THE ROLE OF RENEWABLE ENERGY IN CHINA

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Executive Abstract

Primary Energy Situation

The energy sector in China is growing rapidly to match the country's economic transformation. This process has triggered a high demand for energy both to feed growing industry and business, and to meet growing consumer demand, having important consequences for China, the whole Asia and the global energy market.

Since 2000, high economic growth has caused energy demand to increase at a rate of about 10 percent per year. But this pursuit of economic growth without taking sufficient regard of the energy requirements has led to a power supply deficit and frequent power outages all over the country.

The total primary energy consumption is expected to grow at least 5 percent per year over the next decade. To satisfy this dramatically increasing request of energy, China is relying mainly on coal and secondly on oil, but the emphasis of the government plans for the next two decades is on new sources of renewable energy.

China must invest an increasing amount in order to exploit the renewable energy sources because it is facing an increased price of oil, a limited resource of coal, and international pressure to reduce global warming and greenhouse effects and fight pollution. Together with the willingness to keep the path of technological development with all the developed countries, China is investing heavily on Wind, Solar, Hydro and Biomass power.

Renewable Energy

The Government set up a plan to increase the renewable energy share to 16 percent of total energy consumption by 2020, up from 8 percent at present. Last year the renewable energy law was issued to define the policy framework about the development of new plants of renewable sources.

Among the renewable sources, hydropower represents almost the totality of the share. With about 120 GW of installed capacity Chinese hydro constitutes the only clean source developed on a large scale, while all the other renewable sources lag far behind. Wind power has reached an installed capacity of slightly more than 2.5 GW, Biomass about 2 GW, and solar PV only 80 MW at 2006 representing all together about 10 percent of the total installed capacity, but less than 1 percent of the total energy production.

The total planned development by 2020 will increase ten to fifteen times the installed capacity of wind and biomass power generation. Both Wind and Biomass will reach 30 GW, however the quota of the total electricity production, made by each of these sources, at that time will be only around one percent. For solar photovoltaic the quota is even smaller and will not reach a critic level before 2050. Only hydropower will represent an important source in the energy production. With over 300 GW it will hold almost 30 percent of the total installed capacity share of power, and about 13 percent of the total energy production.

Economic and environmental impact

The impact of these sources has been and will be extremely important for completing the electrification of rural regions. In remote areas where the grid is not economically convenient, household size biomass digester, small PV cells, as well as solar water heating systems represent a successful solution for improving the local economy and living conditions.

On the other hand the impact on reducing the pollutant emissions is limited. The reduction of carbon dioxide emissions is proportional to the importance they have in the energy mix. Since coal is still the cheapest source in the country, it will provide the majority of the energy to the country at least until 2030. Therefore the pollutant emissions are increasing at the same speed as the energy production increase, with a marginal mitigation effect from clean sources and improved efficiency. China is expected to become the world biggest emitter of carbon dioxide within this or next year, overcoming the United States.

Introduction

The energy sector in China is growing quickly to match the country's economic transformation. Today, China is taking the position as the global leader in the consumption of virtually all-major commodity categories. The rapid rise in production and consumption of energy has taken place mainly as a consequence of the economic reforms introduced in the 80s, which led to a fast industrialization and urbanization of the country.

This process has triggered a high demand for energy both to feed growing industry and business, and to meet growing consumer demand. This demand has important consequences for China, the whole Asia and the global energy market. It is shaping Chinese foreign policy and presents both challenges and opportunities for governments and energy players the world over.

To satisfy this dramatically growing demand of energy, China is relying mainly on coal and secondly on oil, but for the next fifteen years the government plans to place emphasis on new sources of renewable energy.

The necessity to find an alternative solution to the increasing price of oil, to the not unlimited resource of coal, and the pressing urgency to fight pollution and comply with international pressure to reduce global warming and greenhouse effects, combined with the willingness to keep with the technological development of the developed countries, have caused China to continue to increase investment in order to exploit the renewable energy sources, in most of its forms: Wind, Solar, Hydro and Biomass power.

Worldwide Renewable Energy Overview

Abstract: *The renewable energy market is growing worldwide at an annual rate of 14 percent. In 2005 its investments reached $ 38 billion, and the total installed capacity of renewable energy reached 182 GW. Hydropower holds the biggest share, followed by wind power, which has a capacity of 59 GW and Biomass with 44 GW. Solar photovoltaic only 3.1 GW, but it is becoming the world fastest growing sector.*

Renewable energy, is already become the buzzword in the business environment worldwide. With $38 billion invested in 2005 it represents one of the fastest growing sectors all over the world. The developed countries are driving the innovation, and developing countries are taking a record number of new steps to incorporate renewable sources into their energy systems. China is moving from an emerging market to a core market. With $7 billion invested in 2005, it together with Germany ranks first for the amount of investments made in Renewable Energy.

At present China has few plants that use renewable energy, but its use of renewable energy has a great potential for growth considering its abundant resources of water, wind and sun. Considering the current high speed of worldwide renewable development, China wants to take the opportunity to develop renewable energy technologies and its domestic industries.

The global market of renewable energy is increasing at a double-digit growth rate. Overall, renewable energy accounts for 14 percent of the world's energy consumption, and its installed electric capacity reached 182 GW in 2005 up from 160 GW in 2004 with an annual growth rate of 14 percent[1].

Excluding large hydro, the biggest share is held by Small Hydropower, the most mature sector among the non-fossil resources, with an installed capacity of 66 GW, increased by 12 GW during the last year, of which 38 GW were in China alone.

Immediately following is Wind power with an installed capacity of 59 GW, and a growth rate of 24 percent in the previous year.

Biomass energy is increasing both as power generation and heat supply, reaching 44 GW in 2005. This is a relatively new market and in OECD[2] countries the growth rate is of 50-100 percent and 10-30 percent in the developing world.

Solar photovoltaic, considering the absolute value of 3,1 GW (5,4 GW including off-grid application in rural areas) of installed capacity in 2005, has a small part in the global energy share. However, it represents the winning bet for the future in

[1] Excluding large hydro, which alone has an installed capacity of 750 GW.
[2] OECD is the Organization for Economic Cooperation and Development

clean energy and is the fastest growing industry, with a 55 percent increase in the last year, most of which occurred in Germany.[3]

[3] Source: Renewable Energy Global Status Report, from Renewable Energy Policy Network – www.ren21.net,

China Energy situation

Abstract: *Today China is the world's second biggest energy consumer, immediately after the US. However China's energy mix is unbalanced and is heavily dependent on coal, which accounts for 69 percent of the total primary energy consumption. This poses significant social costs. Unsafe mines cause over 6200 deaths every year, SO2 and NOx emissions are causing acid rains over one-third of the country, and China's CO2 emissions are going to overtake that of the US within the next one or two years. China is not required to comply with the Kyoto protocol before 2012, however the government has showed its intention to green its economic development path by reducing sulphur emissions and eventually reducing carbon dioxide.*

At present China, with a demand of 2,200 Mtce[4] in 2005, is the world's second biggest energy consumer, immediately after the US, and is foreseen to overtake the US before 2025. China relies on its domestic production for over 90 percent of its energy consumption. Therefore with an annual production of over 2,000 Mtce in 2005, it is the world's third largest producer after the United States and Russia[5].

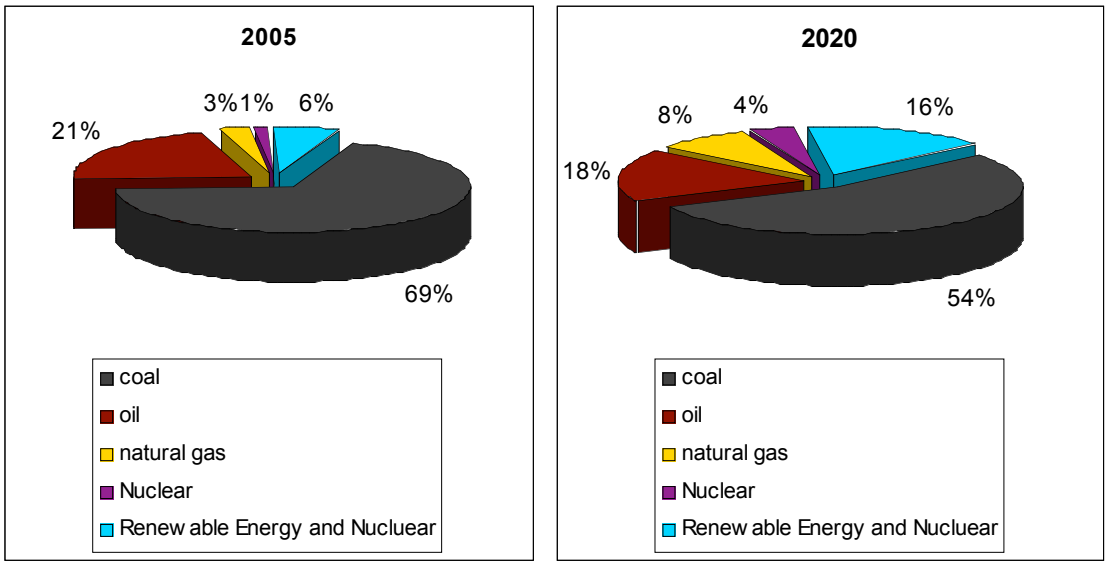
A coal economy

China is dependent on coal for almost 69 percent of its energy consumption, and coal accounts for 76 percent of domestic energy production. Another 13 percent comes from oil, 3 percent from natural gas, and all of the renewable energies as a whole at present account for around 7 percent, of which hydropower represent nearly the entire total[6].

The contrast with the developed world is huge, especially with Europe, which is completely phasing out coal as a mean for generating power. Coal is relatively more important to the United States where it accounts for 23 percent of all US energy consumption. However coal use in the United States has been growing by only about 1 percent annually during the past decade, compared with 10 percent in China, and America burns coal using much cleaner technology than China.

[4] Mtce is Million Tons of coal equivalent. It is one of the units of measurement for energy. It is widely used in China. It is equivalent to ~ 75.08 EJ. Source: China Statistical Yearbook, 2006
[5] Source: Energy Information Administration (EIA), Energy Statistics Agency from the US Government
[6] Source: National Bureau of Statistics of China, Statistical Yearbook 2006.

Fig. 1 – Total energy consumption in China, 2005 and 2020

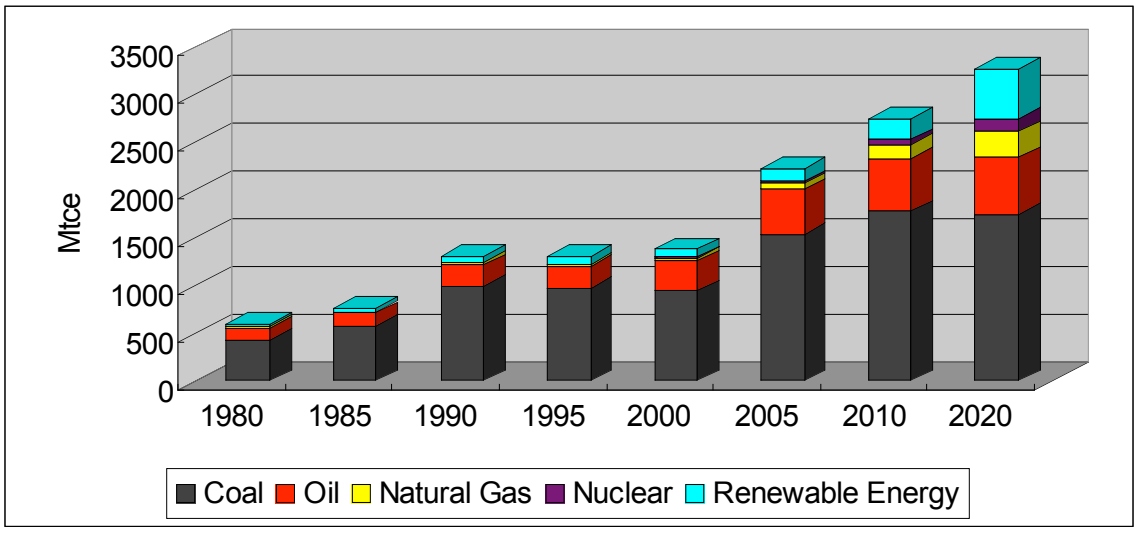


Source: China Statistical Yearbook 2006, China Daily news, China atomic authority, re-elaboration.

