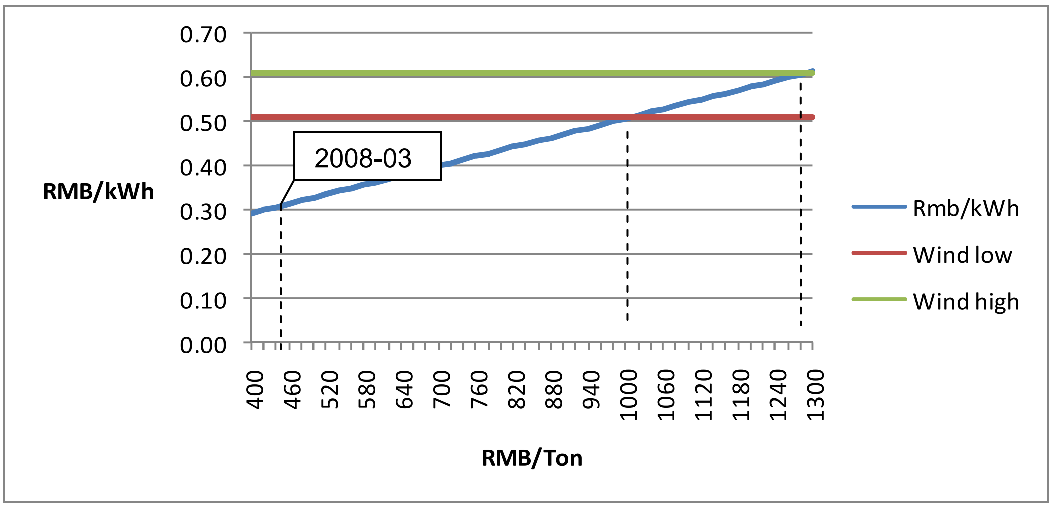

Figure 9: Grid electricity price (RMB/kWh) as a function of coal price (RMB/ton). Low and high concession price for wind farm projects are included as a reference.

The graph in Figure 9 shows that when price of coal in China reaches 1000 and 1200 RMB/ton, cost to produce 1 kWh of carbon-generated electricity reaches 0.51 and 0.61 RMB/kWh. Those prices equal the range of concession price that wind farms receive when they sell electricity to power grid. At such price levels, subsidies are no longer needed. According to China Daily (2008-04-10), China's coal power producers are during the spring of 2008 under much pressure. Because of a rapid increase of coal price (+15%) and a fixed price of electricity, “42% out of 4773 large-capacity power plants made losses during the first two months of 2008”.

6 DISCUSSION AND CONCLUSION

Since implementing the renewable energy law in China which in part obliges the national power grid to connect all new renewable energy initiatives to the power grid, there has been a steady growth of new wind farms in the country. Power companies are also putting more focus in to the sector as NDRC have set high targets for year 2010 and 2020. I see though that because of the CDM and sales of CERs, there is also a high probability of obtaining good revenue of the investment. If also a growing concern about the environment is playing a part here, I can’t tell, but it may not be irrelevant. Employees of power companies are after all also humans who have families that they care about.

As China’s economy is growing, now entering a phase where average GDP has surpassed $US 2000/capita, the lessons from Japan and Korea (Garnaut, 2007) are that the amount of energy needed will increase more than on previous levels because of compounded effects. When people earn above a certain level, they begin to purchase more consumer goods. Goods that are more resource intensive in their production such as, cars, electronics, flight travel, bigger houses etc. There is no longer a linear increase following the GDP growth, the growth of electricity demand increases faster. It will make China’s energy demand situation look even more strained than today. Impacts of that will be felt globally. What we see in 2008 regarding rapid increases of oil, food and coal prices may just be the beginning. In the recent National Party Congress where the 11th 5-year plan was discussed, it was said that the economy needs to cool down. The double-digit GDP growth numbers in the past few years needs to be squeezed down to 7.5% in the near future (People’s Daily, 2008).