The heavy reliance on coal has grown over the years, and even if the government is planning to reduce the weight of coal in the energy mix, the consumption quantity, in absolute terms, is expected to rise even more in the future. In the last 10 years coal consumption has risen 57 percent reaching 2.1 billion tons in 2005, and the eleventh five-year plan has planned a further raise of 14 percent in 5 years, to 2.4 billion tons in 2010.

Coal is, and will remain, the main source of energy for some time in China, since the country has plentiful reserves of good quality coal, available at a very low cost while it has less adequate reserves of oil and even less developed natural gas.

Fig. 2 – Total energy consumption in China, from 1980 to 2005 and forecast



Source: China Statistical Yearbook 2006, China Daily news, China Atomic Energy Authority, re-elaboration

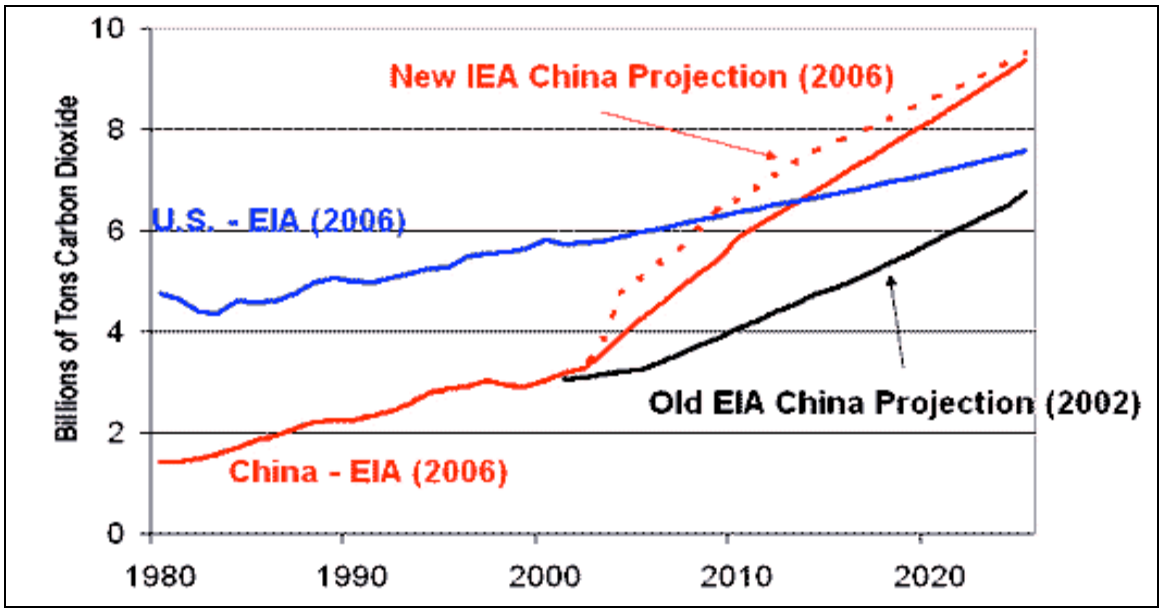
The pollution issue

The described condition put China in a delicate situation that is not sustainable in the long term.

China uses more coal than the United States, Europe, and Japan combined. Nine out of ten of China's new power plants run on coal. Chinese coal production represents 36 percent of the world's share, but accounts for 80 percent of the world's mine death incidents. Official statistics report the death of around 6,200 miners per year, a figure 70 times higher than the United States[7], and China contains 20 among the 30 world most polluted cities[8]. Sometime by 2025, China will become the world's biggest energy consumer, but it is expected to become the biggest emitter of carbon dioxide (CO2), the main Greenhouse Gas (GHG) much sooner. Latest forecast say probably within 2007 or at maximum 2008.

[7] Source: Dave Feickert: China's Energy Coal and Mine Safety, 2006.
[8] Source: World Bank China Overview

Fig. 3 – CO2 Emissions, China vs USA, EIA forecast



Source: US Energy Information Administration, Energy Outlook 2006, World resource Institute, Oak Ridge National Laboratory

These results are not unexpected. Taiyuan, capital of Shanxi Province and leader in coal production, has the world's worst air pollution, with concentrations of particulates (PM10) that are seven times above World Health Organization standards. According to the World Bank, coal usage causes as many as 700,000 premature deaths every year in China, as it is used heavily in the industrial sector, and for heating and cooking.

Since China is still considered a developing country, it is not required to reduce its emission of greenhouse gases (GHG) under the Kyoto Protocol before 2012. According to this treaty all developed country are required to reduce the global emissions of carbon dioxide, the primary GHG, by 5.5 billion tons within 2010. But during the same period, China's increasing coal-fired power capacity will increase emissions totaling 1.2 billion tons.

The country is simultaneously enjoying the benefits of access to cheap coal and the benefits of increased injections of capital and technology to help reduce pollution and emissions. China, indeed, dominates the Clean Development Mechanism (CDM)[9] market, attracting about half of global trading. Meanwhile, China is gaining from similar technology transfers from the United States, which has not ratified the Kyoto Protocol but is seeking to cut emissions and pollution in

[9] See the glossary for an explanation of the mechanism.

China and India, especially, through the Asia-Pacific Partnership on Clean Development and Climate (AP6)[10].

But China is eager to clean up its energy production anyway. President Hu Jintao and Premier Wen Jiabao want to ensure that economic growth is maintained at close to 10 percent per year, but Chinese leaders are also placing a greater emphasis on the quality of the growth as this pollution becomes palpable, and they have stated the willingness to sacrifice part of the economic growth in order to protect the environment.

This is why China plans to invest RMB 1.375 trillion (US$ 180 billion) in social environmental protection during the 11th Five-Year Plan period, of which approximately 10 percent or RMB 137.5 billion is going to fuel gas desulphurization (FGD) to reduce sulfur dioxide emissions, which are causing dangerous acid rain over one-third of the country.

In the 11th five-year plan the government aims to cut sulfur dioxide (SO2) emissions by 10 percent in five years. This means 2 percent per year, a very challenging task, considering that emissions have risen 27 percent in the last five years.

Presently, the installed capacity of desulphurization facilities established reached about 13.3 GW, accounting just for 3 percent of the total installed thermal power (368 GW). It is important to notice that 90 percent of SO2 emission and 70 percent of NOx emission are produced from coal burning, and around 50 percent is from coal power plants for energy production[11].

In 2005 the amount of SO2 emissions from coal power plants alone was about 13 million tons and according to the plan released by NDRC and SEPA it is expected to drop to 5.2 million in 2010[12].

Last year, however, the amount of emissions increased 1.8 percent over the previous year, not reaching the estimated target of 4 percent per year.

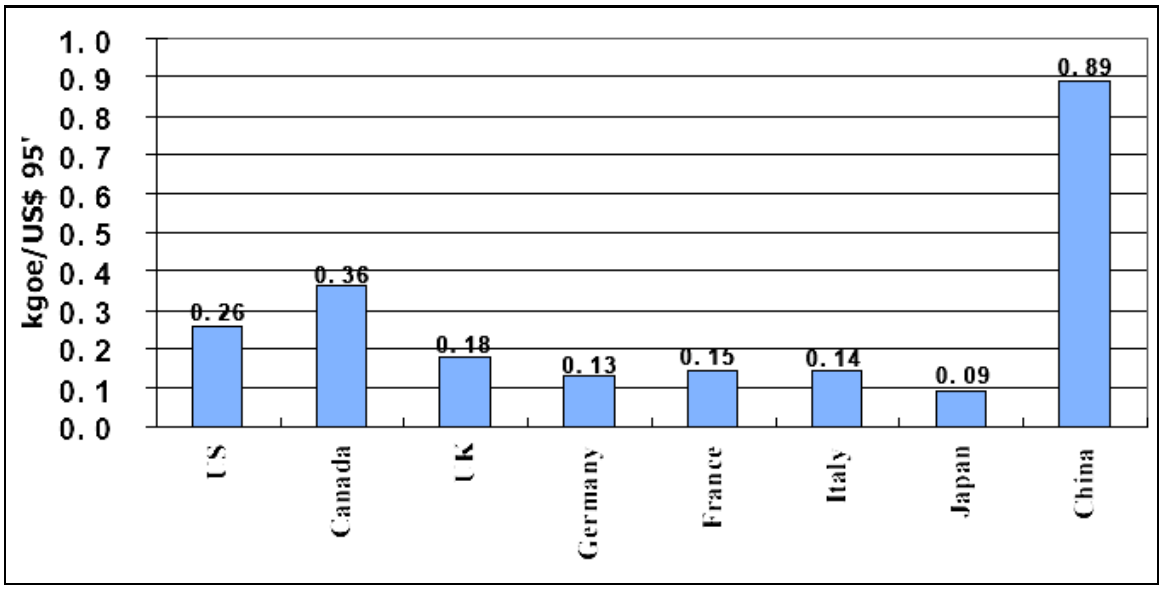
[10] AP6 is an international non-treaty agreement among Australia, India, Japan, the People's Republic of China, South Korea, and the United States launched on January 12, 2006, with the aim to co-operate on development and transfer of technology which enables reduction of greenhouse gas emissions.
[11] Source: Xorte Asia News. May 15 2007 from asia.xorte.com
[12] Source: Xinhua News Agency. March 28, 2007 from china.org.cn

Energy Efficiency

Abstract: *To balance the growing energy demand, in the eleventh five-year plan, the government set a target to considerably reduce inefficiency, reducing the consumption per unit of GDP by 20 percent in the next five years, through energy efficiency plan for both the industrial sector and in residential buildings. Unfortunately despite the efforts carried out the first year mid term target of 4 percent/year was not met and efficiency increased just 1.23 percent; new actions need to be implemented for the future.*

Next to the plan of reducing the SO2 emissions, in the Five Year Plan there is also the intention to cut the consumption of energy per unit of GDP by 20 percent in the next five years. China is consuming around 5 times the amount of energy per unit of GDP than that consumed by the OECD countries, and 10 times the amount of energy Japan consumes per unit of GDP (see chart below).

Fig. 4 – Energy Consumption per Unit of GDP, China vs OECD countries, 2000



Source: World Bank "World development indicators" and IEA "Energy Balance of OECD countries" 2000

This level of high inefficiency means that there is large room for improvements. China already started reducing energy intensity during the last two decades, but

its turning point should have started with the latest Five Year Plan, planning a reduction in energy intensity of 4 percent annually for 5 years.

Unfortunately, despite the huge effort carried out, this did not happen for the first year. In 2006 the reduction in energy consumption amounted to only 1.23 percent, far behind the estimated level.

Chinese government made concerted efforts to meet its goals during last year. Its focus has been on both the modernization of industrial plants, especially in high energy-intensity industries such as iron and steel, petrochemical, cement industry, transportation sector, and residential and commercial buildings.

For the industrial sector, which at present holds the biggest share in energy consumption, the government proposed investments of 774.6 billion Yuan in 163 projects in highly polluting and energy-intensive industries. Moreover, NDRC[13] signed several energy-saving responsibility agreements with 30 provincial governments and 14 central state-owned corporations.