An additional increased energy demand might mean that NDRC’s target levels of installed capacity for 2010 and 2020 are not enough. It makes it a great opportunity for renewable energy to fill the capacity gap. If the domestic wind power manufacturing industry evolves as the authorities hope for, China is likely to see one or two large global producers in this industry in the coming four to five years. When companies reach large economies of scale, prices also start to come down. By the end of April of 2008, NDRC are considering to raise their target for 2020 and wind power up to 100 GW (Chinaview, 2008).

Wind power is in comparison with coal power a rather young technology. It is likely that efficiency of wind power will develop faster than coal power. The length of the blades in wind power has increased gradually. With longer blades the output increases.

Mining is a risky business. In China there have in the past years been about 10000 deaths annually related to accidents in mines (Renner). The authorities in China have for this reason closed down 46000 mining firms in 2006 and 2007 (China Daily, 2008-03-04). To loose jobs in the mining industry for the benefit of wind power will not only save lives because of improved environment it will also save mining workers lives. Authorities will have to launch programs to re-educate unemployed miners in to other sectors of industry. In terms of number of employees needed per MWh, wind power farms needs more workers than coal power plants. In 2001, the ratio was 25% higher in wind (Singh, 2001). However Singh also acknowledge that this ratio will decrease over time as wind power technology evolves. To say that a technology is more labour intensive is however not a positive thing, unless the relative wages are higher in the wind sector it is not a benefit for the society.

6.1 THE CARBON DIOXIDE ISSUE

From my investigation of CDM projects, I found that in average 1 MW of wind power capacity is equal to an annual saving of 2200 tons of CO_2.

China's current target for year 2020 is to have an installed capacity of 30 GW of wind power. Simple math (2200 ton/MW * 30 000 MW) means an annual saving of 66 million tons of CO_2 emissions.

Considering the amount of coal saved. We know that it takes 0.358 ton of coal on average in a Chinese coal power station to generate 1 MWh. A wind farm in China produces annually in average 2229 MWh per capacity of MW.

$$x = 30000\ \text{MW} * 2229\frac{\text{MWh}}{\text{MW}} * 0.358\frac{\text{ton}}{\text{MWh}} = 23\ 939\ 460\ \text{tons of coal}$$

There is an annual saving of nearly 0.024 billion ton of coal consumption. It might sound much but considering that China in 2007 mined 2.65 billion tons of coal, wind power as it is planned for 2020 is only equivalent to 1% of the demand in 2007.

6.2 BOOMING ECONOMY FOREVER?

It was published in China Daily (2008-03-19) that China eventually consumed 2.65 Billion tons in 2007. The country has been implementing energy-saving measures to realize its targeted energy consumption ceiling of 3 billion tons of coal equivalent by 2010.

China's total reserve of coal has been estimated to be somewhere in the range of, 114.5 billion tons (Wikipedia, 2008), 126 billion tons (Clean-Energy US, 2006) and 189 billion tons (China Mining, Demand and Supply of China Coal, 2007). These numbers are not completely true though. According to Dr Minchener (2007) there are much more resources than this in China but they are located in such places that they will be far more costly to mine than those resources that are included in the numbers above. Minchener says that those additional resources currently are to be ignored.

Besides having a big appetite for coal, it is very likely that what is harvested now is the low-hanging fruit. That is, coal that is mined today is probably easier to extract than what will be available 20 years from now. It will have further impacts on the price of carbon.

China is planning to increase their capacity of coal powered energy from 593 GW in 2010 to 805 GW in 2020. Their power plants are now according to China Daily (2008-04-21) using on average 357 kg/MWh whereas the global average is 317 kg/MWh. Assuming that China can reach the global average by 2020, China would still need 5.9 billion tons of coal that year.

$$\frac{317 * 805 * 3}{357 * 365} = 5.9\ billion\ ton/year$$

The gap of 2.9 billion tons would have to either be imported or the domestic production (mining) would have to increase even more. That would only further shorten the number of years before China is out of coal. To import 2.9 billion tons of coal require as an example, 48333 tankers per year (132.4/day) each carrying 60000 tons of coal.