For the residential buildings a new regulation has been issued and energy saving technology must be used in all the new buildings. Energy-efficient construction includes the insulation of windows, doors and walls; low-energy lighting; better heating, gas and electrical systems; and alternative technologies like solar water heaters. Unfortunately all these technologies are still quite expensive, and for the builders, comply with all this energy savings requirements mean an increase of over 10 percent in total production costs. That is why, it is often more economical for them to pay the associate fine of 50,000 Yuan than install the required energy saving systems.

The failure to meet the goals despite these efforts was in part due to over-optimism in the goals themselves. Also, the annual targets were only set in March last year and enforcement efforts only announced after that. It takes time for such measures to take effect, but apparently this was not adequately taken into account. But perhaps more importantly, China’s economy last year grew at a much higher rate than planned. The goals of energy-saving and emissions reductions were based on a GDP growth rate of 8 percent, but China’s GDP actually grew by 10.7 percent. High polluting and energy-intensive industries grew at even a faster rate. Accordingly, emissions of pollutants also exceeded the estimates.

Despite the failure, Mr. Fang Weizhong, president of the China Macroeconomics Society, wrote a report early this year in which he states that the five-year efficiency goal could still be met by massively increasing energy technologies, particularly in the coal-dominated industrial power sector.

But, another expert, Mr. Yang Jianlong, an energy researcher at the State Council's Development and Research Centre, doubts the possibility of reducing energy consumption, since China's economy is experiencing a tremendous

[13] NDRC is the National Development and Reform Commission

expansion of heavy energy-consuming industries, such as steelmaking and car manufacturing. Therefore it seems very difficult to reduce energy consumption as a whole, without it negatively affecting the economic growth of the country[14].

China has long valued economic growth above environmental protection, and has taken economic growth as the dominant criteria for evaluating local officials' performances.

Fundamentally, the central government must change China's current energy-inefficient and environmentally unfriendly pattern of economic growth. Inefficient and highly polluting power plants must be modernized or shut down, and the frequent expansion of highly polluting and energy-intensive industries must be controlled and regulated. Local officials usually strongly resist change, because these companies provide jobs and create tax revenues as well as personal payoffs. Forcing such companies out of business could even trigger local unrest.

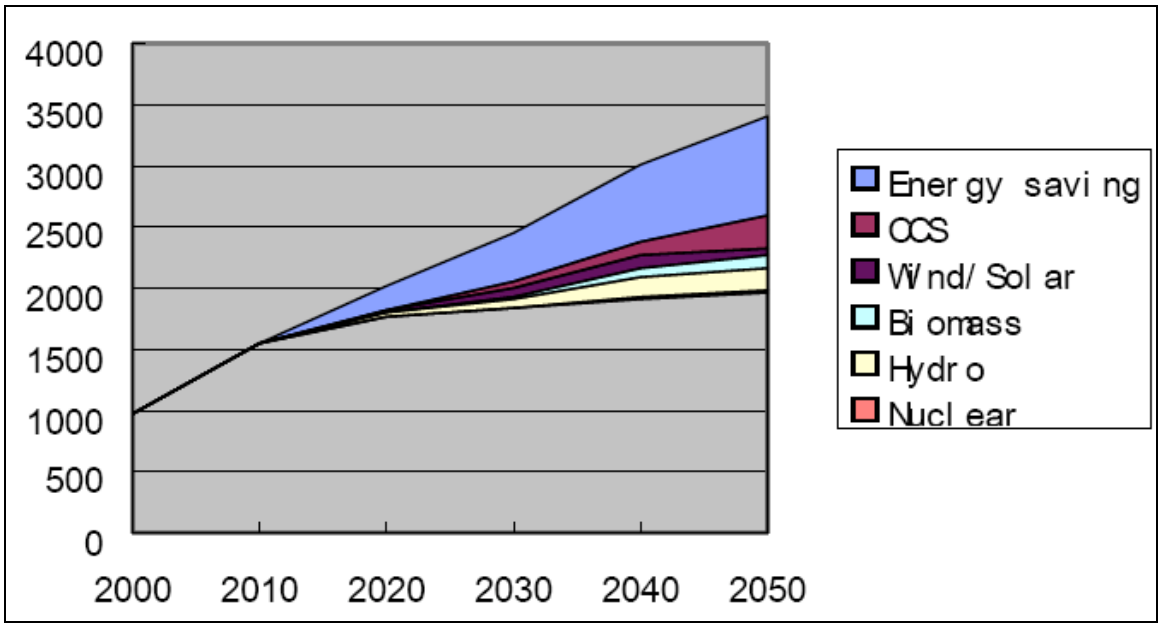
Clearly, the central government needs the cooperation of local officials, but the lack of such cooperation has been a major reason for the failure to meet energy efficiency and environmental goals to date. To gain local officials' cooperation on the environmental issues, new kinds incentives need to be provided. Even if the green pursuit has been slightly considered in their performance evaluation, typically, local officials have been promoted based on how fast they expand their local economies. To correct the currently distorted incentive system environmental performance has to gain greater consideration in evaluation criteria.

Fines must also be raised. The current maximum fine of 200,000 Yuan, for not respecting the regulation, is hardly a deterrent to companies. Many environmental laws exist only on paper, and are weakly enforced. China is missing a monitoring system, which needs to be established and managed.

However President Hu Jintao and Prime Minister Wen Jiabao have incorporated energy-saving and environmental goals into the five-year economic blueprint to clearly distinguish their vision of China's development from that of their predecessors. Last year's results were disappointing, but encouraging signs are now being seen, and hopefully, energy saving will play the most important role in reduction of carbon dioxide emissions over the next fifty years (see chart below).

[14] Source: Hepeng Jia, China misses energy efficiency targets. January 15th 2007. From SciDev.Net

Fig. 5 – Contribution to Carbon Dioxide emission reduction in China, 2000-2050



Unit: Million tons of carbon dioxide (Mt-C)

Source: Energy System Analysis Center, ERI, China Liu Qiang 2007

At the annual session of China's the National People's Congress, Premier Wen Jiabao stated, “We must make conserving energy, decreasing energy consumption, protecting the environment and using land intensively the breakthrough point and main fulcrum for changing the pattern of economic growth” even if it will mean to reduce the GDP growth speed from 10.7 percent to 8 percent annually.

The central government is starting to explore other ways to enhance the efficacy of environmental monitoring and compliance. From April 1 this year, SEPA is working with the People’s Bank of China (China’s central bank) on a new credit evaluation system under which environmental compliance records of companies will be incorporated into the Bank’s consideration of whether or not to provide loans. The Bank could turn down requests for loans from firms with poor environmental records[15].

[15] Source ZhongXiang Zhang, March 13th 2007. From East West Wire, eastwestcenter.org

Development of Renewable Energy

Abstract: *Renewable energy includes all the sources that are regenerative and cannot be depleted with use, namely Hydro, Solar, Wind, Biomass, and Geothermal. The technology for the exploitation is well developed, but high production cost limits their spread over the world. China has a huge amount of resources in hydro, wind and solar. In the long run, they can represent a big potential for the differentiation of energy supply mix. At present they are a successful solution for the electrification of remote areas, and bring forth the economic development of rural regions. The government has shown the will to increase their importance and has already set a 2020 target for all renewable energies to be 16 percent of total energy consumption.*

With the term Renewable Energy (RE) we identify all the sources that can be used to produce energy without using fossil fuels. The Unites States Department of Energy (DOE) defines it as "energy derived from resources that are regenerative or for all practical purposes cannot be depleted"[16].

The definition is wide and includes several sources from which energy can be obtained:

- **Water power**, includes all forms of moving water:
  - Hydropower,
  - Wave power,
  - Tidal Power,
  - Ocean thermal power,
  - Blue power.
- **Solar power** refers to the energy collected from the sunlight and used both for heating and electricity production:
  - Solar Photovoltaic (PV),
  - Concentrated solar power,
  - Solar updraft tower,
  - Solar water heating (SWH),
  - Solar ovens,
  - Solar cooking,

[16] US Department of Energy, Glossary of energy related terms from http://www.eere.energy.gov/consumer/information_resources/index.cfm/mytopic=60001#R

- Solar chimney.

- **Wind Power**, that is the conversion of wind energy into more useful forms, it includes:
  - Wind Mills
  - Wind Turbines
- **Solid Biomass,** combustible used directly to produce heating or electricity or indirectly through gasification process.
- **Biofuels**, liquid combustible used mainly for transportation, the most spread are ethanol (surrogate for gasoline) and biodiesel (surrogate for diesel).
- **Biogas,** the gas produced by a current waste stream, with heating properties similar to natural gas.
- **Geothermal**, the energy obtained from the heat of the earth itself.

All of these sources share qualities that are more environmental friendly than fossil fuels, since they do not produce as many greenhouse gases and other pollutants as fossil fuel combustion. Indeed water, solar, wind and geothermal power are carbon free and biomasses are carbon neutral[17].

Traditional uses of wind, water, and solar energy are widespread in developed and developing countries; but the mass production of electricity using renewable energy sources has recently become more commonplace, reflecting the major threats of climate change, exhaustion of fossil fuels, and the various environmental and political risks of nuclear power. Consequently, many countries' governments have already started to promote renewable energies through tax incentives and subsidies.

Renewable technologies such as geothermal and hydropower are already used economically without subsidies in many countries. Other technologies such as solar power are substantially more expensive, although future costs are expected to decline to a fraction of current levels.

Referring to the present energy situation in China, a series of elements have made them a suitable solution for the country:

- The renewable energy market is growing worldwide, and according to UNDP predictions in the second half of this century the renewable energy will take the primary position. The related opportunities of development of

[17] Carbon free is the technologies that do not produce any carbon dioxide emission in the energy production process. Carbon neutral are technologies who produce carbon dioxide emissions, like burning biomasses, but the same amount of carbon dioxide is absorbed by the photosynthesis during the life time of the plants, therefore if the cycle is completed the emissions are null.

new technologies represent a must-have industry for the safeguarding of national economy, societal development and security.

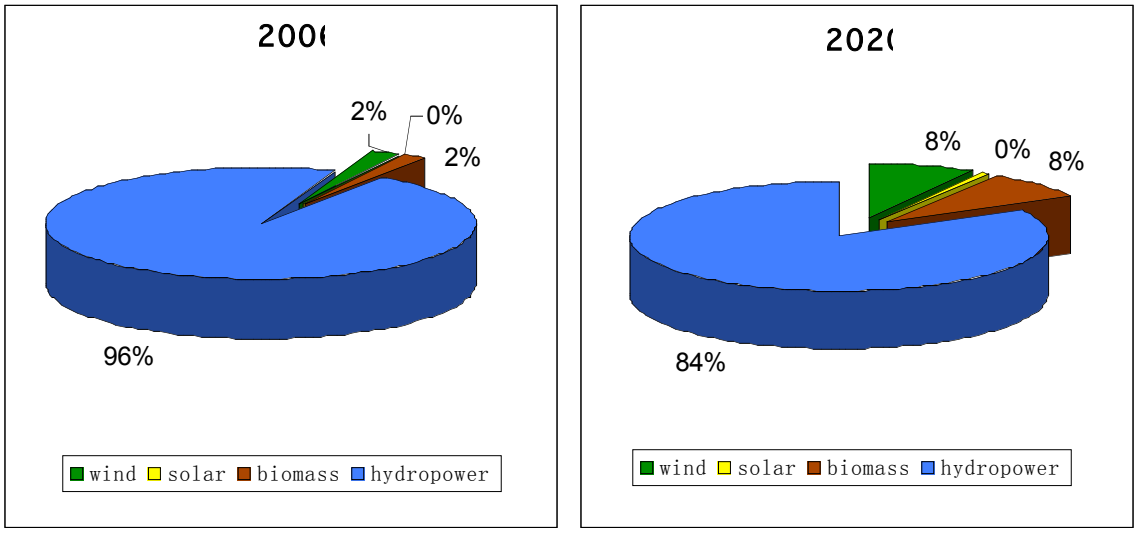
- The necessity to find a solution for electrification of remote rural areas, where off-grid power consumption is already a hot target in the policy landscape.
- The will to sustain economic growth while protecting the environment.
- They represent a viable solution to face the need for differentiation in the energy production mix, to prevent the chance of shortfalls in the import of oil and natural gas.
- The rich potential of exploitation of renewable resources, as solar, wind, hydro and biomass, of which China is largely endowed.