Considering both the best and worst case scenarios regarding coal resources, negligible amount of imports, improving efficiency grade up to year 2020 and no further increase of coal power capacity after 2020, China will run out of domestic coal by somewhere between years 2030 and 2043.

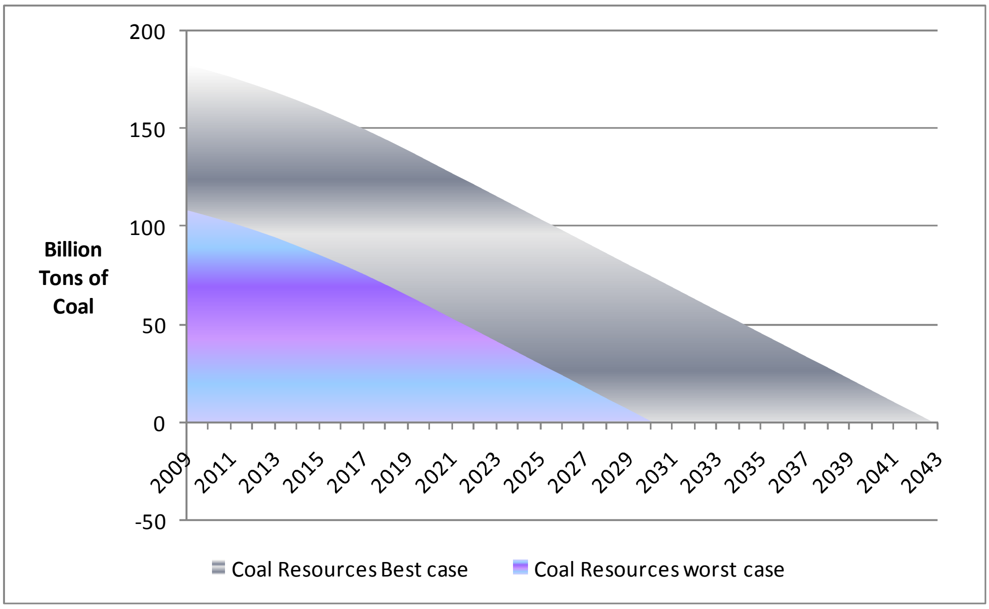

Figure 10: Billion ton of remaining coal resources in China, best and worse case scenarios.

My conclusion regarding this is that either China soon needs to change targets regarding usage of coal or they are in for a big backlash in 20 to 30 years from now. During the coming years, the price of coal is likely to continue to increase at a fast pace thereby increasing the price of electricity even further. The benefit of such an increase is that it certainly leads to search and investment in alternative energy resources that are sustainable and friendly to the environment. Unless the Chinese voracious appetite for coal is quenched, countries rich on coal will in the future belong to the new Middle East.

6.3 SUGGESTIONS FOR FURTHER RESEARCH

What if China suddenly decided to use all its biomass resources it has to produce energy? And what if they on top of that utilize all their land resources of wind power? It is estimated that China has annual waste of biomass from agriculture of 500 mega tons that roughly equals 250 GW of coal capacity. In addition a total of 250 GW of wind power on land. Considering that wind power plants only run 40% of the time that a coal plant does, there is another 100 GW of coal capacity saved. Adding those numbers to the 2020 mix, China could reduce their target of 805 GW of carbon-generated power with (250-30=) 220 GW of biomass and (100-30*0.4=) 88 GW of wind power. That is a substantial reduction from 805 (-220-88=308) down to 497 MW of wind power. The 61.8% share of coal energy in Figure 5 would be reduced down to little less than 40%. These are just high level estimates. It would be interesting to see a thorough investigation about it.

6.4 CONCLUSIONS

I will here give answers to the two questions raised as purpose for the thesis

What price level of Carbon Emission Rights will make wind power an equally profitable investment to carbon-generated power?