Considering these present problems and the future challenges, Chinese government, in the eleventh five-year plan (FYP), set up the ambitious target of reaching 16 percent of the overall energy production share made by renewable sources by 2020.

At present all the renewable energy sources account for about 8 percent of the total installed capacity (~600 GW in 2006). Not all the resources have the same importance (see chart below). China has huge available resource of water, solar energy and wind, however hydropower and small hydropower (SHO) hold more than two thirds of the share because of the use of relatively old technology and low production cost. Biomasses are largely used for heating, and the expansion on large-scale use for electricity production is going to be implemented. Wind power is in the initial phase, but great development is expected for the next years. Solar power is already heavily utilized in water heating, while the photovoltaic is still in the experimentation phase mainly due to the high cost of production. Geothermal does not represent an important quota due to the lack of resources available in the country.

In the next few years, all of the sources will increase in importance, but the relative weight will more or less be unchanged till 2020 (see chart below).

Fig. 6 – Shares of Renewable energy quota, 2006 (total installed capacity 128 GW), 2020 (total installed capacity 362 GW)



Source: China Statistical Yearbook, and NDRC forecast, adaptation.

Solar Photovoltaic

***Abstract**: China is the world biggest user of solar power for water heating, accounting for 40 percent of the global share. Solar photovoltaic (PV) however is still limited with an installed capacity of 80MW, representing less than 1 percent of the country's total power. The main use is in remote areas in independent systems, while grid connected PV is under experimentation. The mid-term government target is 1.8 GW by 2020, but it is expected to have a breakthrough after a half-century, when the production cost will decrease enough.*

Solar photovoltaic is the world's fastest growing technology. In China, its methods of use are essentially thermal like solar water heating (SWH), while only slightly Solar Photovoltaic (PV).

China's PV market capacity was limited at a total installation capacity of 80MW in 2006. During the last years, the additional capacity installation was limited, but it is expected to make a breakthrough in 2007 along with the arrival of the Olympic games, since it will be part of the green Olympics propaganda, reaching a considerable market scale after 2009.

The government medium term target is to reach at least 1,8 GW of installed capacity by 2020.

At present, Chinese PV market is not large in scale. It mainly consists of some demonstration projects in developed areas and township electrification programs in remote areas, used for electricity supply to the household, traffic and communication signs where there is lack of electricity or grid connection.

Some experiment and demonstrations of grid connected PV electricity generation systems have already taken place. There are already 10 solar PV battery power plants all over the country, whose total capacity is about 20MW.

On the other hand, China is the world's main user of solar water heater. There is an installed capacity of 52 million M3 all over the country, representing 40 percent of the global volume of its use.

Industry analysis

The first silicon solar energy battery appeared in USA in 1959. In the beginning it was used in space programs, and after the energy crisis of 1973 it started to be used in the ground.

In China, the use of solar PV started in the 80's, with the sixth and seventh five-year plans, when the national government began to support the development of Photovoltaic industry and its market. But it was only in the late 90's that the

application field was developed, with the initial formation of the PV industry and the reduction of production costs.

Today there are two kinds of generation systems:

- **Independent PV**, used in remote areas, where the grid is not present or the connection is not economically convenient. It is used to provide power supply in small villages. There are household solar power supplies systems, electrical sources for communication signals, streetlights and other independently running PV systems with storage batteries.
- **Grid connected PV,** generation systems connected to the electrical network. They are roof connected PV systems and a Desert Power Plant System. The first kind can vary from several KW to some MW, but for the moment it's still in the demonstration phase, while the desert plants can reach several MW, but there is no concrete application in the country yet.

Resource potential

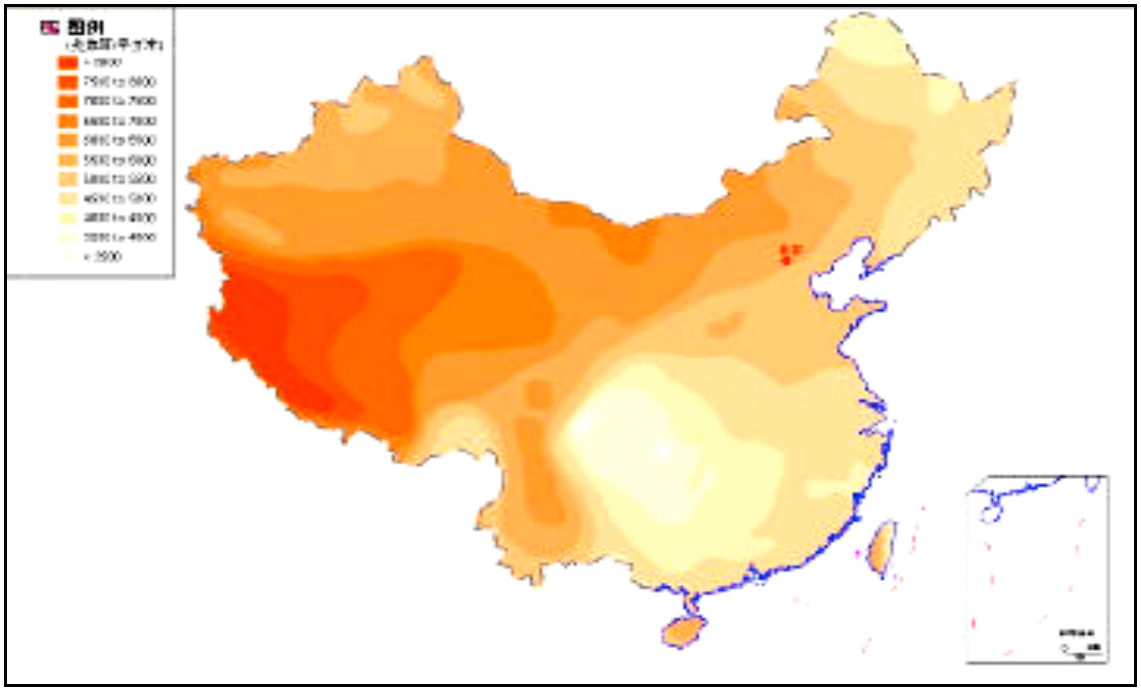
In the whole country, the annual solar radiation energy on the land surface is about 50 MJ, equivalent to 170,000 millions of tons of coal equivalent (Mtce). The annual solar radiation in China is on average 5,852 MJ/m2/yr (equivalent to 140kcal/cm2/yr), but it can be as high as 8,400 MJ/m2/yr (80-200 kcal/cm2/yr)[18]. The areas where solar energy is abundant include the west regions on the Tibetan plateau in Tibet, Qinghai, Xinjiang, the north-east area of southern Inner Mongolia, Shanxi, north Shaanxi, Hebei, Shandong, Liaoning, and partially west Jilin, middle and southwest Yunnan, southeast Guangdong, southeast Fujian, east and west Hainan, and southwest Taiwan.

Solar radiation is the highest in the Qing-Zang Highland (see map below). The average elevation of this area is more than 4,000 meters above sea level; the atmosphere is thin, clean, and very transparent, the latitude is low and sunlight exposure time is long. For example, in Lhasa City (Tibet province), which is called the "Sunshine City," the annual average sunlight is 3,005 hours, the comparative sunshine rate was 68percent, the annual average of clear days was 108.5, and the total solar radiation was 8,160 MJ/m/yr[19].

18 Data source: LI Junfeng, Commercialization of Solar PV Systems in China, Center for Renewable Energy Development (Energy Research Institute)

19 Ibidem

Fig. 7 – Map of Solar Resources over the country



Source: UNEP report for solar and wind assessment, 2005

Developing Pattern

Given that solar energy is a clean, safe, reliable energy source, it is considered one of the major energy sources in the post 2050 world.

China has great potential for development, since most of its areas are rich with solar energy resources. Once the PV power cost becomes competitive, it will be an important replacement for power.

In China in the short term, before 2010, the major utilization of solar PV will still be to provide power in remote areas and for industrial use, but at the same time, grid-connected PV will be a demonstration stage, with several MW stations. The total installed capacity will reach 350MW.

In the medium term, by 2020, grid-connected PV including roof systems and desert systems will be the main utilization of solar energy, and will contribute more consistently in the renewable power structure. NDRC's Energy Research Institute forecasts that the growth rate of solar energy will be more than 50 percent in 2020, and the total capacity will be at least 1.8 GW, however this will represent less than 2 percent of the total installed capacity at that time[20].

[20] According to the Government forecasts the installed capacity in 2020 will be at least 1000 GW.

Considering long-term development, solar PV has the resources for producing thousands of MW and can become one of the important strategies to replace energy in China.

Market Potential

In the eleventh five-year plan there is a strong emphasis on promoting a sustainable path of development, where the gap between rich and poor areas and between rural and urban areas can start to be filled. In this context, the implementation of an **independent village PV** generation plan and grid-connected station projects can help to solve the problem of insufficient electricity in many areas.

At present there are still 30 million people without any electric power supply in 28,000 villages all over the country[21]. They have a small amount of diesel power generation to have light for 2-3 hours a day; otherwise they use oil lamps and candles for lighting. Most of the villages without power supply are in the western part of China, where solar resources are abundant and PV generation has great market potential. Even if the project of *sending electricity to villages* basically resolved the problem for many of them, the problem has yet to be eradicated. And for the remaining villages the market potential will be about 3,000 MW.

The government plan is trying to solve the power supply problem for all the villages with more than 50 households, and at least 15 percent of the scattered households without power, before 2020, while its mid term target is to solve the power supply problem for 1,000 villages and 1 million households by 2010. This represents an incremental PV consumption capacity of 265MW, which will reach the cumulative target of 350MW by 2010.

On the other hand, over the next few years there is no expectation of significant development in the **grid connected power** system. Only trial project of very large-scale PV power station will take place before 2010, in a location close to the main grid in order to reduce the incremental investment on transmission wire.

Government support

While main energy policies have been formulated in China, there is still a need to implement specific supporting regulations in order to solve other issues such as high power generation costs with limited subsidies, coordination with the State Grid Corporation and the formulation of grid connection standards.

[21] Source: China Daily, September 29, 2006

“Industrial support” and “promote regulations” stated in eleventh Five-Year Plan have produced limited effect up to now, on the development of the domestic market scale. Therefore, due to its small base, even if the domestic PV market had a growth rate of about 30-40 percent, it is difficult for the market to reach large scale before 2010. However, given its great potential, several international companies have begun to express their interest in the Chinese market.

The government is not considering the idea of using subsidies for the high price of PV electricity. However, to increase investment in crystalline silicon production, subsidies are practical and necessary. Hopefully, as it is stated in the eleventh Five-Year plan, an amount of 3 billion Yuan will be allocated to develop crystalline silicon industry in 5 years by the NDRC[22] jointly with the Ministry of Science and Technology (MOST), and Ministry of Finance (MOF).

Trends in Chinese PV industry

In terms of diversification of the research, China's PV companies have taken less risk than enterprises in developed countries. The unique value of PV products lies in the long-run investment return. Therefore, the quality of their products and conversion efficiency is decisive for judging the enterprises value. In any case, the growth of investment in a domestic downstream production line will appear in late 2007 and a downstream enterprise will appear to be polarized to certain degree in 2007-2008[23].

Since the PV industry in China is developing rapidly, its industrial scale and technological level has also improved. However compared to developed countries, the gap is still very large. During the past few years, cell/module production developed rapidly, and its 2004 output is six times its output in 2002, due to the *Sending Electricity to Villages* project and high demand from the international market.

At the same time, cell and module quality has been improved greatly, while cell costs have decreased. In the past twenty years, the price has decreased from 65-70Yuan/W in the 1980s to 24-28Yuan/W in 2003, but it returned to 28-32Yuan/W in 2004 due to the international shortage of solar silicon.

Production output in 2004 reached 50MW, of which only 10MWp module was consumed in the domestic market and the rest was exported abroad.

Concerning the technology for production of PV cell and module, *Mono-crystalline silicon* is the main raw material. It seems it will remain so for at least the next 10 years. China is missing the natural resource of silicon, and more than 95 percent of its raw materials are imported from abroad. Price difference is significant and the international shortage of solar silicon increases the price.

[22] National Development Reform Commission, the Chinese macroeconomic management agency, under the State Council.
[23] China Photovoltaic Industry Development Report, 2007

Therefore, due to the current situation of the high price of raw materials is a good time to develop *multi-crystalline silicon* technology. Domestic enterprises of polycrystalline silicon need to take this the chance, even if they will encounter the challenges of improving technique and energy consumption reduction in the future.

In the PV terminal market, price falling is a natural trend. The development process of the PV market will accompany the PV price fall and related adjustments by government from time to time. Thus, the key for PV companies to upgrade their competitiveness lies in scale production, technological improvement and management.

Wind

Abstract: *Wind is an important resource for the future supply of electricity in the country. China has a potential of 1000 GW of exploitable wind power both onshore and offshore, an amount equal to the total forecasted installed capacity in 2020. At present the use is limited to 2 GW, but the mid term target is set at 30 GW by 2020. Considering market trends, the target will likely be overtaken. However important issues must be faced, such as the upgrade of domestic manufacturing, the feed-in system instead of the actual tendering, and the grid facilities to connect new big wind plants.*

Wind power is the conversion of wind energy into more useful forms, usually into electricity using wind turbines. Traditionally, wind power has been used in windmills to do physical work, such as crushing grain or pumping water. Most modern wind power is generated in the form of electricity by converting the rotation of turbine blades into electrical current by means of an electrical generator[24].

At the end of 2006, the worldwide capacity of wind-power generators was 74 GW. Although this capacity currently only produces less than 1 percent of global electricity use, it is growing at intense speed: capacity quadrupled between 2000 and 2006.

In China Wind power accounts for only 2 GW in 2006, but its growth potential is extremely high. The country has a vast territory with a long coastline possessing resourceful wind energy. There is a huge amount of wind energy potential: over 3,200 GW. Among them, around 1,000 GW are considered exploitable: 253 GW onshore and 750 GW offshore[25].

Therefore the government has already planned to make advances towards increasing their usage of wind power, which is expected to reach 30 GW of installed capacity within 2020.

Wind power can be used in large-scale wind farms for national electrical grids as well as in small individual turbines for providing electricity to rural residences or grid-isolated locations.

[24] Adapted from wikipedia.org in Wind Power

[25] Source: Shi Pengfei, Expert committeeman in China Hydro Energy Consultants Company - 2005

Resource Potential

As China is a big country with a lot of wind, it's resource potential is high, but it is not equally distributed. The country has huge area with complex orographic condition and this influence the distribution of wind energy (see map below).

The most important resource areas are:

- **North and west area**: including three provinces in the northeast country: Heibei, Inner Mongolia, Gansu, and three in the west: Qinghai, Xingjiang and Tibet. These regions represent the biggest wind energy zone in China. There is no destructive wind and due to plainness of their land they are suitable for a large-scale wind farm to be connected to the national grid. The main problem in these zones is the small capacity of the actual local electricity networks that limit the scale of the plants, and the fact that these regions are far from the loading centers, mainly the big cities in the costal areas.

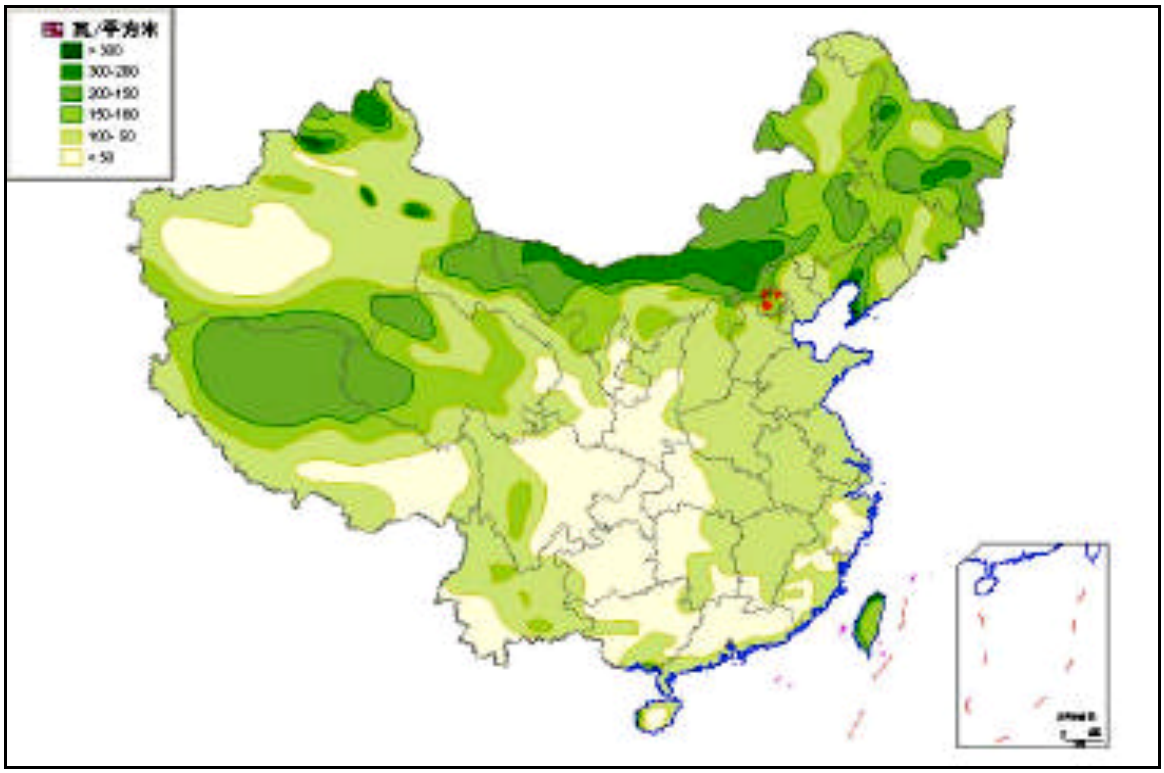
- **Littoral area**: mainly in the provinces of: Shandong, Jiangsu, Shanghai, Zhejiang, Fujian, Guangdong, Guangxi, Hainan.

  These areas are characterized by cold air in spring and winter, and typhoon in summer and autumn. They represent a huge potential energy source. These areas are close to the loading center of the economy-advanced cities, and they have a well-developed electricity system.

  The problem is that most of these areas have been exploited by aqua farms or are shelterbelt, so that the available land for wind turbines is very narrow.

- **Offshore zone**: these are the areas of seashore water between 2 and 15 meters deep, it is very large area close to the electricity loading center. Unfortunately this technology is yet to be well developed and the price of production is very high. It represents a high potential for the future, considering that its exploitable power potential is 3 times the onshore potential.

Fig. 8 – Map of wind resources over the country.



Source: UNEP report for solar and wind assessment, 2005

Industry analysis

The first wind farm in China was set up in Rongcheng, Shadong province in 1986. Since then the national technology has greatly increased in development.

At present there are over 20 manufacturers in the wind power sector in China. They have developed turbines technology up to 750KW, while they have been working since 2005 on sample projects for 1.2 and 1.5 MW turbines. However compared with international standards, Chinese manufactures are still lagging behind the cutting edge technologies of large wind turbines. Already the most advanced technology available is for 5MW turbines.

The cumulative market share of Chinese manufactures was 31 percent by the end of 2006, while the rest of the market share is produced by foreign owned manufactures or joint ventures.

The cost of production is decreased over the last few years, from about 1yuan/KWh in 1995 to about 0.6yuan/KWh on average today. The cost of production depends mainly on the initial investment and the full loading hours of the plants. Since the country is wide and its territory conformation is varied, this figure differs greatly from an area to another, as shown in table below:

Considering that the average investment outlay in the country is around 9,000yuan/KWh and the equivalent full load hours are 2,000 on average, the price is about 0.63yuan/KWh. However this price is still about twice the average price of thermal power (on average it is around 0.30 Yuan/KWh). This is the main obstacle to this kind of energy gaining competitiveness.

Market trends and existing problems

Considering the huge country potential and the targets defined by the Chinese government there is a bright future for development in the wind sector. However some problems need to be faced:

- The government set a requirement for 51 percent of Chinese capital in joint ventures and a requirement of 70 percent of domestic made components; otherwise the projects are not approved. This represents a big obstacle to the welcoming of foreign investments and industry development.

  Reducing such kind of restrictions can open up the market and allow more foreign investments to bring advanced technology to the country.

- The existing manufacturing level is far behind the technological needs of the market. The power of domestic finalized wind turbines is below the MW level (maximum 700KW), while the most needs are for MW level types, up to 5 MW as they are in European countries. Independent research is too weak and the minimal research funds input by the government are inadequate.

  A new emphasis on research should be guaranteed by both public funds and a higher price that can allow more R&D activities by the companies.

- Wind power pricing is relying on a tender system that assures low costs, but undermines the quality and the investments in R&D. This can be effective in the short term, but is not sustainable in the long run. The effect is that after only 2 years of work there's a failure rate of 30 percent among the Chinese manufactured turbines. With the immediate consequence of reducing the energy output and increasing the cost of production per unit.

  A feed-in system price, as it is already implemented for all other forms of renewable energy represents the most effective solution as is shown by the European experience, where the countries that adopted this system presented the highest industry growth rate.

- The electricity network lacks the facilities for connecting new big wind power plants. The wind energy is clean, since it doesn't produce any carbon dioxide, but brings a lot of negative externalities to the grid. Wind power lower the precision of predicting the network load and affects the

schedule and operation ways, the voltage adjustment, the distribution, the accident level and in general the quality of electricity and the stability of the network. This is due to the intermittence and wave character of wind power.

To overtake this drawback the network companies need to invest in research and equipment, in order to develop a national grid able to welcome more wind power. The Spanish experience shows that with the adequate technology wind energy can be used in the grid in large amount, next to the traditional sources.

Biomass

Abstract: *Biomass includes solid biomass, biofuels and biogas. Solid biomass represents an important substitute of coal as a solid combustible. In China they are mainly agriculture and forestry residue, but also industrial and domestic waste and livestock excreta. At present biomasses are largely used as fuel for burning in households of rural areas, but the related industry for production of electricity is still limited. In 2005 the total installed capacity was 2 GW, and the target for 2020 is 30 GW. Since there is an abundance of raw material, biomass use can increase drastically. However some problems limit the large-scale use, such as scattered distribution and seasonal production. While technological, economic and policy barriers need to be overcome.*

Biomass energy or "bio-energy" is the energy produced from plants and plant-derived materials. It has been the first source of energy since people began burning wood to cook food and keep warm.

Today there are several kinds of technology available to exploit the energy stored in the biomasses. Biomass can be used directly as fuel or used to produce liquid biofuel, or treated to obtain biogas.

Direct use is usually the utilize of **solid biomass** in the form of combustible solids, wood or other forestry residues, organic municipal solid waste or combustible field crops. Field crops may be grown specifically for combustion or may be used for other purposes, and the processed plant waste may be then used for combustion.