Considering the benchmark IRR for coal power stations at 10%, the price level of long-term CER contracts should increase up to € 12 so that the majority of prospects are on par with coal power stations. When subtracting the governmental subsidies so that the grid price is equal the price that coal power plants receive, 0.31 RMB/kWh, the price level of long-term CER contracts needs to increase up to ca. € 30. However, when currently many power plants are incurring losses from daily operations due to the increased price of coal and fixed price of grid electricity price, that benchmark figure of 10% is greatly overestimated. In my opinion there is currently no business case at all to invest in coal power plants in China. The only thing that makes it happening is an order from the central government or an optimistic belief from the power companies that the situation will change, coal prices going down and/or grid price of electricity going up. The current price conditions for coal are definitely a cause for the recent increase of investment in wind power.

What price of coal would lift the cost to produce carbon generated electricity (RMB/kWh) to the same level as the cost of wind power?

An increase to the price range of 1000-1200 RMB/ton will make production of coal reach the range of 0.51-0.61 RMB/kWh. That is the same amount that wind farms now receive from the power grid. At such a price level of coal, there is no further need to subsidize wind. The business will “fly” on its own. In the long run both wind and carbon-generated power will be cheaper to produce because of technical advancement. While wind is still a somewhat new technology in comparison to coal, it is likely that time is working for wind even further. I expect that the efficiency and technical advancements of wind power stations will happen faster than coal plants in the future.

Policy makers can use the above information to decide costs to society for pollution. The delta between those future prices and today's prices are what we pay as a society to continue to pollute our environment. Today the CER price only includes costs for CO2 emissions. By burning coal to produce electricity there are also emissions of SO2 and Methane that also damages the environment. Adding on such costs as well would even further show the benefits of switching to renewable energy. If nations considered the cost of depletion of their own resources in to their Net National Product, more officials would remember Chief Seattle's wise words.

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8 APPENDIX

8.1 PREVIOUS RESEARCH

Here is a summary of previous research found related to the essay. It is summarized and referred to in Chapter 2.6.

Author	Title	Country	Period	Method	Result
Johan Wahrby	The smoking dragon: A study of how China frame their climate change policy	Sweden	2007	Data analysis and interviews	Until now, China has taken the approach, develop first, cleanup later. Renewable energy investments take a very long time due to lack of funding. Coal will be the main source of energy in China for the foreseeable future.
Josefin Öjner	The implementation of the CDM in China	Sweden	2006	Data analysis	The study explains well the Chinese economy, its development and its environmental problems. Foreign investment is important for the spread of cleaner technologies. China is not yet part of emission trading. The implementation of CDM will help the world to reduce emissions via pure market forces (via trading of Certified Emission Rights) and it is implemented in China
Philippe Coquet, Sophia Ang, Cap Gemini	Capgemini uncovers $180 billion investment gap in Chinese power market by 2020	UK	2006	140 Interviews with industry regulators, foreign investors and industry experts	An extra 280 GW of electricity generation will be required by 2020 on top of the 950 GW currently planned. Capgemini's assumption is based on a slightly higher impact of GDP growth on electricity consumption for the period 2010-20, taking into consideration standard of living catch-up effects as well as large-scale heavy industry investments.

Andrew Minchener	Coal Supply challenges for China	UK	Sept 2007	Data collection from books, articles, ministries and companies	The report discuss the complex matters of increasing coal production in China, transport problems, environmental impacts, China is likely to become a net importer of coal by 2030. The report also highlight the balancing act that the Chinese government needs to address, a steady economic growth while not totally neglecting the impacts of using coal as prime source of energy.
Ross Garnaut, Ligang Song (on behalf of Rio Tinto)	China's resources demand at the 'Turning Point'	Australia	August 2007	Data collection from books, articles and companies	In countries where income/person has passed $2000 US, demand for natural resources begin to grow at a faster pace than before until income/person reaches $20000 as in South Korea and Japan.

8.2 INTERVIEW WITH CHINA NATIONAL POWER GRID

I was able to make an interview with an employee at the Schedule and Communication Centre at the China National Power Grid. It was expected that the answers would be politically correct but some answers were also unexpected. The interview took place in February 2008.

Q: How does the coal market work in China, who sets the price of coal?

A: Most of the coal enterprises are national owned. Personal Owned is only a very small part. The coal price is set by the government organization (Development and Reform Commission).

Q: Does the power companies pay the market price or are their subsidies that lower the cost for them to use power?

A: Power companies have to negotiate the price with the coal companies to settle the price. Anyhow as government has a guidance price for power coal, so power company pay lower price than other industries which also need to use coal, normally 30-50 % cheaper than the other industries. Now China consumes about 2 billion tons of coal every year, and 50% of it is power coal.

Q: Are the power companies supposed to make a profit or only to cover their expenses in order to deliver electricity as a public service?

A: Power companies are supposed to make a profit. Some power companies are state own company, some are joint-ventures. Big power companies are listed companies already, and the others are in process of becoming listed. As a state owned company, state assets should keep the value and even need to increase its value, the target is 10-20% value increase every year, so the company profit is also controlled by the government, the power price is set by the government also. The power price has been kept the same for several years by the government. As the coal company want to increase the coal price every year, so government intervention to the power coal price is needed.

Q: At what price of coal will other electricity generating alternatives become competitive with coal and carbon-generated electricity?

A: Now there is a new law called "RENEWABLE ENGERGY DEVELOPEMENT" law, and all the government organizations should comply by the new law. Price is not the highest priority for power companies to consider now. Clean energy is the first thing to consider, then the price. The clean energy---First is water electricity, second is wind electricity, nuclear electricity, the last is coal electricity.

Q: How do you see that the energy mix will look like in China year 2020?

A: Year 2010, the total power install base will be 950M KW, and in year 2020, the installed base capacity will be 1.5 Billion KW.

Q: Do you have reliable statistics about electricity production in the past and forecasts for the next 10-12 years up to 2020?

A: Water electricity is under development, in year 2020, 20--25% of total power should be water electricity. About 4 % wind electricity. China would like to develop nuclear, but unfortunately we do not have the needed resource (Uranium) .Only 50M KW is nuclear electricity in year 2020.

8.3 AVERAGE GRID ELECTRICITY PRICE

When comparing wind farm operations with other technologies, it is interesting to compare how much money is received per kWh in average for all electricity production. A good way to obtain the information is to analyze information from some of the big 5 power companies. See Huaneng and Datang below:

Huaneng	2006-12	2007-12E	2008-12E	2009-12E
Power generation (kWh)	150792	169709	191141	204841
Power attributable capacity (MW)	28382	32446	35006	37206
Wtd-avg power tariffs (Rmb/kWh)	0.29	0.3	0.31	0.32
Unit coal costs (Rmb/kWh)	0.16	0.17	0.17	0.17

Table 5: Excerpts from Huaneng Q1 and Q2 results 2007(2007-08-15).

Datang	2006-12	2007-12E	2008-12E	2009-12E
Power generation (kWh)	88,038	113,182	137,652	144,287
Power attributable capacity (MW)	15,243	16,461	18,242	19,262
Wtd-avg power tariffs (Rmb/kWh)	0.28	0.3	0.29	0.28
Unit coal costs (Rmb/kWh)	0.12	0.14	0.16	0.16

Table 6: Excerpts from Datang International Power Generation full year result 2007 (2008-03-27).

8.4 RESEARCH DATA TABLES

The following tables are a summary of data research performed on wind farm projects in China under the CDM scheme. Data is available at the CDM web: http://cdm.unfccc.int/Projects/projsearch.html . A search on the key word wind plus selection of China as host country result in a long list of projects. From that first page, project design documents have been searched for useful information. The findings are summarized below in tables 7-10.