Most sorts of biomasses, including dried animal excreta, can actually be burnt to produce energy in the form of heating, to heat water or to drive turbines and produce electricity.

Liquid biofuel is usually either a bio-alcohol such as ethanol or a bio-oil such as biodiesel and straight vegetable oil. They are largely used as fuel for transportation. They have the advantage of using natural renewable sources and drastically reducing the emissions of pollutants compared with fossil hydrocarbures.

In some countries there are cultures specifically devoted to produce **ethanol**, like corn, cornstalks, sugar beets, sugar cane, and switch grasses. The technology to produce this kind of natural fuel is already well developed and is being phased into the current energy infrastructure. For example in Brazil ethanol is sold to consumers as surrogate of gasoline as E85 (a fuel composed of 85 percent ethanol and 15 percent gasoline) or even higher percentage. The cost is basically comparable with the gasoline obtained from oil, but it requires a tailor made engine in the car.

Biodiesel on the other side has got the advantage that it can be used in modern diesel vehicles with little or no modification to the engine. But the production cost is still higher and therefore it is not yet well widespread.

In the future, there may be biosynthetic liquid fuel available produced through the Biomass-To-Liquids (BTL) process[26].

Biomass can also be gasified, and used to produce heating or electricity.

Biogas can easily be produced from current waste streams, such as: paper production, sugar production, sewage, animal waste and so forth.

These various waste streams have to be slurred together and allowed to naturally ferment, producing methane gas. When a biogas plant has extracted all the methane it can, the remains are sometimes better suitable as fertilizer than the original biomass.

Alternatively biogas can be produced via advanced waste processing systems such as mechanical biological treatment. These systems recover the recyclable elements of household waste and process the biodegradable fraction in anaerobic digesters[27].

Biogas can be upgraded to renewable natural gas (a gas with similar properties to natural gas) and distribute to the mass market through traditional grid and used for electricity production, heating or water heating.

There are many benefits, from using biomass, as a direct surrogate of fossil fuels:

- First of all biomass energy has the potential to greatly reduce GHG emissions. Burning biomass releases about the same amount of carbon dioxide as burning fossil fuels. However, fossil fuels release carbon dioxide captured by photosynthesis millions of years ago, which means it's a new, additional greenhouse gas, while Biomass releases carbon dioxide that is largely balanced by the carbon dioxide captured in its own growth.
- Biomass can be used with the same technology, or slight adaptation, used to burn coal; it is in fact possible to use a mix of coal and biomasses to be burned in boilers.
- The use of biomass can reduce dependence on oil, because biofuel is the only renewable liquid usable as fuel available for transportation at the moment.
- Biomass energy supports agricultural and forest-product industries. The main biomass raw materials for power generation are agriculture and forestry residue, but also paper mill residue, lumber mill scrap, and municipal waste.

[26] Source: Wikipedia.org
[27] Source: wikipedia.org

For ethanol, the feedstock is mainly sugarcane, corn and sugar beets, but also bagasse, sorghum, barley, et many others.

For biodiesel they are soybeans, palm oil, rapeseed, jatropha, and others crops.

In the near future agricultural residues such as corn stover (the stalks, leaves, and husks of the plant) and wheat straw will also be used. Ethanol could be extracted also from cellulose through a chemical or enzymatic hydrolysis.

Long-term plans include growing and using dedicated energy crops, such as fast-growing trees and grasses, that can grow on land that will not support intensive food crops. For biodiesel production also algae culture represent a promise in the future, since micro algae grow faster than any other plant on the land.

Globally, Biomass represents the fourth most important source of energy after Coal, Oil and natural gas.

In China, biomasses are largely used as fuel for burning in the households, but the related industry for production of electricity is still limited. In 2005 the total installed capacity was around 2 GW, and the government set a target of 5,5 and 30 GW to be reached respectively by 2010 and 2020. In many rural areas, where biomass resources are abundant they represent the main source for the heating systems.

Industry analysis

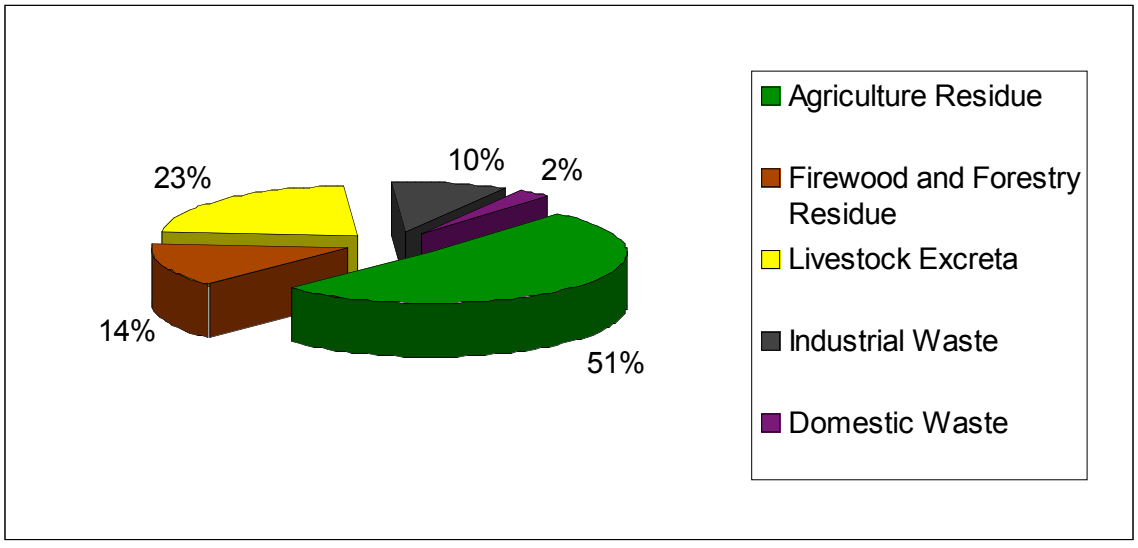
As described Biomass is a multiform source of energy, there are many sources from which is possible to extract energy. Not everyone has the same importance in terms of quantity available and energy stored inside. All over the country agriculture residue represent the most important part of biomass, however other sources are available[28]:

- **Agriculture residues**. At present, they represent the main source of biomass in China, they account for more than 50 percent of total biomass production. The processing of crops like rice, wheat, corn, beans, sugarcane, cotton, tubers produce residues for 715Mt per year, that can produce energy for an equivalent to 250Mtoe
- **Firewood, and forestry residue**. Is another important biomass resource, with a production amount of 157Mt per year that are equivalent to 67Mtoe. The forests in China are concentrated mainly in the regions of the northeast, southwest, northwest, and southern hill areas.

[28] Source: Ma Longlong, Chinese Academy of Sciences, Guangzhou Institute of energy conversion 2005

- **Livestock excreta**. They are the organic residue of the livestock: pigs, sheep, fowls, horses, cattle, donkeys, mules and camels. The total amount of excreta is weighted around 320Mt per year, equivalent to 110Mtoe.
- **Municipal waste**. They are the mixture of household, commerce, and service garbage. They amount to about 150Mt, but they are increasing at 10 percent per year. The heat value is different among different cities (depending on population composition, income, fuel structure and eating habits), on average it is 3,400KJ/Kg, that means that 150Mt can produce on average energy equivalent to15Mtoe.
- **Industrial waste**. It includes solid wastes from grain factories, paper mills, timber mills, sugar refineries, wineries and food factories. It has estimated in 48Mtoe.
- **Bioenergy crops**. At present in China there isn't yet such industry. However, according to statistics China has great potential to exploit it: China has 1.3million Km2 of cultivated land and 1.08 million Km2 of land not yet reclaimed, including 354,000 Km2 available cultivated land. If this area is used to grow some kind of bioenergy crops it can produce biomass for 177Mt equivalent to 80Mtoe.

Fig. 9 – Share of Biomass Sources, 2005



Source: Chinese Academy of Sciences Guangzhou Institute of Energy, Ma Longlong 2005

Technology status and development trends

The technology necessary to produce energy out of solid biomasses is relatively old and it is already well developed. In China however, most of its use is through simple combustion for production of heat. It is used in the households of most rural areas. However this process is really inefficient and only modern system are able to combine the heating, with cooking and the production of hot water.

For the production of electricity the most widespread technology is direct combustion. Biomasses are burned in boilers and a steam turbine generates power. This technology is generally mature and the cost is low, but the average production scale is small and highly inefficient.

The biomass direct combustion power technology is efficient and unit investment is reasonable when the production scale is large. But it requests the biomass concentrated. In China they are scattered, therefore, considering collection and transportation, their costs increase for numerous kinds of biomasses.

Since in the small power plant the investment is high as well as inefficient, a viable solution is mixed combustion with biomass and coal in large-scale coal power plants. The advantage is that equipment made for production through coal does not need to be greatly altered. It means low investment costs, but it can still significantly reduce carbon dioxide emission.

Despite biomass mixed combustion power technology being economical, it seldom applies in China, because it is short of effective operation and out of subsidies or protecting policy[29].

Even if simple direct combustion is the most widely used technique, especially in the rural areas, biomass gasification represents the technology the market is going towards. The first studies started in the 70's and today The Chinese Academy of Sciences (CAS), the Guangzhou Institute of Energy Conversion have carried out many experiments on cycling fluidized-bed gasification and the equipment necessary. This technology can reach a target of efficiency over 40 percent that is very high compared with the average of 20-30 percent of simple combustion. It is the most utilized technology in developed countries.

In China the technology developed has the characteristics of low investment, and low cost and flexibility, and one of the most competitive technologies. Small-scale power generation, which is suitable for utilizing scattered biomass, has been in the business demonstration stage.

[29] Source: China Renewable Energy Development Strategy Workshop, November 2005

Controversial Technology

Since there are several advantages for using biomasses, their use is growing all over the country it, especially in the rural areas, where agriculture residues are more abundant:

- It is logical to use both agriculture and municipal waste materials, where they are available in abundance.
- Biomass represents a viable solution for solving the problem of providing electricity to rural areas.
- The trend for biomass raw material costs, as well as the running costs for energy production is destined to fall, due to the technological advancements. While the cost for using fossil fuels will increase, at the moment coal represent the cheapest source of energy.
- Use of Biomass instead of fossil fuels, is more environmental friendly, since it allows a reduced demand for the Earth's resources, and most of all it reduces the amount of greenhouse gas emissions, since carbon balance is null when the cycle is completed.

However, given the present situation in China there are some critical points that create obstacles the spread of this technology at higher levels:

- Collecting the waste in sufficient quantities can be difficult, especially considering the situation in the countryside, where most of the waste come from scattered small size source. This influences negatively the size of the power plants that can work with biomass. Unless they are collected and concentrated to be used in big power plants. But of course, this increases the price and reduces the environmental benefit since the transportation system contributes to pollutant emissions.
- Some waste materials are not available all year round, due to seasonal production of many agricultural cultures. This implies to produce stocks or compensate the lack of biomass with other fossil fuels.
- Energy comes from the burning of Biomass. Therefore CO2 emissions are present, but they are compensated with the amount of CO2 absorbed during the lifetime of plants or crops. Carbon dioxide emission is null, because the emissions and absorption are the same amount, while using fossil fuels the emissions are “new”, since the plants have absorbed the equivalent amount of CO2 thousands of years ago. However the carbon cycle must be completed, this means that new plants must be planted in the same amount that they are burned. If not, the emission amount will be positive, that means production of Greenhouse gas, in the same manner coal and oil do.
- There are several barriers restricting the application of biomass power technology in China, mainly referable to:

- **Technological barriers**: the research is scanty due to the scarcity of capital for research and powerless equipment enterprises in China. It is mainly attended to small-medium scale biomass gasification for electricity generation. There is a lack of experience in the application of biomass power technology. Except for a few biomass gasification technologies in the demonstration stage. Holistic research is not good enough.
- **Economic Barriers**: there's lack of investments and it is hard to raise money. As described, the typical biomass project has the characteristic of a small scale, relatively high cost and low density of capital investment. Investors invest with discretion considering decentralization of capital and problems of management, because biomass is full of investment risk and not completely understood, it is thus difficult to get a bank loan at present.
- **Policy barriers**: The policies made by the government are limited to general renewable energy and are mainly instructional and not imperative. There is a lack of economic encouragement. The lack of subsidies directly affects the propensity of local government to develop renewable energy.