Name	Province	Capacity MW	Value MRmb	Cost Rmb/W	IRR w/o CDM	IRR with CDM	CER price EUR asmpt	Tariff excl VAT Rmb/kWh
Taonan	Jilin	49.3	433.0	8.78	6.66%	8.70%	8	0.5902
Touli	Xinjiang	30	263.3	8.14	6.80%	8.71%		0.4332
Rudong Co	Jiangsu	100	813.6	8.37	6.93%	9.44%	5.5	no info
Helanshar	Ningxia	111.9	936.8	9.32	8.00%	9.80%	5.4	0.53
Yinyi	Ningxia	49.5	461.6	8.54	7.89%	10.29%	7.1	0.534
Tianjing Sl	Ningxia	30.6	261.3	9.25	8.00%	9.80%	5.4	0.53
Zhangpu L	Fujian	30.6	283.0	9.26	6.61%	8.32%	7	0.53
Nan'ao	Guangdong	45.05	417.0	9.71	7.54%	9.28%	7	0.528
Taobei	Jilin	49.3	478.7	9.85	6.84%	8.23%	7	0.6065
Tongyu	Jilin	100.05	985.4	9.27	6.88%	9.35%	7	0.509
Kangping	Liaoning	24.65	228.4	7.63	7.72%	11.87%	5.7	no info
Changling	Jilin	49.5	455.55	9.20	7.63%	8.41%	5.7	0.65
Zhangwu	Liaoning	24.65	227.29	9.22	6.11%	10.16%	5.7	0.7
Taobei	Jilin	49.5	377.7	8.61	6.77%	8.43%	6	0.556
Chifeng D	Inner Mong	49.3	515.0	9.94	7.14%	9.60%	7	0.545
Average		**52.93**	**475.83**	**9.01**	**7.2%**	**9.4%**	**6.39**	**0.557**

Table 7: CDM projects in 2006

Name	Province	Capacity MW	Value MRmb	Cost Rmb/W	IRR w/o CDM	IRR with CDM	CER price EUR asmpt	Tariff excl VAT Rmb/kWh
Huitenglia	Inner Mong	49.5	547.41	11.06	7.24%	9.07%	7	0.57
Qidong	Jiangsu	91.5	925.15	10.11	5.34%	8.16%	9	0.449
Huitengxi	Inner Mong	100.25	863.26	8.61	6.35%	8.22%	8	0.382
Wulabo	Xinjiang	30	298.21	9.94	6.81%	9.39%	5	0.4332
Shangyi M	Hebei	49.5	468.66	9.47	7.04%	8.18%	7.5	0.6
Weihai	Shandong	69	705.1141	10.22	6.72%	8.66%	8	0.7
Yumen	Gansu	49	455.699	9.30	6.23%	8.54%	7.14	0.516
Tongyu Ti	Jilin	100.3	816.38	8.14	6.74%	10.52%	8	0.509
Huitengxi	Inner Mong	100	780.94	7.81	6.46%	8.47%	6	0.3823
Huafu Mu	Heilongjian	31.2	349	11.19	7.46%	10.07%	8	0.6588
Changling	Jilin	9.35	106.8	11.42	6.83%			0.65
Dongtai	Jiangsu	201	1816.81	9.04	6.64%	8.44%	7.14	0.45
Average		**73.38**	**677.79**	**9.69**	**6.7%**	**8.9%**	**7.34**	**0.53**

Table 8: CDM projects in 2007

Note that projects listed in table 8 are only an excerpt out of all CDM projects in 2007.

Name	Province	Capacity MW	Value MRmb	Cost Rmb/W	IRR w/o CDM	IRR with CDM	CER price EUR asmpt	Tariff excl VAT Rmb/kWh
Zhuozi	Inner Mong	40.00	384.16	9.60	6.44%	8.67%	7	0.498
Changdao	Shandong	27.20	268.68	9.88	6.59%	8.73%	8	0.700
Zhangpu L	Fujian	45.00	418.96	9.31	6.33%	8.62%	8	0.549
Lufeng Jia	Guangdong	30.60	260.79	8.52	6.22%	8.09%		0.530
Xiaocaohu	Xinjiang	49.50	385.04	7.78	6.63%	9.44%	8.5	
Sunjiaying	Inner Mong	50.25	506.16	10.07	6.97%	9.55%	10.21	0.571
Xingcheng	Liaoning	49.50	441.13	8.91	6.20%	8.41%		0.510
Huanren N	Liaoning	24.65	225.46	9.15	6.67%	9.45%	9	0.564
Ningdong	Ningxia	45.00	411.32	9.14	6.54%	8.75%	8	0.530
Dali ph V	Inner Mong	49.50	580.10	11.72	4.75%	8.15%	8	0.564
Dali ph IV	Inner Mong	49.50	546.95	11.05	5.34%	9.50%	10.5	0.564
Shibeisha	Guangdong	100.20	709.30	7.08	7.05%	8.23%	10.5	0.501
Average		**46.74**	**428.17**	**9.35**	**6.3%**	**8.8%**	**8.77**	**0.55**

Table 9: CDM projects in 2008

CER price (Euro/tCO2e)	0	2	4	6	8	10	12	14	16
Tongyu Jilin	6.88%					10.33%			
Huiteng liang	7.24%					9.82%			
Taobei Jilin	6.76%	7.33%	7.89%	8.43%	8.96%	9.49%	10.00%	10.50%	11.00%
Chifeng Dongshan	7.14%					10.59%			
Tongyu Tianjie	6.74%				10.52%				
Huitengxile Jingneng	6.46%			8.47%			10.48%		
Huafu Muling	7.46%				10.07%				
Zhuozi I.M.	6.44%	7.10%	7.74%	8.36%	8.97%	9.56%	10.14%	10.71%	11.26%
Sunyiajing	6.97%	7.48%	8%	8.50%	9%	9.50%	10%	10.47%	10.96%
Liaoning Xingcheng Haibin	6.20%	6.85%	7.49%	8.11%	8.72%	9.30%	9.84%	10.33%	10.81%
Jiangsu Qidong	5.34%	5.99%	6.63%	7.26%	7.86%	8.46%	9.04%	9.61%	10.17%
Inner Mongolia Wudaogou 50.25MW	7.07%	7.61%	8.15%	8.67%	9.18%	9.69%	10.18%	10.67%	11.16%
Inner Mongolia Dali Phase 4	5.34%	6.19%	7.01%	7.80%	8.57%	9.32%	10.04%	10.75%	11.45%
Guohua Hulunbeier Xinbaerhu Youqi	6.29%	7.05%	7.78%	8.50%	9.21%	9.90%	10.58%	11.25%	11.91%

Table 10: Sensitive analysis, price of CER and IRR for wind farm projects

CER price (Euro/tCO2e)	0	16	20	24	28	32	36
Zhuozi I.M.	-2.31%	5.05%	6.44%	7.74%	8.97%	10.14%	11.26%
Sunyiajing	0.00%	5.18%	6.31%	7.40%	8.47%	9.50%	10.52%
Liaoning Xingcheng Haibin	0.44%	6.68%	7.95%	9.15%	10.20%	11.16%	12.11%
Jiangsu Qidong	0.36%	6.08%	7.29%	8.46%	9.58%	10.67%	11.72%
Inner Mongolia Wudaogou 50.25MW	1.28%	6.37%	7.47%	8.53%	9.55%	10.54%	11.50%
Inner Mongolia Dali Phase 4	-6.60%	3.53%	5.26%	6.87%	8.38%	9.81%	11.19%
Guohua Hulunbeier Xinbaerhu Youqi	2.40%	8.74%	10.12%	11.46%	12.77%	14.04%	15.28%

Table 11: Sensitive analysis, price of CER and IRR for wind farm projects, tariff=0.31 RMB/kWh for all projects