Hydropower

Abstract: *With about 118 GW of installed capacity all over the country, hydropower is the most important source among renewables. Particularly important in China is small hydropower (SHP) – plants less than 50MW – that up to now constitutes the most successful solution for bringing electricity to remote rural areas, and represent 40 percent of total hydropower. With over 5000 rivers, China has a huge hydropower potential, of which 378 GW are considered exploitable. The government set a target of 300 GW by 2020 of which 88 GW will be of small hydropower. This technology however is not harmless; it comes with environmental problems and the social cost of people displacement. Failures of big dams can cause enormous damages and the biomasses left after the water level lowers produce methane, a GHG with the same effects to global warming as CO2. The main issue to be faced for SHP is the inefficiency due to old technology.*

Hydropower is the technology that captures the energy of moving water and transforms it into electricity. Prior to the widespread availability of commercial electric power, hydropower was used for centuries to power mills and machinery through the use of waterwheels. Today the most widespread use of hydropower is the use of hydroelectric energy through hydroelectric dams, and future technology will use tidal power and wave power to capture the energy in tidal and waves.

As of 2005, hydropower stations installed worldwide, amounted to 816 GW and they were able to supply 19 percent of the world's electricity. Among these, large hydropower produces most of the energy (750 GW installed) small hydropower (SHP) is very widespread and especially in China is very popular. Over 50 percent of the world's shares of small hydropower installation are in China (38.5 GW)[30].

The amount of available hydro energy resource is mainly determined by surface flow and water drop. China has suitable natural conditions with plentiful surface flow and great water drop thanks to the stepped geographical feature of the high drop between the west and east of the country. From the Qinghai-Tibet Plateau to the coastal plain the water drop is over 4,000m. This makes China the world's top country for hydro energy resource potential as well as installed capacity.

In China, there are more than 5,000 rivers with watershed level above 1,000 square kilometers. Among them, more than 3,000 have installed some form of hydro energy plant over 10MW. The total theoretical hydro energy potential is 676 GW. Of these, 378 GW are considered exploitable for a potential equivalent of 1920 TWh of annual electricity production[31]. In 2005 the installed capacity was

[30] Source: Global status report 2006, data updated at 2005. From ren21.net
[31] Source: Liu Jinghe (Ministry of Water Resources) Oct, 2005

of 118.5 GW (80 GW in large hydro and 38.5 in small hydropower) representing almost 20 percent of the total installed capacity.

Small Hydropower

Small scale is defined as plants with up to 50 MW of installed capacity. The country has plentiful areas suitable for small hydropower stations and its total potential exploitable amount is around 120 GW. At present the installed capacity (38.5 GW) represents 40 percent of the total hydropower capacity, but it is only 32 percent of the total exploitable amount which means there is a large room for further development.

Most of the resources are distributed in the west and central regions, especially in the provinces of Guangdong, Sichuan, Fujian, Yunnan, Hunan, and Zhejiang.

In China small hydropower is particularly important because it represents the most successful solution, up to this point, in providing electricity to remote rural areas.

It is considered important that the development of small-scale hydro is combined with the development of rural economy and electrification. Small-scale hydro has played and continue play an important role with a multi-objective system to meet rural electric demand, to reduce the population which cannot enjoy electricity, to alleviate poverty and to protect environment by replacing the traditional electricity sources[32].

Industry analysis

Small-scale hydro technologies mainly include basin plan technologies, hydro building design and construction technologies: generating sets and equipment manufacturing technologies, hydro power plant computer control technologies, power grid automatic management technologies, and power transmission and distribution computer controls technologies.

Over 30 scientific research institutions, including government institutes as well as universities, are active in this sector by doing research and development of the technology and equipment for SHP. Up to now small-scale hydro technologies have been notably improved. The new frontier of hydro technology provides complete automatic control and dispatch as an automation system that can realize no person operating system. The power grid for small-scale hydro power plants has been developed rationally. It is more reliable and flexible and can supply more energy and better quality.

[32] Source: Liu Jinghe (Ministry of Water Resources) Oct, 2005

Unfortunately this technology is not yet widely adopted and most of the plants still work with outdated technology that is usually characterized by high level of inefficiency. However the government goal is to have, over 50 percent of the small-scale hydro power plants and related power grid, modernized before 2010; and to have them completely modernized by 2015.

Also the manufacturing sector is particularly active with over 160 small-scale hydro equipment manufacturers. Among them, over 20 large-scale equipment manufacturers produce mainly turbine and generator set with unit capacity under 50MW and over 100 medium-scale equipment manufacturers who produce turbine and generator sets with a unit capacity under 10MW and other auxiliary equipment.

Developing trends

The Chinese Government has implemented policies that strongly support hydropower, especially small hydropower, which has been included in Chinese rural electrification plans. According to national targets the capacity of hydropower will reach 180 GW in 2010 and 300 GW in 2020: which will be around 30 percent of the total installed capacity. Of these, 88 GW will be for Small hydropower, i.e. 68 percent of the exploitable resource.

In that time, rural electric consumption in China will be 590TWh annual, 13.4 percent of all electric consumption in China, and around 76 percent of this (448TWh) will be supplied with small-scale hydropower[33].

The aim of the government, supporting the small hydropower industry, can be summarized by the following intents[34]:

- To meet rural electric demand and reduce the population which cannot access electricity. At present there are still over 30 million people without access to electricity, they live in remote areas and cannot be easily reached through by expanding the grid.
- To develop rural economy and to raise income in the poorest areas. Exploiting small-scale hydropower can promote the development of family enterprises and workshops, increase rural employment opportunities and therefore raise income.
- To protect the environment.

  Small-scale hydro is a type of clean and renewable energy, since it is not exhaustible and does not produce CO2 emissions. Moreover, small-scale

[33] Ibidem
[34] Ibidem

hydro projects combine river harnessing and power generation, and can be used to manage and protect the environment.

- To substitute traditional energy sources.

  In order to create a more sustainable pattern of development the problem of clean energy production must be addressed. Hydropower represents a viable solution to, at least partially, reduce the reliance on coal and oil.

Existing Problems

Even if Hydropower is a clean renewable source, it involves a series of problems that make it the most invasive towards the environment among all the renewable energies.

- First of all, the impact on the environment is very strong and the implications of building a dam are sometimes more negative than the benefits that can derive from it. Dams worsen living conditions of fish, damage local vegetation, and affect local climate.
- Secondly, hydropower stations do not produce carbon dioxide emissions, but they are also not greenhouse gases free. Recent studies in Canada, Brazil and Finland have demonstrated that big dams, especially in tropical areas, can produce huge amount of methane, another important green house gas. There's no certainty at the moment on how to compare the global warming potential (GWP) of CO2, versus methane, produced by the biomass left after the downstream of the water. However it's important to consider hydropower carefully and evaluate time by time the alternatives available.
- Third, the construction of dams always implies a forced human displacement that of course has heavy social costs. This is particularly problematic for large-scale hydro. For instance, the building of the three gorges plant alone required the displacement of 1.3 million people.
- The risks connected to the possible failure of a hydro plant are the highest among all renewable energy. If a dam fails the consequences can be catastrophic. For instance, the failure of Banqiao dam in 1975 caused over 200 thousands deaths.
- Moreover big dams are considered to be an easy military target, especially for terrorist attacks, since they are relatively easy target, able to provoke big effects. For example the three gorges is considered at risk for a possible attack by terrorists, and it is constantly watched by the military.

In addition to the listed problems due to the nature of hydropower technology itself, the specific characteristics of Chinese small-scale hydropower present a series of related problems:

- Small scale is in itself a drawback in terms of low energy output versus high investment letting the energy price rise. In fact, even in developed countries small-scale hydro cannot compete with the routine energy in markets.
- Lack of scheduling. Since most of the plants are runoff types there is a contradiction between high/low water level and peak/valley electricity with the consequence of waste or shortage of electricity.
- Outdated technology. As seen, most of the equipment is old with low technical and efficiency levels. Statistics shows that the operating efficiency is under 80 percent for half of the plants.
- Conflicting goals: Many small hydropower plants are attached to hydraulic projects. They must first prevent flooding and then supply water for irrigation, which leads to little electricity when they are storing water or preventing floods, and extreme low water operation level when irrigating, etc.
- The supporting policy is limited. Policies are based on planned economy incentives, not on the market. New incentive policies should aim to correct market distortions

Final Remarks

The energy issue

China's global demand for energy supply is increasing at a rate of over 10 percent annually from 2000 to 2005. It is now expected to **grow** at about **5 percent per year** for the next decade, versus a GDP growth of 10 percent annually. Whatever the fuel mix, if economic growth in China stays on course, China is likely to account for 25 per cent of the world's increase in energy generation in the next 30 years.

This has caused a mismatch between power supply and demand, with the result of power supply deficit and the emergence of **power shortages** across the country. Both household and industries are experiencing planned power outages on a regular basis. This is mainly due to the pursuit of economic growth, without taking sufficient regard for the energy requirements involved or enough lead-time to build the necessary generation and distribution infrastructure.

In addition to the issues concerning supply and demand, China must face the problems about the composition of the actual supply system.

As described, the present **energy mix** in China, presents some important problems that could, in the long run, undermine the system's sustainability:

- The proportion of coal is higher than desirable, with all the related problems
- Chinese carbon dioxide emissions are going to be the highest in the world overtaking the United States within this or next year
- Production efficiency of most thermal power plants is far lower than the world average
- Energy consumption per unit of GDP is higher than any other country, five times higher than the OECD[35] average and 10 times higher than Japan
- There is a huge difference between urban and rural areas, the former are consuming twice the amount of energy per capita compared to the latter.

The government now has taken into consideration these issues and is pushing ahead with plans to raise the country's installed generating capacity, in order to face growing demand for energy. The plan is to reach **1,000 GW** of installed capacity by **2020**, or more, according to the international forecast at least 1,230 GW will be necessary to face the demand[36].

[35] OECD, Organization for Economic Cooperation and Development
[36] Capgemini Consultant, in *China Electricity Market 2006* report.

The national energy strategy emphasize the focus of the following drivers:

- **Coal** and oil reserves
- **Energy conservation** plans
- Increasing use of **renewable energy**

It is important to notice that coal is and will remain the main source of energy for at least the next two decades. It will still be providing over half of China's energy needs in 2030.

The ambitious plan to cut energy consumption 20 percent in five years through improvement of efficiency has failed to meet the mid term target for the first year; reduction has been only 1.3 percent against the planned 4 percent.

The renewable energy development plan has been carried out in the eleventh five-year plan and through the ***renewable energy law***, issued last year. The target is ambitious: it plans to use 16 percent of total primary energy from renewable sources by 2020, up from an 8 percent actual share.

Development planning includes technology targets by 2020 of 300 GW of Hydropower, 30 GW of Wind power, 30 GW of Biomass, 1,8 GW of solar PV, and a smaller amount of geothermal. In addition to the power installation there is a target of 300 million M3 of solar hot water, and a target of 12 billion tons of biofuels (10 of ethanol and 2 of biodiesel) by 2020.

The bet on renewable sources

During the last few years renewable energy production has grown on an average of 25 percent per year, reaching the installed capacity of 110 GW in hydropower, 2 GW in Wind power and 2 GW in Biomass plus about 80 MW of solar power facilities installed nationwide in 2006.

However comparing with total installed capacity of 600 GW for all forms of energy, the **overall shares** of renewable sources remain **limited**. The quota is even less compared with the huge country potential in either hydro, solar and wind power.

The country's investments have been high, with $ 7 billion last year, which is almost 20 percent of the global investment in renewable energy.

The private sector is active as well; companies across the country are longing to implement a renewable energy project, since it is believed that will soon become a "gold mine". For the state owned companies, it is the government support that gives them the initial spur.

Foreign companies are attracted in the same way. For example all of the world's biggest wind power manufactures have already established their production facilities in China (Vesta, GE, Gamesa, and Suzlon). The same is true for international financial corporations who are trying to enter the Chinese market by filling the gap in its financial system.

This is because, the 30 GW target of wind power for 2020 alone represents a window of opportunity of US$ 26 billion, and all the renewable sources combined a market of US$ 100 billion in order to reach the 2020 share target of 16 percent of total energy consumption.

And usually local government officials are enthusiastic about promoting renewable energy projects. If on one hand they are not happy to support the closedown of old and polluting power plants, because it can cause economic halt and this influence negatively their performance evaluation; on the other hand, they are supportive towards new investments in renewable energies plants. This is because they represent a lucrative source of government tax revenues, create a "green" government image, and help by adding a "bright spot" to their work performance records.

Unsolved Issues

Many weaknesses still affect the system.

First of all, as seen above, there is a lack of independent technology development. China is importing all of the technology used for most of the renewable equipment, whether for wind, biomass or solar power, from developed countries. This carries the obvious consequence of limited national innovations. The problem is that China is not working hard on the technological frontier. The investments are big but limited in importing technology already well developed abroad. The government is aware of that, and the outline of National Medium and Long term (2006-2020) Program for Scientific and Technological Development, recognized energy as the top area needing "urgent scientific and technological support"[37]. However the funds allocated are not enough to carry out relevant R&D in any of the renewable energy subjects. What is needed are government supported plans in some key fields, cutting edge technology and a large-scale implementation program.

Secondly there is a necessity for the implementation of large-scale plants. To date, excluding large hydro, most of the installed capacity of renewable energy is in small-scattered plants supplying electricity in rural areas. The implementation of large-scale plants is essential to carry on the development of the country. And in order to make a breakthrough in the energy supply system and step away from

[37] Source: Asia Times, September 21, 2006

coal dependence it is necessary to invest in big, grid connected plants like wind farms, desert solar photovoltaic or large scale biomass power plants.

Thirdly the renewable energy law represents an important step, however it is still too general to be practical. There is a lack of enforcement; many of the points are just general principles, not mandatory. Some measures remain controversial and need to be fixed, such as the wind power bidding system to fix the price. It is shared knowledge that this is the worst way to push the industry. Tender system means low price, but prices are actually too low to be sustainable, therefore this means reduction in R&D activities and low quality equipment, that of course will bring failure in the long run, or even in the short run as is already happening to wind turbines after only 2 years. Up to now seven bidding processes have been carried out, and they have been all won by state owned companies. Instead of pushing the industry as a driver for sustainable development, the risk to bring it down under a planned economy system labeled as a bidding system is incredibly high[38].

Another problem to be faced is the lack of adequate human resources. China aims to heavily develop its own industry, however there is a lack of specialized workers available. For instance to supply the wind sector industry alone about 10 thousands experts will be necessary, but among the top 1,000 academic institutions just one offers a degree program dedicated to wind energy[39]. The situation is not different for solar industry and Biomass. It is necessary to address the issue through a coordinated activity among the central and local governments, social institutions and private organizations.

At the same time, prices for electricity have not been allowed to rise sufficiently. Price rises would provide signals both to the power industry to invest in additional generation and transmission capacity and to consumers to enhance their energy efficiency and conserve energy. Last year the rate for electricity consumption rose by 0.025 Yuan per kWh, of which only a very small fraction (0.001yuan/kWh), was being collected for the development of renewable energy. There is basically a lack of support about the energy pricing in the government policymaking. The present system of subsidies is too weak to allow a self-sustained development of renewable energies. There is need for a more concrete approach of cross-subsidies that will allow renewable sources to be competitive with the fossil sources.

Lastly, the pricing method itself, for energy made by renewable sources, is a problem. At present renewable energy is priced using the coal price plus a premium system. Coal price varies widely among different regions, causing an inconvenient paradox: since renewable energies projects tend to be placed in a location where the coal price is higher, that rarely coincides with the optimal conditions for power generation. This is the case, for example, for wind power:

[38] Shi Pengfei, *New Energy Project* part of the *China Hydropower Engineering Consulting* Group, 2006

[39] *Jianxiang Yang, journalist on energy. From: Global Environmental Institute (GEI) Beijing.*

wind farms tend to be installed in the southern regions, because the coal-based energy price is higher, instead of the northern regions around Inner Mongolia, where the wind potential is much higher. Obviously this represents a distortion in the market and does not allow the system to reach the optimal localization in terms of efficiency.

Energy Efficiency versus Renewable Energy

Investing in developing new clean sources of renewable energy, as well as investing to reduce energy waste and increase the efficiency is equally important. However the impact of the investment is not the same, and, since the resources available are scarce, some factors need to be analyzed in order to obtain the best outcome, at parity of investment.

First of all the cost of producing energy through renewable sources must be compared with the cost of increasing efficiency and therefore reducing the energy consumption of an equal amount. In other words a cost analysis must be carried out and determine what is the cost of reducing energy consumption per KWh in residential and industrial sectors, compared with the cost of producing extra KWh with renewable sources. If the value for money is higher in the first case, it is probably better to invest primarily in reducing inefficiency and only secondly to develop new sources of renewable energy.

Second the proportion of electricity on the total energy consumption in the country must be taken into account. At present the electricity represents around 11 percent of the total energy consumption. It means that most of the energy is used in its thermal form in heavy energy consuming industries. This situation implies that increasing the share of electricity made by renewable energy will affect only a small portion of the total energy, while reducing, even by a small percentage the inefficiency in the use of thermal energy can affect largely on the total energy production, with positive consequences in terms of cost saving and pollutant emissions.

Thirdly in terms of energy efficiency must be considered that at present the cost of primary energy is very cheap. It implies that often companies are not stimulated to carry out investments for increase the efficiency and reduce the energy consumption. This is because the economic return they can have by the saved cost of energy is smaller than another possible investment in a different part of the productive process. Companies will invest in the part of the value chain where the return is the highest, and, till the energy price is so low, there is no incentive to reduce the consumption. Ad hoc policies are, therefore, necessaries, or higher energy price, at cost to probably slow down a little the economic growth or subsidies to stimulate energy efficiency.

Renewable Energy and Climate Change

A last consideration must be taken about the environmental issue. The investment made on the development of renewable energy is large, but what is the impact on climate change and pollutant emissions? The sustainers and detractor have seen the results achieved in opposite ways. However it is evident that the target of 16 percent of renewable energy among the total energy consumption by 2020 is an important increase from the present situation. However it will remain a small share, compared with the 60 percent of coal usage. Therefore it will not represent a substantial alternative to fossil fuels, which are going to hold the bulk of the pie in the energy share for some more decades. The emission problems remain.

As seen, China is going to be the largest emitter of carbon dioxide emission within no more than one year. Even if China is not required to implement the Kyoto protocol measures until 2012, this situation does not help the country in creating a positive image, since the government is committed to show a path of sustainable development, some alternative solutions must be brought in.

The contribution of renewable energy is and still will be marginal in this sense, especially as most of renewable energy is hydropower (it will be over 80 percent of the total renewable sources in 2020), a technology that it CO2 free. However this is offset by the up and down movement of the water level, which causes a quantity of biomass left over and produces a natural chemical reaction, freeing methane, the second most important Green House Gas. It is still under scientific experimentation as to how much of this methane is caused by the presence of hydro plants; however in such cases the problem is simply shifted from carbon dioxide to methane, while the greenhouse gas emission problem remains.

Statistical analysis of the Energy System Analysis Center (ERI) have shown that, under this path of development, the main player in reducing the CO2 emission will be the energy saving program, at least until 2050. That will operate by reducing energy waste, but since the energy demand is increasing faster than the improvement of efficiency, emissions will still increase in absolute terms.

Since most of China's energy comes from coal, it must be invested more in finding clean technologies that allows using the cheap abundant reserve of coal, and still reduce the greenhouse emissions. A viable solution can be supporting more the *carbon capture and sequestration* (CCS), or the cutting edge technology of *algae culture*, which consists in using the coal power plant's CO2 emission to push the growth of a kind of micro algae that can be used efficiently to produce bio diesel.

Glossary

Mt – Metric tons

M3 – cubic meter

J – Joule – Energy Unit in the International System (SI). Equivalent to 0.238 cal

W – Watt – It is the SI unit of measure for power. It is equal to one joule per second.

Wh – Watt Hour – It is a unit for measuring energy, it is not part of the International System, because hour is not a SI unit. However it is widely used, especially for measuring electricity. It is equivalent to 3600J.

TOE – Tons of Oil Equivalent. It is another unit of measure for energy, widely used in EU and US. It is equal to the amount of energy released by burning one metric ton of crude oil. For convention it is equivalent to 41,868GJ.

Mtoe - Million Tons of Oil Equivalent

TCE – Tons of coal equivalent. It is another unit of measure for energy. Widely used in UK and China. For convention it correspond to 29.3076 GJ.

Mtce – Millions Tons of Coal Equivalent

K- Kilo, 10^3

M- Mega, 10^6

G- Giga, 10^9

T- Tera, 10^{12}

P- Peta, 10^{15}

CHP – Combined Heat and Power

PV – Solar Photovoltaic

SWH – Solar Water Heating

SHP – Small Hydropower

CDM – Clean Development Mechanism, It is an arrangement under the Kyoto Protocol allowing industrialized countries with a greenhouse gas reduction commitment to invest in emission reducing projects in developing countries as an alternative to what is generally considered more costly emission reductions in their own countries[40].

GHG – Green House Gas, are components of the atmosphere that contribute to the greenhouse effect. Some occur naturally in the atmosphere, while others result from burning of fossil fuel and coal. They include water vapor, carbon dioxide, methane, nitrous oxide, and ozone.

NOx – Term used to indicate NO (Nitrogen Oxide) and NO2 (Nitrogen Dioxide), they are produced during combustion and are pollutant gases cause of acid rain.

SO2 – Sulphur Dioxide, a gas that comes from the combustion of sulfur compound, contained in oil and coal. It is cause of acid rain.

CO2 – Carbon Dioxide, It is an important greenhouse gas, it is the main component of the carbon cycle

CCS – Carbon capture and storage, is an approach to mitigating climate change by capturing CO2 from sources like power plants and storing it safely instead of releasing it into the atmosphere.

FGD – Flue gas desulphurization, it is the current state-of-the art technology used for removing SO_2 from the exhaust flue gases in power plants that burn coal or oil to generate energy.

CREIA – China Renewable Energy Industry Association

ERI – Energy Resource Institute (china)

NDRC – National Development and Reform Commission (China)

SEPA – State Environmental Protection Agency (China)

MOST – Ministry of Science and Technology

MOF – Ministry of Finance

CAS – Chinese Academy of Science

IEA – International Energy Association

OECD – Organization for Economic Cooperation and Development

[40] Source: United Nations Framework Convention on Climate Change. www.unfccc.int

DOE – Department of Energy (United States)

NREL – National Renewable Energy Laboratory (United states)

UNDP – United Nations Development Programme

UNEP – United Nations Environment Programme

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